

# Safer, Faster, Better? Evaluating Electronic Prescribing

## Report to the Patient Safety Research Programme (Policy Research Programme of the Department of Health)

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# Contents

	<b>Page</b>
List of Figures	5
List of Tables	6
List of Abbreviations	8
Executive Summary	9
1. Introduction	13
1.1 Background	13
1.2 Aims and objectives	18
1.3 Evaluation framework	19
2. Two electronic prescribing systems	21
2.1 Introduction	21
2.2 The ServeRx system at Charing Cross Hospital	21
2.3 The Meditech system at Queen's Hospital	25
2.4 Discussion	29
3. Measuring error – summary of existing methods and development of new retrospective methods	30
3.1 Introduction	30
3.2 Definitions	31
3.3 Developing a method for retrospectively identifying medication errors from the medical notes	32
3.4 Adapting trigger tool methodology for use in the UK	35
3.5 Discussion	36
4. The prospective evaluation of electronic prescribing at Charing Cross Hospital	38
4.1 Introduction	38
4.2 Setting	39
4.3 Study design, sample size calculations and statistical analysis	39
4.4 Evaluating the safety and quality of each system	40
4.5 Evaluating staff time and system performance for each system	51
4.6 Discussion	57
5. Retrospective quantitative evaluation of two electronic prescribing systems	60
5.1 Introduction	60
5.2 Retrospective evaluation at Charing Cross Hospital	60
5.3 Retrospective evaluation at Queen's Hospital	70
5.4 Discussion	78

6. Comparing four methods of detecting prescribing errors	80
6.1 Introduction	80
6.2 Setting and subjects	80
6.3 Methods	81
6.4 Results	82
6.5 Discussion	91
7. A framework for evaluation of electronic prescribing	96
7.1 Introduction	96
7.2 A context of evaluation of electronic prescribing	96
7.3 Evaluation perspective	99
7.4 SPO evaluation framework	102
7.5 Applying the framework to electronic prescribing	109
7.6 Lessons for EP policy and practice	118
8. Discussion	122
Acknowledgements	137
References	138
List of Appendices	145

## List of Figures

	<b>Page</b>
Figure 1: Framework for IT health technology assessment	20
Figure 2: The ServeRx patient medication screen.	22
Figure 3: Nurse selecting stock medication from drawer in automated cabinet	23
Figure 4: One of the two electronic drug trolleys	24
Figure 5: Overview of the Hospital Information System	25
Figure 6: The Process Orders menu in Meditech	25
Figure 7: A doctor prescribing at the bedside	26
Figure 8: The Meditech medication order screen	26
Figure 9: A drug round at Queen's hospital	27
Figure 10: The patient drug administration screen	27
Figure 11: A current medication record showing scheduled and actual administration times	28
Figure 12: Example of a note from pharmacist to prescriber	28
Figure 13: Data flow diagram showing the relationships within the RRF database.	33
Figure 14: Data flow diagram showing the relationships within the trigger tool database	36
Figure 15: Relationship between prescribing errors, pharmacists' interventions and pharmacists' prescription endorsements.	41
Figure 16: The standards used during an audit of patient's medication charts to assess adherence to medication policies	43
Figure 17: Prescribing errors identified in the pre-serveRx cohort	85
Figure 18: Prescribing errors identified in the post- ServeRx cohort	85
Figure 19: The evaluation framework	102
Figure 20: The ServeRx system (supplier's description)	147
Figure 21: Implementation timetable, ServeRx	148
Figure 22: Principal elements of technology within the system	150
Figure 23: EP roll out at Queen's Hospital	190
Figure 24: Some positive opinions expressed by doctors	199
Figure 25: Possible design for cross over study of electronic prescribing	253
Figure 26: Design for randomised two group study of electronic prescribing	254
Figure 27: Hierarchy of types of decision support, as proposed by Bates (as reported by Franklin, 2003)	264

## List of Tables

	<b>Page</b>
Table 1: Summary of inter-rater reliability test for retrospective review form.	34
Table 2: Demographics of patients admitted during an eight-week period encompassing the majority of data collection pre and post-ServeRx.	44
Table 3: Patients' notes retrieved and medication orders written.	45
Table 4: Summary of prescribing errors identified and pharmacists' interventions made	45
Table 5: Prescribing errors presented according to stage of the prescribing process.	46
Table 6: Breakdown of prescribing errors according to their likely origin.	46
Table 7: Examples of prescribing errors identified. The stage of the prescribing process is shown in brackets.	47
Table 8: Examples of the medication administration errors identified. The type of error is shown in brackets.	48
Table 9: The medication administration errors identified.	48
Table 10: Adherence to policies relating to medication administration.	49
Table 11: Adherence to policies relating to prescribing and allergy documentation.	50
Table 12: Summary of endorsements made and not made.	51
Table 13: Nursing time spent on medication-related tasks each week.	55
Table 14: Summary of system performance problems documented pre-ServeRx.	56
Table 15: Summary of system performance problems documented post-Serve Rx.	56
Table 16: Summary demographic data.	63
Table 17: Medication orders written according to stage of patient stay.	63
Table 18: Medication orders written according to type of medication order.	63
Table 19: Summary of the results obtained.	64
Table 20: Prescribing errors identified according to the stage of prescribing process.	65
Table 21: Prescribing errors presented according to stage of the prescribing process.	65
Table 22: Availability of information from the medical notes.	67
Table 23: Initial sampling strategy, based on implementation of different Meditech versions at different times.	71
Table 24: Summary of demographic data.	73
Table 25: Medication orders written, presented according to stage of patient stay.	73
Table 26: Medication orders written, presented according to type of medication order.	73
Table 27: Summary of results relating to prescribing errors.	74
Table 28: Prescribing errors identified according to the stage of patient stay.	75
Table 29: Prescribing errors presented according to stage of the prescribing process.	75
Table 30: Data sources retrieved pre- and post- implementation of electronic prescribing.	77
Table 31: Summary of error rates identified using each of the four methods.	84

Table 32: Comparison of prescribing errors identified using each method or combination of methods, presented according to the stage of the prescribing process, for the pre-ServeRx cohort.	86
Table 33: Comparison of prescribing errors identified using each method or combination of methods, presented according to the stage of the prescribing process, for the post-ServeRx cohort.	86
Table 34: Prescribing errors identified using each method or combination of methods, presented according to whether or not the error was rectified before the patient received (or should have received) one or more doses, for the pre-ServeRx cohort.	87
Table 35: Prescribing errors identified using each method or combination of methods, presented according to whether or not the error was rectified before the patient received (or should have received) one or more doses, for the post-ServeRx cohort.	88
Table 36: Prescribing errors identified using each method or combination of methods, presented according to stage of patient stay, for the pre-ServeRx cohort.	88
Table 37: Prescribing errors identified using each method or combination of methods, presented according to stage of patient stay, for the post-ServeRx cohort.	89
Table 38: Clinical severity of the prescribing errors identified using each method.	89
Table 39: Positive triggers and prescribing errors identified.	90
Table 40: Advantages and disadvantages of each method for the detection of prescribing errors.	94
Table 41: Charing Cross Hospital: ServeRx system.	105
Table 42: Queens Hospital: Meditech System.	107
Table 43: Prescribing error reduction following electronic prescribing in UK studies.	134
Table 44: Demographic details of the patients interviewed.	168
Table 45: Staff interviews and observations (all data).	193
Table 46: Patient demographics.	212
Table 47: Comparing medication incidents identified in interviews and by records review.	236
Table 48: Patient sample frame.	241
Table 49: Values of $f(\alpha, \beta)$ .	257
Table 50: Sample sizes for various ICC values, calculated using the formula above.	258
Table 51: Summary of the decision support available and actually in use for each system.	265

## List of Abbreviations

ANT	Actor Network Theory
CD	Controlled Drug
CI	Confidence Interval
COE	Care of the Elderly
CPOE	Computerised Physician Order Entry
CXH	Charing Cross Hospital
EP	Electronic Prescribing
GEE	Generalised Estimating Equation
HCP	Health Care Professional
HIS	Hospital Information System
ICC	Intra-class Correlation Coefficient
ICT	Information and Communication Technology
ICU	Intensive Care Unit
INR	International Normalised Ratio
MAE	Medication Administration Error
NPSA	National Patient Safety Agency
NPV	Net Present Value
OE	Opportunities for Error
OR	Ratio of Odds
PACS	Picture Archiving and Communications Systems
PCA	Patient Controlled Analgesia
PODs	Patients' Own Drugs
PRN	Pro Re Nata (when required)
QALY	Quality of Life Year
QHB	Queen's Hospital, Burton on Trent
RCT	Randomised Controlled Trial
RRF	Retrospective Review Form
S/HO	Senior/ House Officer
SPO	Structure/ Process/Outcome
STAT	Statim (immediately)
TTA/O	To Take Away/Out (Discharge medication)



## Executive summary

1. The project's purpose was to develop and pilot ways of evaluating, prospectively and retrospectively, the impact of hospital electronic prescribing (EP) systems on patient safety. Given this purpose the report is structured around methodological issues.
2. We have used an evaluation framework which can be adapted to any stage of EP development. It is based on a matrix of structure/process/outcome and the perspectives of technology, stakeholders and the organisation.
3. A set of definitions and research methods that allow the quantitative, prospective study of medication errors is presented. We developed a data set suitable for the study of the incidence of prescribing errors and associated harm in retrospective studies of patient notes. We also adapted trigger tool, a method of detecting adverse drug events, for the UK context.
4. Two EP systems were studied: the introduction of ServeRx to a surgical ward in a London teaching hospital (Charing Cross Hospital, CXH), and Meditech, a system long established and now in hospital wide use at a general hospital (Queen's Hospital, Burton upon Trent, QHB). ServeRx is a "closed-loop" system which combines EP with electronically controlled stock cupboards, linked to electronic drug trolleys which use bar coded patient identification to allow drug administration. Meditech is an EP system using wireless laptop computers operating as part of a powerful Hospital Information System.
5. At CXH, pre-ServeRx, we compared four ways of detecting prescribing errors in the same set of patients: prospective daily detection by pharmacists; retrospective review of the patients' notes; trigger tool and spontaneous reporting. 93 patients had 1258 medicines prescribed, there were 135 errors detected in total and no cases of harm. Prospective collection found 48 of the errors (36%), retrospective review found 93 (69%), spontaneous reporting found one and trigger tool found none but generated many false positives. Only seven errors were found by both prospective and retrospective means, suggesting that they mainly detect different types of prescribing error.

6. At CHX the ServeRx system was studied prospectively before and after implementation to examine its effects on prescribing error (detected by pharmacists' daily inspection), medication administration error (MAE, detected by observation), checking of patient identity (observed), and compliance with several other protocols and areas of good practice. Staff use of time was also measured. The summary results are:

- a. 4803 prescriptions were studied and prescribing errors were reduced from 3.8% to 2.0% (95% CI difference -0.9 to -2.7%)
- b. 2822 drug administrations were observed and administration errors (excluding intravenous errors) fell from 7% to 4.3% (95% CI difference -0.9 to -4.5%)
- c. Checking of patient identity before administering medicines rose from 17% to 81%
- d. Staff time on medication related activities increased significantly for all professions.

7. Both EP systems were studied, by retrospective review of patients' notes to detect prescribing errors, before and after each system was implemented. The purpose was to pilot the methodology, it was not powered to detect an effect. 93 patients were studied before the introduction of ServeRx and 114 after (a total of 2872 prescriptions), the prescribing error rate was 7.4% pre- and 6.5% post-implementation (95% CI difference -2.8 to +1.0). Meditech was studied across four wards which introduced it at different times. Records from the earliest admissions could not be accessed on the EP system. 150 patients (2872 prescriptions) were studied. There were 8.6% prescribing errors before implementation, 8.8% after.

8. Pooling all studies of patients' notes (two sites, pre and post EP) we reviewed 357 admissions and found 8 cases of harm (2.2%) resulting from prescribing errors.

9. Each system was evaluated qualitatively. Although the hospitals, EP systems and their stage of development were very different, several common issues emerged:

- a. EP needs to be addressed as a sociotechnical innovation, not just a technical solution “there for the taking”.
- b. An extended implementation period needs to be resourced to provide support and to help good new practices embed.
- c. Emergent change should be expected and be managed. This can be quite profound, for example, EP could lead to a reduction in interaction with patients and between other professionals.
- d. Technical systems are never perfect; they should continue to be developed both to improve performance and to embody new and changing understanding. For example, the extra staff time on ServeRx could be reduced by software changes.
- e. Hence, software should be specified so it is possible to adapt it locally, and so that the data held are easily accessible for multiple purposes.
- f. Decision support is not straight forward; the purpose and limitations of decision support needs to be clear to all concerned.

10. The combination of quantitative findings and the understanding of why they are so, allows organisational learning to take place. Our evaluation framework worked well for both EP systems, and produced a rounded picture in which quantitative findings are set against the context in which they were produced. This serves not only the interpretation of the specific findings, but also allows better estimates of their generalisability to other settings and guidance for better subsequent implementations.

11. A research agenda emerges from this work which includes:

- a. The setting up of a patient database for “in vitro” testing of future EP systems before being used with patients.
- b. Systematic evaluation of EP systems being trialled at present to provide shared learning.
- c. The extent of harm caused by medication error, and the relationship between error and harm need further exploration. Costing the consequences of harm would then be the foundation for the economic evaluation of EP.
- d. Decision support in this area is under theorised.

12. Our findings, taken overall, tentatively suggest that for every 100 prescriptions written in a hospital there will be around 10 errors; the introduction of an electronic prescribing system, at the current stage of development, would avoid two or three of them.

*Word count: 957*

# 1. Introduction

## 1.1 Background

Medication error is arguably the most prevalent type of medical error in both primary and secondary care. In the USA it kills 7000 patients a year <sup>1</sup> and accounts for nearly 1 in 20 hospital admissions; a similar admission rate to that of cancer <sup>2</sup>.

In the UK, the incidence and consequences of medication error in secondary care seem to be similar to those in the USA: errors occur in hospitals in at least 1.5% of prescriptions <sup>3</sup>, and 3-8% of medication administration is incorrect <sup>4</sup>. Indeed, the work presented in this report suggests the frequency of prescription error (depending on the method used) may be as much as three times higher than previous research shows. We also know that one month after discharge from hospital around half of all patients are not taking the right medicine in the right way<sup>5</sup>.

Given figures such as those above it is not surprising that the NHS plan for patient safety, "Building a safer NHS for patients." has the reduction of harm from medication error as two of its four firm targets <sup>6</sup>.

In both the USA and UK, the use of information and communication technology (ICT) to reduce errors is seen as a major element of strategy. Medication errors, it is argued, can be reduced by electronic prescribing with decision support, electronic medication administration records, robots, automated pharmacy systems, bar coding, smart IV pumps, electronic discharge prescriptions and targeted patient information<sup>7</sup>. The gains, it is suggested, could be spectacular - at one hospital electronic prescribing with decision support reduced serious medication errors by 88% <sup>8</sup> and saved \$5-\$10m each year <sup>9</sup>.

Consequently, electronic prescribing (called Computerized Physician Order Entry, CPOE, in the USA) has been (1) proposed in "Building a Safer NHS" as a method of quickly improving patient safety, (2) a part of the NHS information strategy (which originally committing to electronic prescribing in all acute hospitals by 2005<sup>10</sup>), and (3) recommended by the Audit Commission <sup>11</sup>. The NHS is currently asking local service providers to provide a solution to electronic prescribing in hospitals by 2008 to 2010.

With the current policy being to move to electronic prescribing (EP) in all hospitals, it is important that EP's potential effectiveness is understood through appropriate evaluation activities (note plural to indicate need for multiple approaches). This is important to ensure that the various benefits it might deliver are well understood, that appropriate and robust technical systems are developed and available, but also to understand the appropriate ways in which such technical systems can be implemented in health care settings and come to be used so as to serve the best ends of the individual NHS institutions (wards, hospitals), patients, and the service as a whole.

The work reported here pursues these goals, but it does so recognising two particular confounding issues that need to be addressed. First, the evaluation of complex ICT systems that reshape work processes is itself a complex and problematic activity – there are no easy routes to deliver simple solid answers. Following from this we find that the evidence base that supports the policy of adoption of electronic prescribing has little generalisability to hospital wide commercial systems in the UK, drawing as it largely does on experience in the significantly different context of US health care.

The limited generalisability of the available literature comes from many sources:

1. The benefit of new innovations with electronic prescribing depends to a large part on how effective the human systems of work and the human actors were in the original setting *before* any intervention. Studies in the literature seldom compare their control data to other studies to establish how well the human system was working in their specific context before electronic prescribing.
2. The effectiveness of an electronic prescribing system will be specific to the institutional context in which it is embedded. For example, in the USA a large source of error is identified in transcribing of the prescription by nursing staff and clerks. Electronic prescribing can eliminate this step, and hence significantly reduce one aspect of the observed error rate. However, the same benefit would be limited in UK hospitals in which there is little transcribing, and that done by pharmacists.
3. Most studies which show electronic prescribing has significant benefits are of "home-grown" systems which have been developed in-house over many

years. Examples are the Brigham and Women's Hospital, the decision support system in Salt Lake City and the renal system in Birmingham, UK. In these cases the electronic prescribing system has been designed specifically to solve local problems at that hospital (or ward within it), and is likely to have had a great deal of local support and commitment.

4. In contrast, there has been little evaluation of “commercial off the shelf” systems; we conjecture that experience in such cases will be substantially different. There have been several small studies of commercial and other systems, however they are limited because they did not use standard methodology, or give sufficient detail of their methodology and definitions for the data to be interpreted with great confidence.

More recently a number of studies have emerged which question whether electronic prescribing when it is implemented is delivering the expected benefits. The UK was a world leader in the introduction of electronic prescribing into primary care; however, when compared to other countries we seem to have similar rates of non-adherence and admission to hospital as a result of preventable adverse drug events <sup>2</sup>. Recent work <sup>12</sup> has shown significant limitations in the current computer programmes used by GPs, and in Australia electronic prescribing has been associated with a marked *increase* in unwanted antibiotic prescriptions, estimated at potentially half a million a year <sup>13</sup>.

In 2005 two significant papers emerged which described errors following the introduction of CPOE. Koppel et al. <sup>14</sup>, conducted research in a US teaching hospital using a standard package, which raises a number of substantial questions as to the ability of such a system to actually facilitate error: for example, errors in dosing, antibiotic renewal and in medication discontinuation. Nebeker et al <sup>15</sup> report high rates of adverse drug events (27% caused by medical error) following implementation of CPOE. Neither study included a quantitative comparison with pre-implementation prescribing and in general we must acknowledge that the evidence base to suggest problems with electronic prescribing in hospitals has similar weaknesses to the evidence base suggesting its benefits.

We do not see it as remarkable, or treasonous, to suggest that computer systems may increase error and harm. This evidently may be the case simply if the technical system is poorly designed, works with inadequate data or has a poor user interface. But beyond such considerations, it is also worth considering how

important it is that the people who work with such a system understand its functionality and work in balance with it. For example, in health care there have been a number of deaths related to the use of computers in radiotherapy. At the North Staffordshire Royal Infirmary around 1000 cancer patients were underdosed with radiotherapy over nine years. Staff were unaware that the software contained a decision support system that reduced the dose of radiation in certain circumstances, so calculated the dose reduction manually and applied it again. Patients thus received twice the reduction needed and tens of patients are estimated to have died<sup>16</sup>. In the USA the Therac 25 computer controlled radiation therapy machine killed several patients and burned many more. If the operator made a mistake and corrected it in under eight seconds, then, unintentionally, a protective shield was withdrawn and a dose of radiation 120 times that required was administered<sup>16,17</sup>.

The considerations introduced above do not mean that the UK policy to pursue electronic prescribing is wrong or ill-founded, but they do underline the importance of undertaking extensive evaluation in the UK so as to better understand the issues being addressed, the benefits expected, and the appropriate ways to ensure that they are delivered or surpassed. Our view is that, given the above, it is legitimate, and even essential, that we ask both whether electronic prescribing systems in the UK will significantly reduce various forms of medication errors, but also if they might introduce some new ones. We need to ask whether all technical systems can do it to the same extent or whether some are more relevant and perform better than others. How do those that focus on prescribing compare with those that focus on administration, or those that link to other systems (for example, tests, medical records etc.), or closed loop versions that seek to integrate the medicines use process? Finally, we need to be able to recommend how these systems could be introduced and, over time, improved or expanded so as to give more of the desired benefits.

There are significant barriers to answering each of these questions, and to generating a credible, generalisable, evidence base upon which to base decisions. This brings us to the central question of this report, how electronic prescribing systems should be evaluated. What are the practical and methodological difficulties in delivering and analysing prospective and retrospective evaluations, and what is the best way to establish the baseline data to work from, including the rate of medication errors, but also the quality of the human system and its ability to successfully engage with new technical systems?



As is well understood and extensively discussed in the literature, the evaluation of Information Systems in health care settings poses a number of problems, and the systems themselves are prone to failure<sup>18,19</sup>. While medical research provides clear guidelines on evaluative activity for medical innovations, such as new drugs, for example in a phased process (toxicity studies, phase 1, 2 and 3 trials culminating in large-scale randomised controlled trials and pharmacovigilance), there is far less consensus as to appropriate ways to evaluate ICT based innovations in health care settings.

In contrast to a drug, evaluation of ICT based interventions, with their diverse aims and the extensive and visible ways in which they are experienced as they are tested, piloted and rolled out, must be carefully considered – the blinded, randomised controlled trial is almost impossible to achieve. In contrast to a drug, technology may (indeed will) change its characteristics over time, as software is updated, optional modules are purchased, hardware is replaced and local users learn a system's quirks and adapt the system to their local needs. Over time we should expect things to change, including structures, work processes and individual and group attitudes. For this reason a system assessed in 2005 may well perform differently (better or worse) in 2007, and the reasons for such a shift must be incorporated into our understanding. Thus such systems must be understood as taking their form and achieving their outcomes in intimate relations with their local context; recognising distinctive and different organisational cultures and structures and variations in local work practices. Study of the context, and the potential to accept change, then becomes fundamental in explaining consequent change and outcomes.

For these reasons careful attention needs to be paid to how technology based systems come to be aligned with particular organisational goals, existing work practices and the interests of diverse stakeholder groups. These contextual and temporal elements to any information system implementation pose problems for the generalisability of findings from any particular study beyond its unique time and place. A study in one context may prove very misleading as a guide to experience or outcomes in another, even if at first sight the two contexts are very similar. We therefore see qualitative and ethnographic work as being required (alongside more structured assessments) to help people to interpret and translate any local evaluation across different contexts. In this way we believe we can start to enhance the generalisability of findings and build the evidence base.

The shifting properties of the technology, and the shifting sands of the context in which it is embedded, mean that it is important to adopt both formative and summative approaches.

This suggests to us that we should listen carefully to the distinguished software engineer David Parnas "As a rule software systems do not work well until they have been used, and have failed repeatedly, in real applications." <sup>20</sup>. Electronic prescribing systems for hospitals in the UK are at an early-stage of development (at the time of bidding for this grant they only existed across a whole hospital at three sites). We must be vigilant for their harmful as well as beneficial effects, particularly in the development phase.

## **1.2 Aims and objectives**

Our proposal was for a study to pilot evaluations of electronic prescribing based on the framework of Cornford et al <sup>21</sup>. We gave the following aim and objectives:

Aim:

In the pilot we wish to show the feasibility and practicality of the proposed framework of evaluation, and of methods used to conduct prospective and retrospective studies.

Objectives:

1. To recommend a framework for the evaluation of electronic prescribing, and to evaluate our initial framework of Cornford et al <sup>21</sup>.
2. To pilot a prospective evaluation of the Serve Rx system at Charing Cross Hospital.
3. To pilot a retrospective evaluation of the electronic prescribing system at Queens Hospital, Burton upon Trent.
4. To establish the practical issues in retrieving information from the notes and from the different computer systems, sites and ward types.
5. To adapt and apply trigger tool methodology from the USA to a selection of patients' notes; to establish its specificity and sensitivity, and make suggestions for change if necessary.

6. To develop methods, based on the patients' notes, to identify the incidence, nature and severity of medication errors.
7. To compare the incidence and nature of medication errors detected prospectively from observation, and retrospectively, from the notes, in the same cohorts of patients.
8. To describe the decision support software in each system, and assess aspects of it.
9. To establish the nature and accessibility of data required for an economic evaluation of electronic prescribing.

In order to help meet these aims we evaluated two electronic prescribing systems. First was ServeRx which was being introduced to a general surgical ward at Charing Cross hospital. Second was the Meditech system at Queen's Hospital, Burton upon Trent; one of only three hospitals in the country which had implemented a hospital-wide system at the time of the study. At the time of bidding for this study we already had some funding to prospectively evaluate the ServeRx system from the manufacturer of ServeRx (MDG Medical, Israel) under an unrestricted grant. We have integrated the two studies and do not distinguish between the sources of funding in this report.

### **1.3 Evaluation framework**

Our approach has been to apply Cornford's structure for the evaluation of ICT (Figure 1). We examine and evaluate this later in the project; however we introduce it here as it underlies the structure of the subsequent evaluations. The framework was chosen because it brings together the structure/process/outcome approach to quality (a commonly used model in health care) with three key perspectives – those of the technology, of the humans that use it, and the organisation that adopts it. This dimension can be mapped onto Reason's model of accident causation, and hence has the potential to be particularly useful in evaluating systems designed to reduce error. As Reason argues, to understand error, one must look beyond the technical system, and beyond the individual "guilty" party, to the distributed work processes and organisational setting.

	<b><u>Systems function</u></b>	<b><u>Human perspectives</u></b>	<b><u>Health care system</u></b>
<b><u>Structure</u></b>	<b><i>Technology</i></b> <i>Detailed description of each system, including flow diagrams</i>	<b><i>Work practice</i></b> <i>Description of work practices, process variation</i>	<b><i>Sustainable</i></b> <i>Interviews with key managers</i>
<b><u>Process</u></b>	<b><i>Processing</i></b> <i>Pharmacists' interventions, time measurement, stock control, system performance</i>	<b><i>Social interaction</i></b> <i>Description of communication patterns– between HCPs and between HCPs and patients</i>	<b><i>Consequent change</i></b> <i>Adherence to Trust medication policies</i>
<b><u>Outcome</u></b>	<b><i>Correct</i></b> <i>Prescribing errors, supply and administration errors</i>	<b><i>Quality service</i></b> <i>Delays while patients wait for discharge medication</i>	<b><i>Contribution to strategy</i></b> <i>Interviews with managers, availability audit data</i>

**Figure 1. Framework for IT health technology assessment (Cornford et al,<sup>21</sup>). Text in italics refers to examples of the outcome measures included in the present study that relate to each element of the framework; HCPs = Health Care Professionals**

The rest of the report is divided into chapters which describe the computer systems then cover:

- Chapter 3: methodology, including the devising of new tools and data collecting programme
- Chapter 4: the prospective study of the ServeRx system at Charing Cross Hospital
- Chapter 5: the retrospective evaluations of the Serve Rx system, and of the Meditech system at Queen's Hospital, Burton upon Trent
- Chapter 6: comparison of four methods of detecting prescribing error
- Chapter 7: review of the evaluation framework and qualitative findings
- Chapter 8: discussion and recommendations

As the body of this report is limited to 50,000 words there are also substantial appendices, including qualitative evaluations of ServeRx (Appendix A), and of Meditech (Appendix B), and invited essays of issues in economic evaluation of EP (by Professor Buxton) and of statistical and design considerations (from Dr Carpenter).

## 2 Two electronic prescribing systems: ServeRx and Meditech

### 2.1 Introduction

This Chapter gives a brief description of the two electronic prescribing systems studied.

Ethics approval for the evaluation at Charing Cross Hospital was obtained from Riverside local research ethics committee (LREC); approval for the Queen's Hospital study was obtained from South East Staffordshire LREC. The relevant local Research and Development offices also gave their approval.

### 2.2 The ServeRx system at Charing Cross Hospital

The ServeRx system (MDG Medical, Israel) went live in June 2003 as a beta test on a 28-bed general surgery ward in Charing Cross Hospital, part of Hammersmith Hospitals NHS Trust, in West London. Different versions of the system were introduced at different stages, as various upgrades were put into place. The post-implementation evaluation was conducted while version 1:13 was in use.

ServeRx is a closed-loop system, comprising the following three elements:

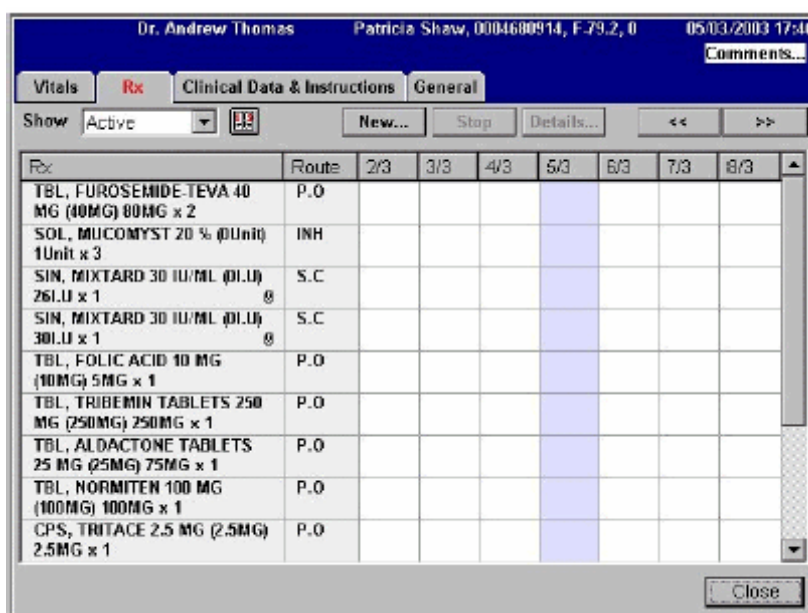
1. Electronic prescribing, scheduling and administration software;
2. Ward-based automated dispensing;
3. Electronic drug trolleys.

Each of these will be described in turn.

#### ***Electronic prescribing, scheduling and administration software***

There were two prescribing terminals on the study ward, plus one in the pharmacy department. There were also two hand-held tablet computers on the study ward which can be taken from patient to patient and used to view, prescribe and discontinue medication orders. These had to be synchronised with the ward-based server via a docking station before and after each use. The software used on the prescribing terminals and hand-held computers was windows-based; the patient medication screen was intended to resemble an inpatient drug chart (Figure 2).

When prescribing, a doctor could access pull-down lists of all drug products stocked on the ward, all drug products in the Trust's formulary and all products in the drug dictionary. Prescribing was by product (aspirin 75mg soluble tablets) rather than by drug (aspirin). Default doses were suggested for most products; decision support will



**Figure 2: the ServeRx patient medication screen. This image is taken from the ServeRx user manual; at Charing Cross Hospital, Generic drug names and lower case letters are used.**

be discussed in more detail in Appendix E. If the patient had any allergies entered, these were displayed on the prescribing screen. When patients were transferred from other wards, pharmacists were authorised to transcribe their existing medication orders onto the computer system. When patients were transferred from the study ward to other wards, their medication was printed out in a format representing the Trust's standard medication chart, which allowed a further three days of medication administration to be documented. The prescription of intravenous fluids remained on paper drug charts, as did warfarin and patient controlled analgesia. "Dummy" orders for the latter two items were prescribed on ServeRx to act as a reminder that a separate paper chart was in use.

Once drugs were prescribed, a nurse (or less often, a pharmacist or doctor) scheduled the doses to specific drug round times and indicated the drug round at which the first dose is to be given.

Pharmacists checked and approved medication orders from a separate pharmacy screen, which indicated unapproved medication orders. Medication orders did not have to be approved before they could be administered by nursing staff. At the approval stage, pharmacists could enter additional instructions relating to

administration; further instructions cannot be entered once orders have been approved.

The facility for prescribing discharge medication was not in use at the time of this study; discharge medication was therefore prescribed on the Trust's standard paper discharge prescription.

### ***Ward-based automated dispensing***

The majority of medication was stored in large automated cabinets; the doses required were transferred by nursing staff to an electronic drug trolley at each drug round (Figure 3). The automated cabinets, containing computer-controlled drawers and a touch-sensitive non-Windows based computer screen, were situated in the ward's treatment room. Products that were ward stock were in product-specific drawers containing only that product, in original packs. Non-stock medication dispensed for individual patients was stored in patient-specific drawers, which could contain several products dispensed for that patient. The patient's name was indicated on the drawer using a liquid crystal display. The computer screen indicated the patients for whom doses were due in the next two hours. To prepare for a drug round, the nurse selected each patient using the touch-sensitive screen and was then presented with a list of the doses due. On selecting each dose, the relevant drawer in the cabinet opened so that the nurse could take the number of dosage forms required and place these in the electronic drug trolley. It was not possible for the nurse to view details of previous medication administration from this screen.

Nursing staff were able access medication that was not currently prescribed using a "stat" facility; this was used if medication was needed in an emergency or was prescribed on a paper drug chart that had not yet been transcribed onto ServeRx.

To restock the cabinet, a pharmacy technician printed a list of products below the specified reorder level. Barcodes on each drug product were used to confirm the identity of the medication loaded into



**Figure 3: Nurse selecting stock medication from drawer in automated cabinet. The patient-specific drawers can be seen below the open drawer, and the screen to the right.**

each drawer. Non-stock medication was ordered by nursing staff via the ward pharmacist.

### ***Electronic drug trolleys***

There were two electronic drug trolleys (Figure 4), one for each half of the ward. Each contained twenty drawers and docked with the automated cabinet. When medication was being prepared for a drug round, one drawer in the drug trolley opened at a time, and the patient's name indicated on the drawer's liquid crystal display. When all medication for a given patient had been prepared, the system instructed the nurse to close that patient's drawer in the drug trolley before medication for the next patient could be prepared. Once all medication had been prepared for a given drug round, the trolley could be disconnected from the main system and taken around the ward. The barcode on each patient's wristband was scanned which triggered the system to open that patient's drawer in the trolley so that the medication could be administered. The nurse confirmed administration using a touch-sensitive screen on the trolley, and entered the reasons for any doses not given. It was not possible to view details of drugs due at other times of day, or of previous doses administered or omitted.

On completion of the drug round, details of all doses administered and reasons for any omitted were uploaded to the main server once the trolley was docked.

Medication prescribed to be given "when required" was generally given separately outside of the main drug rounds.

### ***Training and security***

All users required a username and password to access the system; further confirmation of the password was needed whenever any action was carried out. Different staff groups had access to different features of the system. Staff were given a username following completion of training, which was provided by the pharmacy computer services team.



**Figure 4: One of the two electronic drug trolleys. One drawer is allocated to each patient for whom medication is due and their name shown on the liquid crystal display. The barcode scanner is on the top of the trolley.**



## 2.3 The Meditech system at Queen's Hospital

Electronic Prescribing at Queen's Hospital was part of the wider Meditech Hospital Information System (HIS) (Figure 5). Medical notes were maintained in the traditional paper format but all other records were made and stored electronically. The intensive care unit, theatres, outpatients and the private ward were the only departments not to use EP at the time of the study.

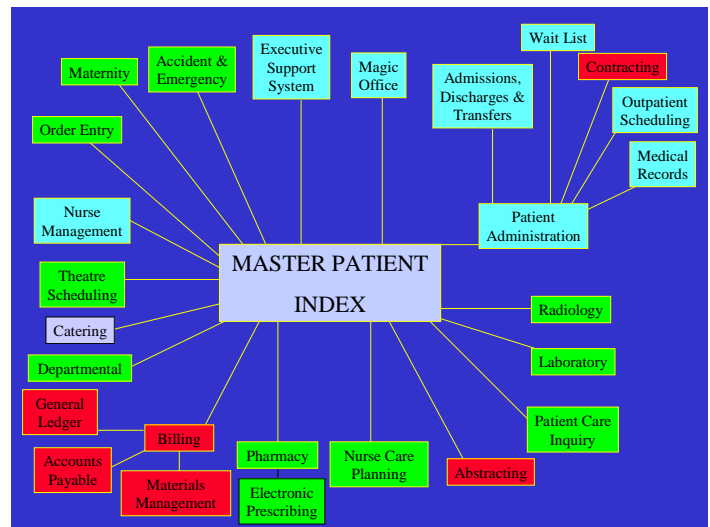


Fig 5: Overview of the HIS

The HIS allowed all authorised staff involved in patient care access to any type of record and supporting information (Figure 6). The gateway into the system was through the Patient Care Inquiry module, which allowed the patient to be identified. To enter the system, staff must key in a personal identification number (PIN), which changes every 3 months, and a password, which does not change. Staff

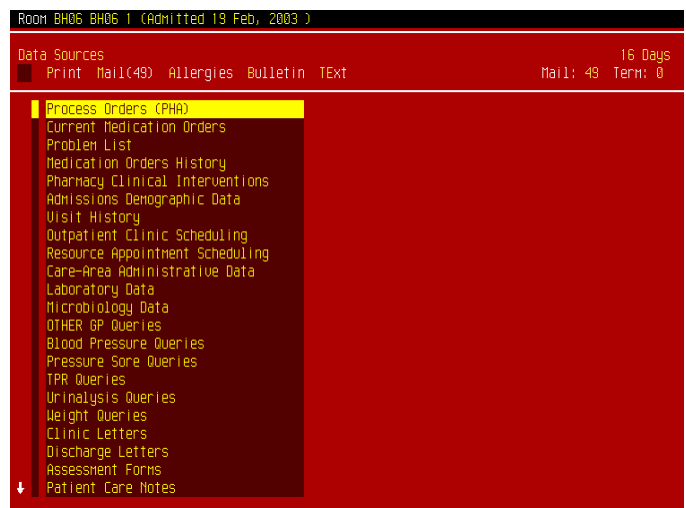


Fig 6: The Process Orders menu in Meditech

had to be trained before they could receive a PIN. Two full-time trainers provided training for all new medical and nursing staff. Pharmacy training was done within the department by members of the core implementation team.

Within the hospital, the HIS could be accessed almost anywhere using mobile wireless laptops or static computers or older “dumb” terminals. Most wards had three static terminals and two laptops. Senior staff could also access the system from home. The system had been extensively developed and customised since the initial pilots between 1994 and 1996, and there had been three software upgrades by the time of our study. Version 4.8, which ran on a non-Windows platform and did not require use of a mouse, was in use at the time of this evaluation. Navigation was by

function keys, often in combination with shift and arrow keys. The functions assigned to “F keys” could vary depending on the type of static terminal used.

### Prescribing

The EP prescribing (order entry) screen followed the logic of the paper drug chart, listing drug, route, dose, times, start and stop dates, administration dates and times (Figures 7 and 8).

There were “look-up” functions for drug names, doses and routes, and a print monograph option for individual drugs.

There were some decision support rules (see Appendix E for details) but dose checking was not routine at the time of this evaluation. The *aide memoire* given to newly trained prescribers warned that checking for allergies or incorrect doses was their responsibility. Coloured pop-up boxes warned if certain information (such as a stop date for an antibiotic) had not been entered or if a particular caution applied. Full interaction checking was carried out.



Fig 7: A doctor prescribing at the bedside

There were two types of once-only orders: ONE, which was a single dose and STAT which indicated a dose to be given straight away.

These had default start and stop dates entered automatically.

Regular medicines were allocated times corresponding to ward medicine rounds, with a 2-hour window around the scheduled time to allow for variation in practice.

Enter/Edit Inpatient Medication Order

Patient	PILL, PPENNY	Acct No	B0000426/01	Loc	BH04	U No	B000223
User Name	FORD, NICK	Ag/Sx	50/F	Rm	BH04	Reg	06/11/01
Consultant	BUCKNALL, T E	Status	ADM IN	Bed	2	DIS	
Ord Type	REG	Regular (SCH) medications					

Med AML00ST  
(Med, Dose, Route, Frequency, Schedule, Par, Total Doses)  
AMLODIPINE 5 mg TABLETS  
PACK/28 TAB

Clinical Indication  
Dose 5 (mg )  
Route PO ORAL  
Frequency 00 0000 000  
Schedule SCH Charge on Adm? Dose Instr Taper

Start Date 25/02/03 Start Time 1652 Total Doses Initial RF  
Stop Date Stop Time

Stop Date Comment  
Edit Dose Instructions?

Fig 8: The Meditech medication order screen

A patient’s current medicines could be listed to screen; paging down gave the details of who prescribed, who gave, and where relevant, who dispensed, the medication. This was called the order history. Discharge medication had to be flagged by the prescriber, then “converted” from inpatient orders in the pharmacy

before dispensing. These electronic prescription orders were called down by the pharmacy system in batches, at a frequency set by the dispensary manager. Discharge medication information could be imported automatically into an electronic discharge summary, a printed version of which was sent to patients' general practitioners.



**Fig 9: A drug round at Queen's hospital**

The laptop was usually placed on the shelf on the side of a conventional drug trolley, where paper drug charts/clip boards or files would rest in other hospitals (Figure 9). The nurse picked the patient name from the list of current admissions, then checked the patient's identity in the traditional way by reading the patient's wristband.

The drug administration screen for a patient (Figure 10) resembled a compressed drug chart, with medication orders listed on left-hand side of screen and a series of columns to the right. As required and stat medication orders were listed after all other regular medication. New orders for drugs which are not carried as ward stock were flagged \*NS\*. These items would be picked up by the pharmacy system during regular scans for new orders.

Drugs due at the current round were highlighted on the screen. The nurse selected each medication to administer by selecting a tick mark in the relevant column. The screen flagged up any doses which were scheduled, but not given on

Process Orders										0 / of 14	
Patient	PILL, PPENNY	Acct No	B0000426/01	Loc	BH04	U No	B000223				
User Name	FORD, NICK	Ag/Sx	50/F	Rm	BH04	Reg	06/11/01				
Consultant	BUCKNALL, T E	Status	ADM IN	Bed	2	DIS					
HEIGHT: 5 ft 5.0 in 165.1 cm WEIGHT: 0.000 kg (no date) BSA: 0.00 m2 Alerts: *** Insulin dependant diabetic *** *Dysphagia?*											
Allergies: PENICILLIN ALLERGY PEANUTS SAUSAGES ↓ADRS:											
Function											
(Rx's for account no. B0000426/01) → Med Data											
Generic Name	Typ	Dose	Freq/SCH	Route	RF	Start	Stop	Note	T	Last Doc	Gun
WARFARIN	I	1 mg	VARIABLE	PO		05/02	11/02	*UNR			
WARFARIN	I	5 mg	VARIABLE	PO		05/02	09/02	*UNR			
IBUPROFEN	I	400 mg	TDS	PO		05/02	None				
OLANZAPINE	I	10 mg	OD	PO		14/08	None	*NS			
TIMOLOL 0.25% EYE DR	I	EYE ONLY	BD	BEYE		16/10	None	*UNR			
SODIUM VALPROATE MR	I	200 mg	BD	PO		17/10	None	*NSR		17/10-1529	Y
FERROUS SULPHATE (CT)	I	200 mg	TDS	PO		20/11	None	*UNR	*		
AMLODIPINE	I	5 mg	OD	PO		25/02	None	*UNR			
ONDANSETRON	I	8 mg	PRNQB/P	PO		05/02	None	*UNR			
ONDANSETRON	I	4 mg	PRNQB/P	IU		05/02	None	*UNR			
PARACETAMOL	I	1000 mg	PRNOM/PR	PO		17/10	None				

**Fig 10: The patient drug administration screen**

a previous round. Nurses could view the order history screen to see the reason why previous doses were not given, and can add comments themselves.

The recording of each drug administration was signed off separately, as it would be on a paper chart. The system records the actual administration time, and the theoretical “drug round time” (Figure 11).

### Pharmacy review

Pharmacists could access and review patient medication orders from anywhere in the hospital. They had the same access as prescribers. However, they normally limited themselves to changes in dose form or dose if these were incorrect, and contacted the prescriber if the drug itself needed changing. They could do this electronically by writing free text notes for prescribers and nurses into the patient record (see Figure 12).

Medication	Dose	Rte	Instruct	Start	Stop	St	Last Admin
KALETRA	3 CAP	PO	BD BM	15/01			*22/02 0830Y0800
CO-TRIMOXAZOLE 80/400	1 tablet	PO	OD	19/01			*22/02 0830Y0800
SCANDISHAKE various fl	85 g	PO	BD	19/01			*22/02 0830Y0800
TRIZIVIR	1 tablet	PO	BD	04/02			*22/02 0830Y0800
RISPERIDONE	1 mg	PO	BD	11/02			*22/02 0830Y0800
NIQUITIN CQ STEP TWO	14 mg	TOP	OM	12/02		*I	*22/02 0830Y0800
PREDNISOLONE EC	2.5 mg	PO	OM	23/02	01/03	*NS	*22/02 0830Y
FLUCONAZOLE	200 mg	PO	OD	21/02	17/05	*UNR	*22/02 0830Y0800
TEMAZEPAM	10 mg	PO	PRNON/PRN	20/01			12/02 2351Y

**Fig 11: A current medication record showing scheduled and actual administration times**

Each pharmacist carried out a daily prescription review of their allotted wards or consultant firms using the Meditech system. Prescription screening activity was targeted to newly prescribed items, and those which required monitoring.

New orders which had not been reviewed by a pharmacist are marked \*UNR\*.

Orders for which pharmacists have made an intervention are flagged \*I\*<sup>\*</sup>; these could be audited in detail.

Medication	Dose	Rte	Instruct	Start	Stop	St	Last Admin
LANSOPRAZOLE DISPERSIB	30 mg	PO	BB	16/02			*NSR 22/02 0938Y0600
Infusion:		IV	AP/NR	18/02	22/02		
SODIUM CHLORIDE 0.9%	1000 ml	12 HR	83.333 MLS/HR	Tot Vol: 1000.00 ml			
Infusion:		IV	AP/NR	18/02	22/02		
GLUCOSE 4%/Sod Chlor 0.1000 ml		12 HR	83.333 MLS/HR	Tot Vol: 1000.00 ml			
Infusion:		SC	OD/NR	21/02	22/02		
GLUCOSE 4%/Sod Chlor 0.1000 ml		8 HR	125 MLS/HR	Tot Vol: 1000.00 ml			
Infusion:		SC	AP/NR	21/02	22/02		21/02 2036Y
GLUCOSE 4%/Sod Chlor 0.1000 ml		8 HR	125 MLS/HR	Tot Vol: 1000.00 ml			
Infusion:		SC	AP/NR	21/02	22/02		22/02 1207Y
GLUCOSE 4%/Sod Chlor 0.1000 ml		8 HR	125 MLS/HR	Tot Vol: 1000.00 ml			
Infusion:		SC	AP/NR	21/02	22/02		
GLUCOSE 4%/Sod Chlor 0.1000 ml		8 HR	125 MLS/HR	Tot Vol: 1000.00 ml			

16/02/05 1426 IRELAND, MICHAEL  
LEFT MESSAGE IN DRS BOOK AS NONE OF REG MEDS PRESCRIBED, UNSURE IF INTENTIONAL OR NOT? (RAMIPRIL, SPIRONOLACTONE ETC SEE HISS DRUG HISTORY)

**Fig 12: Example of a note from pharmacist to prescriber**

## 2.4 Discussion

There were many differences between the two systems studied. A detailed comparison is outside the scope of this report. However, some of the key differences included the other systems with which the electronic prescribing system was linked, the computer platform, the extent of use within the study site and the way in which doses were scheduled.

ServeRx was a closed loop system that incorporated ward-based automated dispensing, electronic drug trolleys and barcode patient identification as well as electronic prescribing and administration. The system that we studied was linked only to the Trust's patient administration system for transfer of basic patient demographic data; there were no links to the pharmacy computer system or to laboratory data. In contrast, the Meditech electronic prescribing and administration system was one module in a wider hospital-wide Meditech system and was therefore linked to all other patient and laboratory data. The system comprised only electronic prescribing and administration; the drug trolleys were of traditional NHS design and barcode technology was not used to identify products or patients at the time of our study.

The ServeRx and Meditech systems ran on different platforms, and so differed dramatically in screen layout and navigation. ServeRx was window-based and used touch-screens and a mouse; Meditech version 4.8 was not windows-based; navigation across fields and screens was with a combination of function, shift and control keys. Users' views on this are explored in more detail in Appendices A and B.

ServeRx was a pilot system on one ward; the Meditech electronic prescribing system was used throughout the majority of the hospital.

Finally, there were differences in the way that prescribed doses were scheduled for administration. Using ServeRx, this was done after prescribing as a separate stage, usually by nursing staff; in contrast, scheduling was done at the same time using the same screen with Meditech. Similarities and differences in decision support functions will be discussed in Appendix E.

### **3. Measuring error – definitions and development of new retrospective methods**

#### **3.1 Introduction**

The reported incidence of medical error in general and medication error in particular is enormously influenced by the definition of an error used and the method of detection. Combinations of these factors can alter the reported incidence of error by several orders of magnitude. In this Chapter we report and justify the definitions we have used, and explain how we have developed, and incorporated into computer software, two ways (new to the UK) of retrospectively identifying prescribing errors.

We were specifically asked by the funding body to use three methods of prescribing error detection: prospective, retrospective and use of a “trigger tool”. In the context of prescribing errors, prospective detection refers to health care professionals, usually pharmacists, recording the errors identified in the course of their daily prescription monitoring<sup>3,22</sup>. Retrospective detection refers to studying patients’ medical records to identify prescribing errors; this approach has been widely used to identify iatrogenic injury in general but there are few reports<sup>23</sup> of its use to study medication errors. Finally, a trigger tool is a collection of indicators such as abnormal laboratory values and drugs that may be prescribed as antidotes, used to trigger more extensive investigation into whether medication-related harm has occurred. Various trigger tools, for both prospective and retrospective use, have been developed in the US to identify medication-related harm<sup>24,25</sup>. However, there are no reports of their use in the UK, and no reports of their use to study prescribing errors in particular rather than medication-related harm in general.

The study’s objectives relating to this Chapter were:

- To develop a retrospective method to identify the incidence, nature and severity of medication errors from patients’ medical notes;
- To adapt trigger tool methodology to a UK context, to establish the specificity and sensitivity of the triggers used, and make suggestions for change if necessary.

## 3.2 Definitions

Broadly speaking, medication errors can be divided into two main types. These are prescribing errors and administration errors. While the majority of this study focuses on prescribing errors, we also examined medication administration errors in the prospective study of the electronic prescribing system at Charing Cross Hospital described in Chapter 4.

### ***Prescribing errors***

Prescribing errors were defined relative to normal medical practice, using a practitioner-derived definition that has previously been used in research<sup>3,26,27,28,29</sup> and cited by the Department of Health<sup>30</sup>.

A prescribing error was defined as a prescribing decision or prescription-writing process that results in an unintentional, significant: (i) reduction in the probability of treatment being timely and effective or (ii) increase in the risk of harm, when compared to generally accepted practice<sup>31</sup>. The definition is accompanied by lists of events that should and should not be included as prescribing errors<sup>31</sup>, and includes errors originating in both prescription writing and the prescribing decision.

We used two denominators to express prescribing error rates in this study. These were the number of medication orders written, and the number of patient days. The first gives a measure of the risk associated with each prescribing act; the second presents risk to individual patients. It was assumed that each medication order could be associated with only one prescribing error.

### ***Medication administration errors***

A medication administration error (MAE) was defined as any dose of medication administered (or omitted) that deviated from the patient's medication order as specified on their drug chart or electronic prescription<sup>32,33</sup>.

Pharmacists' endorsements to clarify medication orders were considered to be part of the medication order. Administration of medication in relation to food was not assessed, and failure to follow hospital procedures was not in itself considered an MAE. Doses not administered because they were unavailable on the ward, because the drug chart could not be found, or because nursing staff could not find the drugs concerned or interpret the order were included as MAEs. In common with most

other MAE studies the time at which doses were administered was not considered a source of error, unless this was grossly incorrect for a drug where the time of day was important. Errors prevented by the observer or the patient were included as MAEs; those prevented by other health care professionals were not.

The denominator used to express the MAE rate was the number of opportunities for error (OE), defined as all doses given plus any doses omitted that the observer could classify as being either correct or incorrect.

### **3.3 Developing a method for retrospectively identifying medication errors from the medical notes**

#### ***Methods***

##### Developing the method

We initially conducted pilot work in which ten investigators each assessed two sets of medical notes for prescribing errors using our definition of a prescribing error. However, we found enormous variation in the numbers of errors identified by the different investigators, ranging from one to ten errors for the first patient (relating to 25 different errors), and two to eleven for the second (22 different errors). On discussion, the research team agreed that six of the events identified for the first patient met the study's definition of a prescribing error, and 11 for the second.

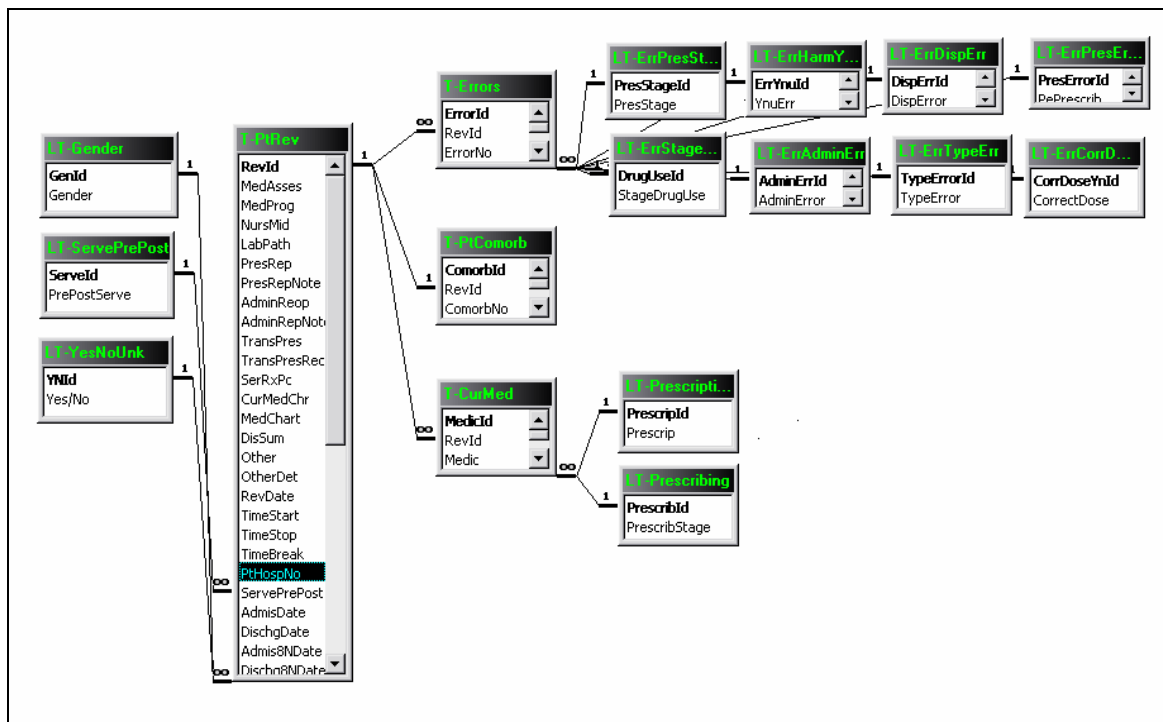
We therefore decided that a more formal approach was needed to improve consistency, and developed a method for the retrospective identification of medication errors based on that used previously in a UK study of iatrogenic injury<sup>34</sup>. The original data collection form was amended to focus on medication rather than iatrogenic injury, and to include all medication errors, whether or not they resulted in harm.

The resulting retrospective review form (RRF) consisted of five main sections:

- summary of the data sources available;
- reviewer information;
- patient information;
- current medication;
- details of any errors identified, including any harm caused.



The form was originally used in paper form (Appendix F) but subsequently transformed into electronic format, so that data could be entered directly into an Access database. The data flow diagram showing the relationships within the database is given in Figure 13. The database is designed so as to guide the reviewer through the stages of data collection and collect all relevant information. The RRF was designed for the identification of all types of medication error, including administration errors; however, only the aspects relating to prescribing errors will be considered in this report.



**Figure 13: Data flow diagram showing the relationships within the RRF database.**

### Inter-rater reliability

Inter-rater reliability was explored for five patients. Two pharmacists each independently applied the RRF to each of these sets of medical notes, and compared the results.

## **Results**

### Inter-rater reliability

The results relating to inter-rater reliability are summarised in Table 1.

Patient	Prescribing errors detected		
	Reviewer 1	Reviewer 2	On discussion
1	5	1	3
2	2	5	4
3	12	9	15
4	3	2	3
5	2	2	3
<b>TOTAL</b>	<b>25</b>	<b>21</b>	<b>28</b>

**Table 1: Summary of inter-rater reliability test for retrospective review form**

There was considerable variation between the two reviewers. The prescribing errors initially detected by only one of the two reviewers, but subsequently agreed to be errors, were:

- Two errors involving “when required” medication, where the prescribed dosing frequency could allow the total daily dose to be exceeded;
- Morphine and metoclopramide prescribed intramuscularly in a patient with liver impairment, an international normalised ratio (INR) of 6 and haematomas;
- Warfarin 3mg prescribed in a patient with an INR of 5.0;
- Enoxaparin 20mg once daily by subcutaneous injection prescribed for an obese medical patient. The dose should have been 40mg once daily as patient is at higher risk of thrombosis.
- Oxygen not prescribed for a patient who required (and was being given) oxygen;
- Two errors where an asthmatic patient was not prescribed a salbutamol inhaler on admission;
- Patient prescribed fluticasone inhaler 125 micrograms once daily, when twice daily dosing is required;
- Tramadol 50mg capsules (which cannot be split) prescribed to be given in a dose of 25mg every 6 hours when required;
- Patient on ciclosporin prescribed trimethoprim, which increases the risk of nephrotoxicity;
- Ciprofloxacin 500mg twice daily prescribed in a patient on warfarin;
- Omeprazole 40mg daily prescribed in a patient on warfarin.

The ensuing discussion of these cases was used to further clarify the methods and definition used for the remainder of the study.

### 3.4 Adapting trigger tool methodology for use in the UK

#### **Methods**

We adapted a published US trigger tool<sup>24</sup> for UK use. The 24 US triggers were reviewed for their applicability to the UK. Reference ranges were changed to reflect the units used in the UK, and where the drugs used reflected differences in practice between the USA and the UK, UK equivalents were suggested. The original US triggers alongside proposed UK equivalents were then sent to three clinical pharmacologists, two clinical pharmacists and a senior medication safety expert at the National Patient Safety Agency for comment and approval. Some minor comments were incorporated and the final UK version agreed. Again, a paper data collection form (Appendix G) was designed, which was then transferred to an Access database (Figure 14).

As for the RRF, the trigger tool was designed for the identification of all types of medication error; however, only the results relating to prescribing errors will be considered in this report.

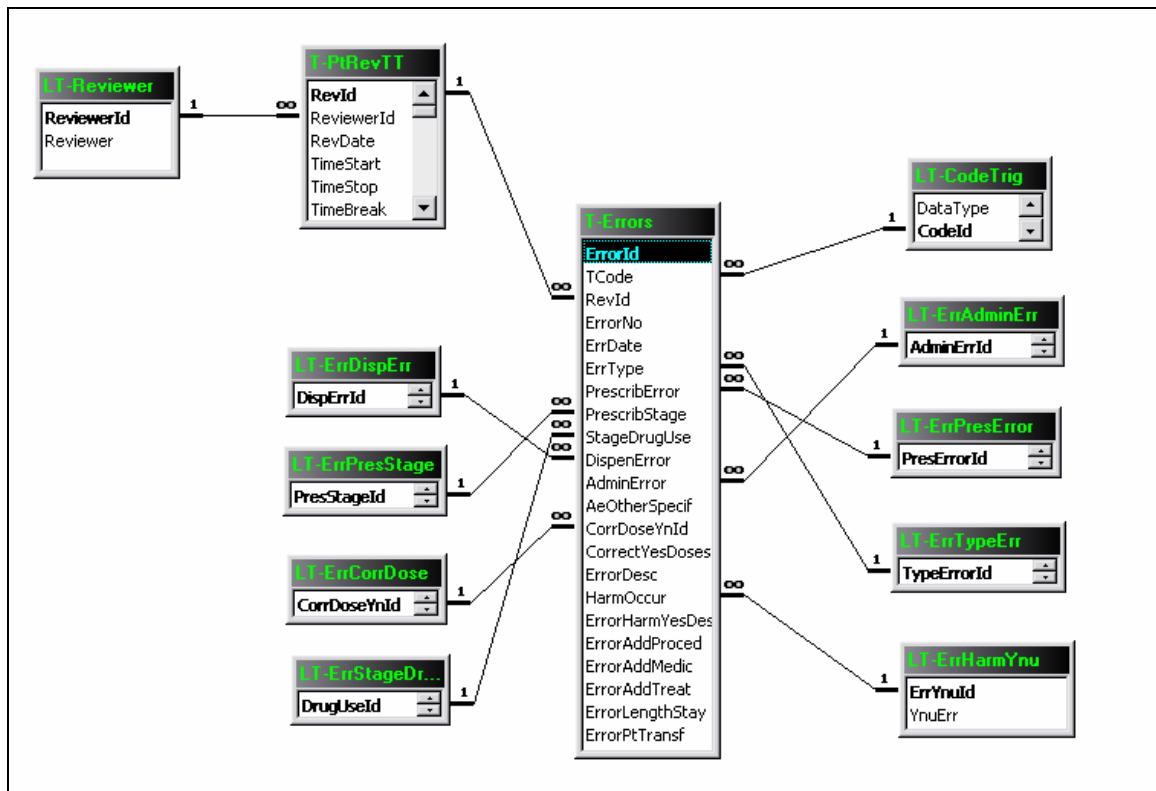
#### Inter-rater reliability

Inter-observer reliability was explored in the same five patients as for the RRF. Two research pharmacists each independently applied the trigger tool to each of these sets of medical notes, and the results compared.

#### **Results**

#### Inter-rater reliability

When reliability was explored, neither reviewer identified any prescribing errors in the five patients reviewed. However, since each trigger was an objective measure, such as a drug being prescribed or levels being outside a fixed range, we would not expect difference between assessors.



**Figure 14. Data flow diagram showing the relationships within the trigger tool database.**

### 3.5 Discussion

In this Chapter we have described the development of the first method for retrospectively reviewing patients' medical notes to identify prescribing errors (and other types of error) suitable for use in the UK, and the first UK-specific trigger tool for the identification of prescribing errors and other types of adverse drug event. Access databases were also developed for each of these to allow direct data entry into a laptop computer, and to facilitate automated reporting of key outcome measures.

While the RRF was designed to facilitate consistent identification of prescribing errors, when two investigators assessed the same sets of medical notes, different errors were identified. We used these findings as part of the development work to clarify the methods and definition used for the remainder of the study and therefore did not formally test inter-rater reliability. However, we would recommend that this be formally tested in future work of this type.

Chapter 5 describes the use of these two methods to identify prescribing errors before and after the introduction of electronic prescribing in two different hospitals. Chapter 6 then compares the results obtained using four methods of detecting prescribing error: the RRF, trigger tool, prospective recording by the ward pharmacist, and spontaneous reporting.

## 4. The prospective quantitative evaluation of electronic prescribing at Charing Cross Hospital

### 4.1 Introduction

This Chapter describes the prospective, quantitative, evaluation of a closed-loop electronic prescribing system at Charing Cross Hospital. The qualitative evaluation of this same system is presented in Appendix A .

The objective of this part of the study was to prospectively evaluate the impact of a closed-loop electronic prescribing and automated dispensing system (“ServeRx”), using quantitative methods. The outcome measures explored were:

#### ***Safety and quality***

- Incidence of prescribing errors and potential for harm;
- Incidence of medication administration errors and potential for harm;
- Interventions and prescription endorsements made by pharmacy staff;
- Actual patient harm resulting from medication errors;
- Adherence to the trust’s medication policies;
- Completeness of allergy documentation;
- Timeliness of drug administration;
- Percentage of doses for which administration or non-administration was correctly documented.

#### ***Staff time and system performance***

- Amount of staff time spent on different medication and system-related activities;
- Measures of system performance;
- Efficiency of stock control;
- Delays to discharge caused by patients waiting for discharge medication.

The remainder of this chapter is presented in two main sections. The first describes the methods used to evaluate the outcome measures relating to safety and quality, together with the results obtained; the second section presents the methods and results relating to staff time and system performance. However, first we briefly describe the setting, the study design and our sample size calculations.

## 4.2 Setting

We studied a 28-bed general surgery ward at Charing Cross hospital, part of Hammersmith Hospitals NHS Trust. Scheduled drug rounds took place four times each day with one round serving one half of the ward; there were therefore eight rounds each day. In general, one nurse carried out the majority of medication-related tasks on each half of the ward. The ward received a pharmacy service typical of that in UK hospitals, with a daily visit from the ward pharmacist on weekdays and a short visit on Saturdays. In line with policy in the study hospital, the ward pharmacist made a “chart-focused” visit on Mondays, Wednesdays and Fridays, checking all drug charts, resolving urgent issues and identifying less-urgent issues for follow-up. On Tuesdays and Thursdays the ward pharmacist conducted a “patient-focused visit”, resolving less-urgent issues, and checking patients’ medication histories. Prior to the introduction of ServeRx, medication orders were prescribed on paper drug charts and medication stored in two drug trolleys plus stock cupboards. ServeRx is described in detail in Chapter 2; in brief, it is a closed-loop system comprising electronic prescribing, automated ward-based dispensing, barcode patient identification and electronic medication administration records.

## 4.3 Study design, sample size calculations and statistical analysis

We used a before and after design, and collected data on all outcome measures 3-6 months before, and 6-12 months after the introduction of ServeRx. To compare these two periods, we collected demographic data for all patients admitted during an eight-week period pre- and post-ServeRx. These eight-week periods encompassed data collection for all outcomes except prescribing errors; basic demographic data were therefore recorded and compared separately for the prescribing error studies.

The primary outcome measures were the prescribing error and medication administration error rates. The sample size for the prescribing error study was 2,319 newly written medication orders pre-ServeRx and 2,319 post-ServeRx. This was based on being able to identify a reduction in the prescribing error rate from 2%<sup>3</sup> to 1% ; we estimated that four weeks’ data collection would achieve this sample size. The sample size for the medication administration error study was 906 opportunities for error (doses observed plus any doses omitted) pre-ServeRx and 906 post-ServeRx, based on being able to identify a reduction from 5%<sup>35</sup> to 2.5%. We

estimated that observation of 56 drug rounds would achieve this. Both calculations were based on two-sided tests using  $\alpha$  of 0.05 and  $\beta$  of 0.2. Nominal data were compared using the chi square test and continuous data by the unpaired t-test or Mann-Whitney test for parametric and non-parametric data respectively. The 95% confidence intervals (CI) were calculated for differences.

#### **4.4 Evaluating the safety and quality of each system**

In this section, we consider prescribing errors and pharmacists' interventions, medication administration errors, adherence to the Trust's medication policies, and pharmacists' prescription endorsements. The methods relating to each of these will be described in turn, before presenting the results obtained.

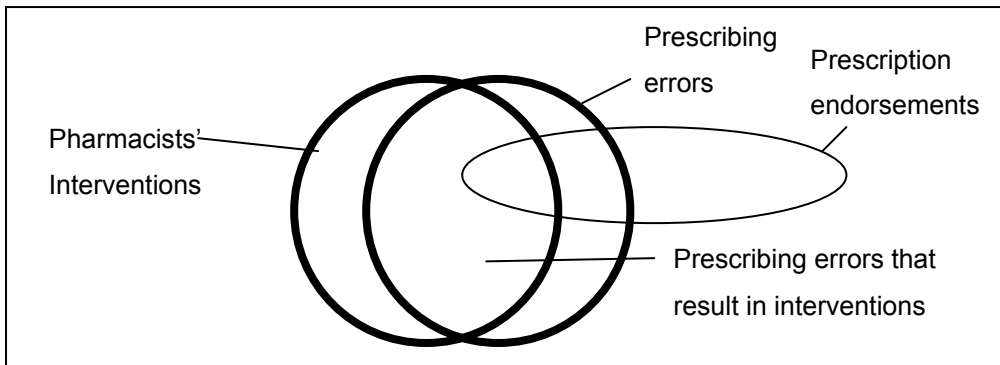
##### ***Methods***

###### **Prescribing errors and pharmacists' interventions**

Figure 15 illustrates the relationship between prescribing errors and interventions. Prescribing errors were defined as in Chapter 3<sup>31</sup> and classified as previously<sup>3</sup>. An intervention was defined as any proactive or reactive (in response to a question from another health care professional) activity undertaken by the pharmacist to suggest changes in drug therapy or monitoring, which involved contacting medical or nursing staff.

The same ward pharmacist (with the exception of five days pre and two days post-ServeRx, when different pharmacists provided cover) identified prescribing errors and recorded interventions on the study ward during a four-week period using methods developed previously<sup>3</sup>. However, in addition, a second investigator checked for prescribing errors once a week to help identify any that had not been documented by the ward pharmacist. We also recorded whether or not errors were rectified before the patient received any doses, and whether we judged the error to have arisen in the prescribing decision or in medication order writing<sup>3</sup>. We avoided the first two months after a change of junior medical staff. To obtain a denominator, we retrieved the medical notes for patients who were on the ward at any time during each study period<sup>3</sup> and counted the number of medication orders written during that time. Where patients' medical notes could not be located, we extrapolated the total number of medication orders written based on the notes retrieved.





**Figure 15: Relationship between prescribing errors, pharmacists' interventions and pharmacists' prescription endorsements.**

Those events falling within one or both of the two bold circles were included in this aspect of the evaluation. Prescription endorsements are addressed separately in a later section.

The potential severity of the errors identified was assessed by five judges<sup>36</sup> using a scale from 0 (no harm) to 10 (death), and the mean severity score calculated, based on methods described and validated previously<sup>37</sup>. According to this method, a mean severity score of less than 3 indicates an error of minor severity, a score between 3 and 7 inclusive indicates moderate severity and a score of more than 7 major severity.

#### Medication administration errors (MAEs)

Pharmacists observed a sample of 56 drug rounds during a two-week period, using validated methods<sup>32,33</sup>. Rounds conducted during night shifts and weekends were included. The denominator was the number of opportunities for error (OE), defined as all doses administered plus any doses omitted, that we could classify as either correct or incorrect. Each observed IV dose comprised two OE, one for preparation and one for administration<sup>33</sup>. An MAE was defined as any dose of medication that deviated from the patient's current medication orders; timing and documentation errors were excluded. The severity of the MAEs identified was assessed by four judges using a scale from 0 (no harm) to 10 (death), and the mean severity score calculated, as previously<sup>37</sup>.

#### Adherence to the trust's medication policies

Adherence to policies relating to drug administration was assessed during the observation of MAEs; policies relating to allergy documentation, the wearing of wristbands and prescribing were assessed during an audit of patients' medication charts.

During the observation of MAEs, for each patient to whom medication was administered, we recorded whether or not their identity was checked, defined as visually checking or scanning the patient's wristband, or asking them to state their name and date of birth. We also recorded the time of administration and whether or not nursing staff observed the patient take the dose. Finally, we recorded how each dose was documented as well as whether or not it was given and the reason for any omissions. "Potentially significant" documentation discrepancies were also identified, defined as any case where the action documented (drug given versus not given) was opposite to that observed.

To assess standards relating to allergy documentation, wearing of wrist-bands and prescribing, we audited about 50 patients and their paper or electronic medication charts both pre- and post-ServeRx. A series of audit standards were selected from the Trust's Medication and Drugs Transfusion Policy, the Formulary and Clinical Management Guidelines, and the pharmacy endorsement standards (Figure 16). Medication orders for dietary supplements, oxygen, anti-thromboembolism stockings, blood products, anaesthetic agents and other medication prescribed on anaesthetic charts, patient-controlled analgesia (PCA), and continuous intravenous infusion therapy were excluded. The monograph heading in the British National Formulary was taken as the approved name with the exception of nifedipine, diltiazem, theophylline and lithium, for which prescribing by either brand or generic name was considered acceptable.

***Patient-specific standards***

1. All patients' drug charts or ServeRx records should indicate their allergy status.
2. All patients should be wearing a hospital wristband (pre-ServeRx), or a ServeRx wristband (post-ServeRx).

***Medication order-specific standards***

1. All medication should be prescribed by approved name.
2. All medication orders should have the dose units (eg "micrograms") and dose quantity (eg "10") written correctly.
3. All medication orders should be complete.
4. No medication orders should be changed by amending the original medication order.
5. All medication orders should be legible.
6. For all medication orders, the prescriber should be identifiable.
7. All medication orders for treatment courses of anti-infectives should be given stop dates.
8. All anti-infectives on the trust's reserved list should have appropriate documentation added by the pharmacist, stating whether or not they are approved for use.

**Figure 16: The standards used during an audit of patient's medication charts to assess adherence to medication policies**

Pharmacists' prescription endorsements

An endorsement was defined as any clarification required to an regular or "when required" inpatient medication order, according to the Trust's ward pharmacy procedures. These included clarifying generic names and counselling instructions (such as taking with food), the approval status for reserved anti-infectives and maximum frequencies if not already specified. One medication order could require more than one endorsement. Supply endorsements were not included, and the number of days' treatment with anti-infectives was included as a required endorsement pre-ServeRx, but not post-ServeRx. This is because it had been decided at the time of implementation that this feature was not necessary with the ServeRx system. The denominator was the total number of current regular and "when required" medication orders assessed. Dietary supplements, oxygen, anti-thromboembolism stockings and patient controlled analgesia were excluded. Data were collected on four separate days, at least two weeks apart. On each occasion, the investigator recorded all endorsements made by the ward pharmacist as well as all endorsements that should have been made but were not. All data collection took place on a Tuesday or Thursday to ensure that the ward pharmacist would have seen the drug charts or computer records on the previous day.

## Results

### Demographics

Demographic data were similar in each phase of the study (Table 2); the only difference was in mean patient age.

Demographic factor	Pre-ServeRx	Post-ServeRx	Statistical analysis
Total number of admissions (mean number per week)	188 (23.5)	201 (25.1)	-
Mean length of patient stay	7.4 days (n*=185)	7.2 days (n=192)	P = 0.73 (Mann Whitney test)
Mean patient age	59.7 years (n=187)	53.4 years (n=179)	P = 0.002 (unpaired t test)
Percentage male	62.2% (n=188)	52.0% (n=200)	P = 0.05 (chi square test)
Percentage emergency admissions	31.4% (n=188)	30.0% (n=103)	P = 0.92 (chi square test)
Percentage outliers	21.8% (n=179)	24.9% (n=185)	P = 0.57 (chi square test)

**Table 2: Demographics of patients admitted during an eight-week period encompassing the majority of data collection pre and post-ServeRx**

\* In some cases, data were incomplete; results are presented for the patients for whom we had complete data ("n").

### Prescribing errors and pharmacists' interventions

Table 3 presents a summary of the medication orders written during the pre and post-ServeRx data collection periods; Appendix H gives more detail. Fewer medication orders were written per patient post-ServeRx, but total numbers were similar. More discharge items were prescribed pre-ServeRx, and more regular inpatient medication orders post-ServeRx. More medication orders were transcribed onto ServeRx than rewritten on paper drug charts.

There was a statistically significant reduction in the number of prescribing errors identified post-ServeRx; the absolute difference in the prescribing error rate was -1.8% (95% CI -0.9 to -2.7%). Post-ServeRx, more prescribing errors were rectified before one or more doses were administered to the patient, but this difference did not meet statistical significance. There was no difference in the mean clinical severity scores of the errors identified. Pre-ServeRx the ratio of errors of minor:moderate:major severity was 18:73:3. Post-ServeRx this was 9:33:6.

Table 4 summarises the prescribing errors identified and the pharmacists' interventions made.

	Pre-ServeRx	Post-ServeRx	Statistical analysis
<b>Medication orders written</b>			
Patients on ward for some or all of study period	129	147	-
Patients for whom notes retrieved (% of all patients)	113 (88%)	126 (86%)	p = 0.78; chi square test
Number of medication orders written for patients whose notes retrieved	2156	2024	-
Projected number of medication orders written for all patients	2450	2353	-
Median number of medication orders per patient during study period	16	10	p = 0.009; Mann-Whitney test

**Table 3: Patients' notes retrieved and medication orders written**

	Pre-ServeRx	Post-ServeRx	Statistical analysis
<b>Prescribing errors</b>			
Prescribing errors identified (% of projected number of medication orders written)	93 (3.8%)	48 (2.0%)	p = 0.0004; chi square test
Errors rectified before dose given (% of prescribing errors)	45 (48%)	32 (67%)	p = 0.06; chi square test
Mean severity score	4.2	4.6	p = 0.24; unpaired t test
<b>Pharmacists' interventions</b>			
Interventions made in response to prescribing error (% of prescribing errors)	38 (40%)	27 (56%)	p = 0.12; chi square test
Other interventions made	35	18	-
Total interventions made (% of projected number of medication orders written)	73 (3.0%)	45 (1.9%)	p = 0.02; chi square test

**Table 4: Summary of prescribing errors identified and pharmacists' interventions made**

Table 5 summarises the types of prescribing error; most types were reduced. Table 6 presents the prescribing errors according to whether they occurred in the prescribing decision or in medication order writing. The reduction in errors arising in medication order writing is statistically significant (1.3%; 95% CI 0.5 to 2.1%) whereas the reduction in errors arising in the prescribing decision is not (0.4%; 95% CI -0.1 to 0.9%).

Table 7 gives examples of the errors identified. We did not identify any cases of actual harm resulting from prescribing errors using this prospective method.

Stage of prescribing process	Pre-ServeRx number of errors (% of medication orders)	Post-ServeRx number of errors (% of medication orders)
Need for drug therapy	20 0.8%	12 0.5%
Select specific drug	2 0.1%	0 -
Select drug dose	45 1.8%	29 1.2%
Select formulation	3 0.1%	5 0.2%
Give instructions for supply of product	13 0.5%	0 -
Give administration instructions	10 0.4%	2 0.1%
Total	93 3.8%	48 2.0%

**Table 5: Prescribing errors presented according to stage of the prescribing process**

Origin of prescribing error	Pre-ServeRx (% of all medication orders written)	Post-ServeRx (% of all medication orders written)
Prescribing decision	32 (1.1%)	16 (0.7%)
Writing medication order*	66 (2.7%)	32 (1.4%)
<b>Total</b>	<b>94 (3.8%)</b>	<b>48 (2.1%)**</b>

**Table 6: Breakdown of prescribing errors according to their likely origin**

\* The reduction in errors arising in medication order writing is statistically significant (1.3%; 95% CI 0.5 to 2.1%) \*\* Total is more than 2.0% due to rounding

Pre-ServeRx	Post-ServeRx
<ul style="list-style-type: none"> <li>• Patient usually takes simvastatin 20mg at night, but not prescribed on admission (need for drug therapy)</li> <li>• “Vitamin B12 co strong” prescribed when “vitamin B tablets compound strong” intended (select specific drug)</li> <li>• Bendroflumethiazide 20mg once daily prescribed when 5mg intended (select drug dose)</li> <li>• Dipyridamole 200mg twice daily prescribed for secondary prevention of ischaemic stroke, without specifying that modified release required (select formulation)</li> <li>• Beclometasone inhaler prescribed with no strength specified (give instructions for supply)</li> <li>• Prednisolone 10mg prescribed without specifying time or frequency of administration (give administration instructions)</li> </ul>	<ul style="list-style-type: none"> <li>• Tinzaparin and enoxaparin both prescribed (need for drug therapy)</li> <li>• Cyclizine 50mg tablets prescribed to be given one-hourly when required (select drug dose)</li> <li>• A dose of ciclosporin 150mg was prescribed to be given using the 100mg capsules rather than the 50mg capsules (select formulation)</li> <li>• Trimipramine 50mg four times daily prescribed for a patient who usually takes 200mg at night (give administration instructions)</li> </ul>

**Table 7: Examples of prescribing errors identified. The stage of the prescribing process is shown in brackets.**

#### Medication administration errors (MAEs)

We observed 56 drug rounds and 1644 OE pre-ServeRx, and 55 drug rounds and 1178 OE afterwards. MAEs fell after the introduction of ServeRx from 8.6% (141 MAEs) to 4.4% (53 MAEs). The difference in MAE rates was 4.2% (95% CI -2.4 to -6.0%;  $p = 0.00003$ ). The main reductions were in omission and wrong dose errors. Table 8 gives examples and Table 9 the types of MAE; there was a reduction in errors involving the wrong drug, wrong patient, wrong dose, and omission for reasons other than unavailability. There was no difference in omissions due to unavailability. Three of the five wrong dose MAEs post-ServeRx involved medication stored outside the automated cabinet. The post-ServeRx wrong route errors were paracetamol given orally when the rectal route was prescribed and vice versa. MAE rates were highest for IV doses, mainly involving excessively fast administration of IV bolus doses. A potential source of bias was that fewer IV OE were observed post-ServeRx (171 pre-ServeRx; 39 post-ServeRx) because the use of electronic medication records allows one nurse to prepare IV medication while another administers oral medication. However, MAE rates for non-IV doses also fell significantly after the introduction of ServeRx, from 7.0% pre- to 4.3% post-ServeRx (a difference of 2.7%;

95% CI -0.9 to -4.5%; p=0.005). The mean severity score for all MAEs did not change significantly after the introduction of ServeRx: pre- it was 2.7; post-ServeRx it was 2.5 (p=0.39; t-test). We did not identify any cases of actual harm resulting from MAEs.

Pre-ServeRx	Post-ServeRx
<ul style="list-style-type: none"> <li>Levothyroxine 25mcg omitted as could not find medication (omission)</li> <li>Thiamine 100mg prescribed. Observer intervened to prevent levothyroxine 100mcg being given (wrong drug)</li> <li>Ciprofloxacin 500mg administered when 250mg prescribed (wrong dose)</li> <li>Norfloxacin 400mg given twice as first dose was not signed for (extra dose)</li> </ul>	<ul style="list-style-type: none"> <li>Propranolol 160mg not given as not available on ward (omission due to unavailability)</li> <li>Salbutamol 5mg nebulae administered when 2.5mg prescribed (wrong dose)</li> <li>Administration of Tazocin® 4.5g IV over 30 seconds instead of 3-5 minutes (fast administration IV bolus)</li> <li>Administration of paracetamol 1g orally when rectal route was prescribed (wrong route)</li> </ul>

**Table 8: Examples of the medication administration errors identified. The type of error is shown in brackets.**

Type of error	Pre-ServeRx		Post-ServeRx	
	Number identified	% of OE	Number identified	% of OE
Wrong drug	2	0.1%	-	-
Wrong dose	29	1.8%	5	0.4%
Wrong patient	5	0.3%	-	-
Wrong route	2	0.1%	6	0.5%
Wrong form	-	-	-	-
Wrong time	-	-	1	0.1%
Extra dose	2	0.1%	-	-
Expired drug	1	0.1%	-	-
Omission due to unavailability	26	1.6%	25	2.1%
Other omission	42	2.6%	11	0.9%
Wrong diluent	1	0.1%	-	-
Fast administration IV bolus	31	1.9%	5	0.4%
TOTAL	141	8.6%	53	4.4%

**Table 9: The medication administration errors identified**



### Adherence to the Trust's medication policies

The results relating to medication administration are presented in Table 10. Post-ServeRx, there was a dramatic increase (from 17% to 81%) in the percentage of patients whose identity was checked prior to administration, and an increase in the doses whose consumption was observed by the nurse (4% to 24%). Medication administration was more timely. However, while there was no significant difference in the percentage of doses documented correctly, there was an increase in the incidence of potentially significant documentation discrepancies. This was largely due to doses being recorded as unavailable because they were not in the automated cabinet, whereas the patient had a supply at their bedside and did receive the dose.

	Pre-ServeRx	Post- ServeRx	Statistical analysis
<b>Quality of documentation</b>			
Doses assessed	2167	1623	-
Doses documented correctly (% of doses assessed)	2086 (96.3%)	1557 (95.9%)	p = 0.66; chi square test
Potentially significant documentation discrepancies (% of all doses)	5 (0.23%)	33 (2.03%)	p < 0.0001; chi square test
<b>Identity Checking</b>			
Doses assessed	1344	1291	-
Doses for which identity checked (% of doses assessed)	234 (17.4%)	1047 (81.1%)	p < 0.0001; chi square test
<b>Observing patients taking the dose</b>			
Doses assessed	1031	1009	-
Doses for which administration observed by nurse (% of doses assessed)	45 (4%)	243 (24%)	p < 0.0001; chi square test
<b>Time difference between time prescribed &amp; time administered</b>			
Doses assessed	2188	1678	
< 1 hour	1719 (79%)	1475 (89%)	p < 0.0001; chi square test
1 – 2 hours	422 (19%)	203 (11%)	
> 2 hours	47 (2%)	0 (0%)	

**Table 10: Adherence to policies relating to medication administration**

During the audit of medication charts, we collected data on 47 patients (561 medication orders) pre-ServeRx, and 53 patients (564 medication orders) post-ServeRx. The results are presented in Table 11. There was no significant difference in the percentage of patients with allergy status documented or who were wearing wristbands. However, there were significant (although sometimes small) improvements in prescribing by approved name, completeness of medication orders, medication orders being rewritten rather than amended, legibility, identification of the prescriber and the use of stop dates for anti-infectives. Incorrectly written doses were more common post-ServeRx; these related mainly to selection of confusing

doses or volumes such as orders for 50ml of 50mg/ml cyclizine injection to be given orally, and 1,000 co-codamol tablets to be given when required. Documentation of the approval status of reserved anti-infectives was also worse post-ServeRx.

	<b>Pre-ServeRx</b>	<b>Post-ServeRx</b>	<b>Statistical analysis</b>
<b><i>Patient-specific audit standards</i></b>			
All patients' drug charts or ServeRx records should indicate their allergy status	83% (n = 47)	94% (n = 53)	p = 0.14; chi square test
All patients should be wearing a hospital wristband (pre-ServeRx), or a ServeRx wristband (post-ServeRx)	94% (n = 47)	92% (n = 51)	p = 0.91; chi square test
<b><i>Medication order-related audit standards</i></b>			
All medication should be prescribed by approved name	84% (n = 561)	97% (n = 564)	p < 0.0001; chi square test
All medication orders should have the dose units (eg "micrograms") written correctly	91% (n = 539)	91% (n = 564)	p = 0.92; chi square test
All medication orders should have the dose quantity (eg "10") written correctly	99.8% (n = 561)	97% (n = 564)	p = 0.0005; chi square test
All medication orders should be complete	63% (n = 561)	99.9% (n = 564)	p < 0.0001; chi square test
No medication orders should be changed by amending the original medication order	87% (n = 561)	100% (n = 564)	p < 0.0001; chi square test
All medication orders should be legible	96% (n = 561)	100% (n = 564)	p < 0.0001; chi square test
For all medication orders, the prescriber should be identifiable	73% (n = 561)	87% (n = 473)	p < 0.0001; chi square test
All medication orders for treatment courses of anti-infectives should be given stop dates	8% (n = 64)	99% (n = 68)	p < 0.0001; chi square test
All 'reserved' anti-infectives should have appropriate documentation added by the pharmacist, stating whether or not they are approved for use	36% (n = 14)	0% (n = 26)	p = 0.006; chi square test

**Table 11: Adherence to policies relating to prescribing and allergy documentation** Percentages are presented according to the relevant number (n) assessed.

#### Pharmacists' prescription endorsements

During the four pre-ServeRx endorsement data collection periods, only 87 (78%) of a total of 112 patients' drug charts were included as a result of patients being in theatre, having investigations or their charts otherwise being unavailable. During the post-ServeRx data collection periods, all 106 patients (100%) were included, as it is

possible to view patients' medication orders regardless of whether or not the patient is physically present on the ward.

A total of 787 (mean 9.0 per patient) and 897 (mean 8.0 per patient) regular and "when required" medication orders were reviewed in the pre- and post-ServeRx periods respectively. Table 12 summarises the endorsement opportunities identified in each phase of the study.

	<b>Pre-ServeRx</b>	<b>Post-ServeRx</b>	<b>Statistical analysis</b>
Drugs charts/electronic records examined	87	106	-
Medication orders examined (mean number per patient)	787 (9.0)	897 (8.0)	-
Total endorsement opportunities (% of all medication orders)	390 (50%)	190 (21%)	p < 0.0001; chi square test
Endorsements made (% of all endorsement opportunities)	214 (55%)	57 (30%)	p < 0.0001; chi square test

**Table 12: Summary of endorsements made and not made**

Following the introduction of ServeRx, fewer endorsements were required. However, the ward pharmacist made endorsements for only 30% of these, compared with 55% pre-ServeRx. Pre-ServeRx, the most common types of endorsements required were the addition of generic names, strengths, and full names for drugs prescribed using abbreviations or chemical symbols. These endorsements were not required following the introduction of ServeRx. In both phases of the study, other endorsements commonly required involved counselling or administration instructions.

#### **4.5 Evaluating staff time and system performance for each system**

In this section, we consider medical staff time, pharmacy staff time, nursing staff time, delays to discharge, system performance and stock control. Again, the methods relating to each of these will be described in turn.

##### ***Methods***

##### **Medical staff time**

We observed staff prescribing regular inpatient medication orders and recorded the start and finish time for each. Where several medication orders were written or transcribed together for the same patient, mean time per medication order was

calculated. In the post-ServeRx data collection period, both doctors' prescribing and pharmacists' transcribing of orders onto the computer system were timed.

#### Pharmacy staff time

The ward pharmacist self-reported the time taken to provide a clinical pharmacy service to the study ward each weekday for four weeks, and pharmacy distribution staff recorded the time taken to restock the study ward for six weeks. A more detailed observation-based study of the ward pharmacist's activities was carried out for two weeks, during which the ward pharmacist was observed and her activities recorded using two-dimensional activity sampling based on methods described previously<sup>38</sup>. A signalling device was used to identify 32 random time samples each hour when the pharmacist's activity was recorded. The two dimensions were "activity" (11 categories) and "contact" (5 categories).

#### Nursing staff time

To assess nursing time, the time required to carry out each scheduled non-IV drug round was observed during the MAE study. We then used activity sampling<sup>38</sup> to evaluate the proportion of nursing time spent on medication-related activities in between scheduled drug rounds. Ten data collection periods were therefore selected both pre- and post-intervention, on different days and shifts, during which a research pharmacist shadowed the nurse responsible for medication-related activities on one half of the ward. A signalling device was used to identify 32 random time samples each hour when the nurse's activity was recorded.

#### Delays to discharge

Data on delays in dispensing discharge medication (TTAs) and delays to patients' discharges were collected for six weeks. We contacted the nurse in charge of the study ward on a daily basis, and asked for details of any patients whose discharge had been delayed in the last 24 hours (72 hours at weekends) due to a delay in the dispensing of their discharge medication.

#### System performance

System performance problems were investigated by leaving data collection forms on each drug trolley for a six-week period pre- and post-ServeRx. Nursing staff were asked to note down "any problems encountered with the system of medication prescribing, supply and administration". Following the introduction of ServeRx, the pharmacy-based project nurse also routinely recorded problems of which she was

made aware. Her records were analysed for the same post-ServeRx six-week period.

### Stock control

The numbers of medication lines on the stock list, the value of the stock list, and the total value of stock and non-stock medication physically on the study ward, were determined. All stock and non-stock medication on the ward was counted manually. Any medication that had exceeded its expiry date was also noted. Intravenous fluids, dietary products, chemical testing strips and devices, and medication stored at the patient's bedside were all excluded. Controlled drugs (CDs) were included, using the stock levels documented in the CD register.

Pre-ServeRx, this count took place on a single day, the day before the once-weekly pharmacy top-up. Details of the items subsequently supplied as the top-up were also recorded. Post-ServeRx, data were collected over a one-week period. At the time of this stock count, there were two pharmacy top-ups carried out each week (Tuesdays and Fridays). These therefore took place during the week of the stock-count.

## **Results**

### Medical staff time

Pre-ServeRx, 32 regular inpatient medication orders were timed, almost all of which were written by house officers or senior house officers. There were 32 new orders timed post-ServeRx, of which 15 were prescribed by house officers or senior house officers, and 17 transcribed by pharmacists. Prescribing increased from a mean of 15 seconds per medication order pre-ServeRx to 47 seconds post-ServeRx ( $p = 0.001$ ). If only medication orders prescribed by medical staff are compared, these took a mean of 15 seconds pre-ServeRx and 39 seconds post-ServeRx ( $p = 0.03$ ; t-test), a difference of 24 seconds (95% confidence interval 3 to 45 seconds).

### Pharmacy staff time

The time taken to provide a weekday ward pharmacy service to the study ward rose from a mean of 68 minutes each day, to 98 minutes ( $p = 0.001$ ; t-test). The percentage of time spent on the following activities increased following ServeRx: changing therapy / monitoring (increase from 4% to 7% of total time), giving advice (9% to 19%), prescription monitoring (16% to 23%) and non-productive time (6% to 11%). Time spent on the following decreased: looking for charts (3% to 0%), checking patients' own drugs (5% to 0%), supply (23% to 14%), and travel (7% to 4%). Time spent on information gathering and prescription annotation remained

about the same. In terms of contact, there was an increase in the percentage of time spent with doctors and a decrease with nurses. Percentages of time spent with patients, pharmacy staff, self and others remained similar, although since the total time providing a ward pharmacy service was greater following ServeRx, each of these increased in real terms. Full details of these results are given in Appendix I. Pre-ServeRx the mean time taken to restock the ward each week was 1 hour 18 minutes; post ServeRx it was 1 hour 14 minutes.

#### Nursing staff time

Results relating to nursing time are shown in Table 13. Drug rounds were shorter, but a higher percentage of time was spent on medication-related tasks in between drug rounds (an increase of 7.6%; 95% CI 2.4 to 12.8%); this included scheduling newly prescribed medication for the appropriate drug rounds and administering medication prescribed to be given when required.

	Pre-ServeRx	Post-ServeRx	Statistical analysis
Drug rounds per week	56	56	-
Mean time spent on each drug round (range)	50 mins (15 –105 mins)	40 mins* (16 – 78 mins)	p = 0.006; unpaired t test
Total time spent on drug rounds each week	46 hours 54 mins	38 hours 16 mins	-
Total time observed outside of drug rounds	16 hours 43 mins	16 hours 11 mins	-
Activity samples recorded outside of drug rounds	521	537	
Medication related activity samples outside of drug rounds (%)	110 (21.1%)	154 (28.7%)	p = 0.006; chi square test

**Table 13: Nursing time spent on medication-related tasks each week**

\*Post-intervention drug rounds comprised a mean 15 minutes preparation time (range 6 minutes to 35 minutes) and 25 minutes administration time (range 8 minutes to 53 minutes).

#### Delays to discharge

Unfortunately we were unable to collect data on this outcome measure, as nursing staff were rarely able to give us any details of patients whose discharges were delayed. A more robust method of investigating this outcome will be required for any future work of this type.

#### System performance

Pre-ServeRx, the system performance questionnaire was completed on 22 occasions. The most commonly noted problem was the non-availability of non-stock medication on the ward (8 cases); the second most common was nurses not re-filling the drug trolley after use, leading to non-availability of stock medication in the trolley (6 cases). More details are given in Table 14.

Post-ServeRx, nurses completed the data collection forms on only six occasions. These comprised six different problems. The project nurse's records had 37 entries recorded for the same six-week period. The most common problems recorded were cart battery failure (10 cases) and software bugs (7 cases). More details are given in Table 15. There was no overlap between the problems recorded pre- and post-ServeRx.

Problem encountered	Number of reports
Non-stock medication not available on ward	8 (36%)
Stock medication not replaced in drug trolley	6 (27%)
Product packaging has changed (delay in finding medication)	2 (9%)
Awaiting drug chart to be rewritten	1 (5%)
Stock medication not available on ward	1 (5%)
Prescription written incorrectly	1 (5%)
Chart annotated incorrectly by pharmacist	1 (5%)
Non-stock medication written after pharmacist's daily visit	1 (5%)
Interruption during drug round	1 (5%)
Total	22 (102*%)

**Table 14 Summary of system performance problems documented pre-ServeRx**

\*Numbers add up to more than 100% due to rounding

Problem encountered	Number of reports		
	Nurses records	Project nurse records	Total
Cart problem	1 (17%)	4 (11%)	5 (12%)
Prescribing error	1 (17%)		1 (2%)
Cart battery failure	1 (17%)	9 (24%)	10 (23%)
Scheduling problem	1 (17%)		1 (2%)
Patient "locked"	1 (17%)		1 (2%)
Drawer in cabinet wouldn't open	1 (17%)		1 (2%)
Software bug		7 (19%)	7 (9%)
Pen-tablet problem		5 (14%)	5 (12%)
Hardware failure		3 (8%)	3 (7%)
Nurse station exception error		2 (5%)	2 (5%)
Cabinet problem		2 (5%)	2 (5%)
Bar code printer		1 (3%)	1 (2%)
Database setting		1 (3%)	1 (2%)
File locked		1 (3%)	1 (2%)
Unable to generate transfer reports		1 (3%)	1 (2%)
Insufficient drawers for narcotics		1 (3%)	1 (2%)
Total	6 (102*%)	37 (100%)	43 (100%)

**Table 15 Summary of system performance problems documented post-Serve Rx.**

\*Numbers add up to more than 100% due to rounding

### Stock control

There were 183 lines on the pre-ServeRx stock list, and 211 post-ServeRx. The value of the stock list pre-ServeRx was £2310.49; the respective value post-ServeRx was £2326.93.

Pre-ServeRx, the total value of goods on the study ward on the day of data collection was found to be £3287.22. There were some expired goods, most of which were



ward stock in the drug trolley, valued at £29.47. The value of the ward top-up was £285.12, giving an estimated maximum value of all goods on the ward of £3572.34. The average value during the course of a week can be estimated to be £3429.78.

Post-ServeRx, the total value of the medication on the ward was £2880.93. Of this, expired medication was valued at £23.20. The figure of £2880.93 represents a 16% reduction in the average stock-holding on the ward.

## 4.6 Discussion

This prospective evaluation suggests that ServeRx reduced prescribing and administration errors, increased adherence to most medicines policies, and reduced stock holding on the ward. However, it resulted in some increases in the staff time required for various medication-related tasks.

### *Impact on safety and quality*

Using a prospective method to identify prescribing errors, we found that ServeRx reduced prescribing errors by 47%. This supports existing US<sup>8,9,39</sup> and some UK<sup>40,41</sup> data suggesting that computerisation can reduce prescribing errors. The majority of the reduction was in errors of medication order writing; a further reduction may be possible with decision support. Our baseline figure of 3.8% was higher than the 1.5% previously identified across a range of wards using the same definitions and similar methods<sup>3</sup>. This may be partly accounted for by the additional check by the principal investigator, who recorded more than a third of the errors in the present study. We believe that this is the first study to have also recorded whether or not errors were rectified before the patient received any doses; this is an important differentiation. We found that pre-ServeRx, almost half of all prescribing errors were rectified prior to administration. This percentage increased to 76% post-ServeRx, although this increase was not statistically significant.

ServeRx reduced non-IV MAEs by 39%, predominantly reducing wrong dose and omission errors. Our baseline non-IV figure of 7.0% is in line with previous UK data<sup>35,42,43,44,45,46,47,48</sup>. The improvement seems likely to be due the design of the automated dispensing system and drug trolley; instead of a drug trolley containing many different drugs, strengths and formulations, the system gives nursing staff access only to the products prescribed. A previous UK comparison of a hospital using electronic prescribing and a hospital using paper-based prescribing found no difference in MAEs<sup>42</sup>.

In line with the reduction in prescribing errors, fewer interventions were made by the ward pharmacist post-ServeRx. There were also fewer endorsements required, but fewer of the endorsements required were actually made. This is likely to be because ServeRx only allows pharmacists' comments to be added on approval of the medication order and not subsequently.

ServeRx improved adherence to the majority of medication-related policies audited. Most prescribing-related standards were improved, with medication orders legible and complete. The only standard that was more often met with the paper system was the writing of doses; this was due to selection from ServeRx menus of inappropriate doses such as "1,000 tablets". ServeRx dramatically increased the percentage of doses for which the patient's identity was checked prior to administration. However, 100% compliance was not achieved; this was due to informal practices such as sticking barcodes to patients' furniture for ease of scanning, which were scanned instead of the patient's wristband. There was no significant difference in the percentage of doses documented correctly, but more "potentially significant" documentation errors post-ServeRx. Medication administration was also more timely.

#### ***Impact on staff time and system performance***

ServeRx increased ward pharmacist and medical staff time required for medication-related tasks. Nursing time spent on drug rounds decreased, which allowed staff more flexibility over planning their time. This is in spite of increasing the amount of time spent checking patients' identities. However, more time was required for other tasks in between drug rounds; these included scheduling of medication, liaison with medical staff and stock control. The increase in the pharmacist's time may be partly due to more patients' medication charts being seen each day, as they were no longer unavailable when patients were in theatre or having investigations, and partly due to the time required to move between different screens to approve medication orders and see an overview of treatment. Prescribing using the computer took longer than on a paper chart; however medication orders were clearly written and associated with fewer errors.

There was a 16% decrease in the value of medication held on the study ward; this was largely due to the removal of the traditional drug trolleys which held large amounts of medication in addition to that in the stock cupboards.

A range of system performance issues were identified both pre and post-ServeRx which could be used to improve the system.

### ***Limitations***

We used a before-and-after study design, which has the inherent limitation of not controlling for changes in the outcome measures that may arise from external factors. However, we are not aware of any changes to practice that could have affected the results obtained and patient demographics were similar both pre- and post-ServeRx.

Other limitations relate to the specific methods used. In particular, studying the impact of system changes on nursing time is notoriously difficult, as we would ideally need to observe all nurses simultaneously. Further work may therefore be required in this area. We relied on the ward pharmacist to identify and record prescribing errors, together with a second check by another pharmacist; however, it is likely that some errors may have been missed. This will be explored in more detail in Chapter 6, where we compare different methods of identifying prescribing errors. In contrast, we feel that the methods used for identifying medication administration errors and assessing adherence to medication related policies are robust.

Wider issues relating to the limited generalisability of a study conducted on one ward, using one system, at one point in time, will be discussed in more detail later in this report.

### ***Conclusions***

This is the most comprehensive UK evaluation of an electronic prescribing system, and the first of a closed-loop system incorporating automated dispensing, barcode patient identification and electronic medication administration records. Our study has shown a reduction in errors and an increase in patient safety, but at the expense of some increases in staff time. Other interventions, involving equivalent increases in staff time, may also reduce errors without the purchase of costly electronic systems. Further studies of such technologies should therefore include economic analyses where possible <sup>49</sup>, as well as a range of outcome measures, to explore these benefits and costs in more detail. Further work is also required to find out whether our results are generalisable to different systems and different sites. The contextual information in Chapter 7 is designed to help with this process.

## **5. Retrospective quantitative evaluation of two electronic prescribing systems**

### **5.1 Introduction**

This section of the report describes the use of the retrospective review method, as described in Chapter 3, to identify prescribing errors before and after the implementation of electronic prescribing systems at two different sites (described in Chapter 2).

The objective of this part of the study, as specified in our original protocol, was to assess the feasibility of measuring the incidence of prescribing errors from a retrospective review of patients' medical notes at two hospital sites (Charing Cross Hospital and Queen's Hospital), both before and after the introduction of electronic prescribing.

The outcome measures explored were:

- The incidence of prescribing errors and the harm caused, before and after implementation of electronic prescribing;
- The proportion of medical notes found and completeness of information, before and after implementation.

The evaluation of the systems at Charing Cross and Queen's hospitals will next be described in turn, then the common lessons drawn in a final discussion.

### **5.2 Retrospective evaluation at Charing Cross Hospital**

#### ***Methods***

Prescribing errors were retrospectively identified for two four-week periods, one about two months before the introduction of ServeRx and one about six months afterwards. These were the same periods as those studied in the prospective evaluation of prescribing errors described in Chapter 4. The pre-ServeRx period was 31 March to 27 April 2003; the post-ServeRx period was 24 November to 21 December 2003 inclusive. Where patients were on the study ward prior to the

beginning of the relevant period, or remained on the ward at the end of the period, only those medication orders written and prescribing errors made between the index dates were studied.

#### Data collection

Retrieval of medical notes and all data collection took place between September 2004 and January 2005. Inpatients who were on the study ward at any time during either four-week data collection period were identified retrospectively from the ward's admission book and their medical notes retrieved from the medical records library. Where patients' medical notes were not initially available, repeated attempts were made to retrieve them throughout the study.

For each patient whose medical notes were retrieved, a research pharmacist completed the retrospective review form (RRF) for the medication orders written and any prescribing errors that occurred during the relevant period. The RRF was completed in paper form for patients reviewed during the first part of the study and then entered retrospectively into the Access database (Chapter 3); later reviews were entered directly. Laboratory data were examined only if considered relevant in relation to the patient's medication or clinical condition, and only the relevant parameters checked. If the patient's weight was not available in the medical notes, an estimated weight of 65kg for females and 80 kg for males was used and a record made that this was an estimate. The serum creatinine measured nearest to the patient's date of admission to the study ward was used to estimate their creatinine clearance using the Cockcroft and Gault equation. The number of medication orders written during the study period was recorded to provide a denominator.

Details were recorded of any prescribing errors identified, including the type of medication order in which the error occurred, the stage of the patient's stay, the number of doses received before the error was corrected, and any harm that was judged to have resulted. Harm was defined very broadly as any identifiable physiological or physical changes that were likely to have resulted from the error concerned.

#### Assessing the clinical severity of the errors identified

Any prescribing errors that had also been identified by the ward pharmacist had already been assessed, as described in Chapter 4. Of those that had not been identified by the ward pharmacist, we assessed the potential severity of all errors that

appeared to have resulted in harm and a 1 in 3 sample of those that did not. Errors were assessed by an expert panel, using the methods described in Chapter 4 <sup>37</sup>.

#### Establishing the practical issues in retrieving information retrospectively

The numbers of patients' notes retrieved, and the availability of key documents within these notes, were documented. Other problems experienced in retrieving information from both the paper-based medical records and the computerised prescribing system were documented as field notes. Finally, we documented the time taken to complete each RRF.

### **Results**

#### Demographic data

Numbers of medical notes reviewed, medication orders written and the patient days in each study period are summarised in Table 16. The two study periods were similar in all of these respects. More details of the medication orders written are given in Tables 17 and 18. More medication orders were classified as being transcribed onto ServeRx than for rewriting drug charts pre-ServeRx, and post-ServeRx, fewer medication orders were classified as being written on admission. These differences are likely to be due to changes in working practice that occurred as a result of ServeRx, rather than differences between the two patient populations. Post-ServeRx, orders written on admission would be likely to be written initially on a paper drug chart and then transcribed onto ServeRx. In contrast, patients in the pre-ServeRx cohort would only need an inpatient drug chart to be rewritten if they were in hospital for two weeks or more.

	<b>Pre-ServeRx</b>	<b>Post-ServeRx</b>	<b>Statistical analysis</b>
Patients listed in admissions book	129	147	-
Patients notes reviewed (% of patients listed)	93 (72%)	114 (78%)	p = 0.37 (chi square test)
Medication orders written during study period (mean per patient)	1258 (13.5)	1614 (14.2)	p = 0.77 (t-test)
Patient days in study period (mean per patient)	438 (4.7)	501 (4.4)	p = 0.66 (t-test)

**Table 16 Summary demographic data**

<b>Prescribing Stage</b>	<b>Pre-ServeRx</b>	<b>Post-ServeRx</b>	<b>Statistical analysis</b>
On Admission	399 (31.7%)	274 (17.0%)	p < 0.0001; chi square test
During stay	620 (49.3%)	882 (54.6%)	
Re-writing drug chart/ transcribing onto ServeRx	110 (8.7%)	353 (21.9%)	
Writing discharge prescription	129 (10.4%)	105 (6.5%)	
<b>TOTAL</b>	<b>1258 (100%)</b>	<b>1614 (100%)</b>	

**Table 17: Medication orders written according to stage of patient stay**

<b>Prescription type</b>	<b>Pre-ServeRx</b>	<b>Post-ServeRx</b>	<b>Statistical analysis</b>
Regular	609 (48.4%)	858 (53.2%)	p = 0.01; chi square test
Intravenous fluids	360 (28.6%)	396 (24.5%)	
Once only	86 (6.8%)	86 (5.3%)	
When required	203 (16.1%)	274 (17.0%)	
<b>TOTAL</b>	<b>1258 (100%)</b>	<b>1614 (100%)</b>	

**Table 18: Medication orders written according to type of medication order**

#### Prescribing errors identified using the RRF

Table 19 summarises the numbers of prescribing errors identified. A prescribing error was identified in 7.4% of all medication orders pre-ServeRx, and in 6.5% post-ServeRx. The difference of 0.9% is not statistically significant (95% confidence interval (CI) -2.8 to 1.0%). When expressed per patient day, the number of errors was the same pre- and post-ServeRx. There was no statistically significant difference in the proportion of errors that were rectified prior to administration.

	Pre-ServeRx	Post-ServeRx	Statistical analysis
Prescribing errors identified (% of medication orders written)	93 (7.4%)	105 (6.5%)	p = 0.39 (chi square test)
Prescribing errors per patient day	0.21	0.21	-
Prescribing errors that resulted in harm (% of medication orders written)	0 (0%)	4 (0.25%)	p = 0.14 (Fisher's exact test)
Prescribing errors that resulted in harm per patient day	0	0.008	-
Prescribing errors rectified before the patient received any doses (excluding cases where outcome unknown)	26 of 76 (34%)	18 of 67 (27%)	p = 0.44 (chi square test)

**Table 19: Summary of the results obtained**

Four prescribing errors that resulted in harm were identified in the post-ServeRx patient cohort. None of these would appear to be specifically related to ServeRx.

The errors were as follows:

1. A patient on warfarin with a target international normalised ratio (INR) of 2-3 had an INR of 3.4, and then was prescribed ciprofloxacin 500mg twice daily with no reduction in warfarin dose. The enhanced anticoagulant effect resulted in an INR of 6.1 the following day.
2. A patient was prescribed a total of 120 mmol potassium in their intravenous fluids over a three day period, without checking a recent serum potassium level. This resulted in a serum potassium of 4.6 mmol/L (desired range 3.5 – 5 mmol/L) on day 2, and 6.7 mmol/L by day 3, which required treatment with calcium resonium.
3. A patient's usual ferrous sulphate tablets were not prescribed on admission, resulting in their haemoglobin dropping from 10.9 to 9.8 g/dL two days after admission.
4. A patient usually took moxonidine 300mcg twice daily, which was not prescribed on admission. Their blood pressure increased from 111/77 on admission to 215/120 the following day, when the error was identified and the drug prescribed.

Table 20 presents the prescribing errors identified according to the stage of patient stay. There was a statistically significant difference pre- and post-ServeRx, with relatively more errors occurring on admission pre-ServeRx, and more occurring during the patient stay and on transcribing post-ServeRx. However, this may be partly accounted for by the different numbers of medication orders written in each of these categories. When the error rates are presented according to the number of medication orders of that type, error rates are similar pre- and post-ServeRx.



Prescribing Stage	Pre-ServeRx	Post-ServeRx	Statistical analysis
On Admission	52 (13.0%)	43 (15.7%)	p = 0.04; chi square test
During stay	22 (3.5%)	32 (3.6%)	
Re-writing drug chart /Transcribing onto ServeRx	4 (3.6%)	15 (4.2%)	
Writing discharge prescription	15 (11.6%)	15 (14.3%)	
<b>TOTAL</b>	<b>93 (7.4%)</b>	<b>105 (6.5%)</b>	

**Table 20: Prescribing errors identified according to the stage of prescribing process. Percentages are calculated as a percentage of all medication orders of that type.**

Table 21 presents the errors identified according to the stage of the drug use process. Numbers are too small to permit statistical analysis, but the only obvious difference is in the number of errors involving the provision of sufficient instructions to permit supply of the correct product. These errors, usually involving specification of strengths and formulations for products available in more than one of these, appear to have been reduced post-ServeRx.

Stage of prescribing process	Pre-ServeRx (n = 1258 medication orders)	Post-ServeRx (n = 1614 medication orders)
Need for drug	39 (3.1%)	45 (2.8%)
Selection of drug	3 (0.2%)	6 (0.3%)
Selection of drug dose	34 (2.7%)	43 (2.7%)
Selection of formulation	2 (0.1%)	2 (0.1%)
Give instructions for supply	9 (0.7%)	1 (0.06%)
Give administration instructions	6 (0.5%)	8 (0.5%)
<b>TOTAL</b>	<b>93 (7.4%)</b>	<b>105 (6.5%)</b>

**Table 21: Prescribing errors presented according to stage of the prescribing process. Percentages are expressed as a percentage of all medication orders written.**

#### Clinical severity of the prescribing errors identified

The mean severity score for the sample of errors assessed pre-ServeRx was 4.1; post-ServeRx it was 4.6. This difference was not significant ( $p = 0.4$ ; t-test for unequal variances). There was one error with a score of more than 7 (representing a "serious" error) pre-ServeRx, and six post-ServeRx. The four errors that resulted in

harm were given scores of 5.6, 6.4, 2.4 and 4.6 respectively. Removing these from the post-ServeRx error scores does not affect the mean score.

#### Practical issues in retrieving information retrospectively

In terms of the time taken, application of the RRF took a mean of 40 minutes pre-ServeRx and 46 minutes post-ServeRx ( $p = 0.08$ ; t-test). The overall mean time was 44 minutes. However, this excludes the time taken to identify and retrieve the medical notes; in practice we were only able to review an average of four patients' records each day.

We identified a range of practical issues with the retrospective retrieval of information. These related to retrieving the medical notes, availability of information within the medical notes, retrospective access to electronic data post-ServeRx, and the retrospective interpretation of information. Each of these will be addressed in turn.

First, we were not able to retrieve all of the relevant medical notes in the sample. Of those patients listed in the ward admissions book, for some there was no record of admission to the study ward or to the hospital in their medical notes (one patient pre-ServeRx and ten post-ServeRx). We are not sure whether these patients were admitted to the study ward and a temporary set of medical notes used, or whether they were anticipated admissions who were not then admitted to the study ward at all. For another six patients (four pre-ServeRx and two post-ServeRx), while a record of admission existed, there was insufficient information in the medical notes to be able to carry out a review. Finally, for another 31 patients pre-ServeRx and 21 post-ServeRx, the medical notes could not be retrieved as they were booked out to other clinical areas. Notes relating to admission to the study ward were therefore examined for only 93 (72%) of 129 patients listed in the admissions book pre-ServeRx, and 114 (78%) of 147 post-ServeRx.

Second, not all of the information required was available within the notes retrieved. For those patients whose medical notes were examined, the availability of the various sources of information is summarised in Table 22.

Document	Pre-ServeRx n = 93	Post-ServeRx n = 114
Initial Medical Assessment	83 (89%)	102 (89%)
Medical progress notes	88 (95%)	104 (91%)
Nursing/midwifery progress notes	85 (91%)	103 (90%)
Laboratory/Pathology reports	81 (87%)	97 (85%)
Prescription Report	N/A	58 <sup>#</sup> (51%)
Administrations Report	N/A	67 <sup>§</sup> (59%)
Transfer Prescription Record	N/A	40* (46%)
ServeRx computer record of stopped medication	N/A	40** (82%)
Current medication chart	85 (91%)	N/A
Previous medication chart(s) (not applicable for all patients)	15 (16%)	62 (54%)
Discharge Summary	38 (41%)	46 (40%)

**Table 22: Availability of information from the medical notes**

N/A: Not applicable

<sup>#</sup>For four patients, one or more pages were missing from this report.

<sup>§</sup>For two patients, one or more pages were missing from this report.

\*Not applicable for 27 patients, percentage therefore calculated based on n = 87. For five patients, one or more pages were missing from the report.

\*\*Not applicable for 65 patients, percentage therefore calculated based on n = 49

It can be seen that there were particular problems with the availability of ServeRx printouts, which should be filed in patients' medical notes on discharge or transfer to another ward. We also suspect that paper IV fluid charts were often not filed in patients' medical notes post-ServeRx, although we cannot identify those patients for whom they should have been present. We identified some patients for whom pages were missing from the printed ServeRx records. However, it was impossible to identify whether or not pages at the end of these reports were present; this was because, with the exception of the transfer summary, the page numbering does not state the total number of pages.

Third, some key data could not be accessed retrospectively from ServeRx. While it was possible to access prescribing information, users cannot access administration data retrospectively. We did subsequently obtain a report of doses administered to patients in the study after requesting this from the manufacturer of ServeRx. We were therefore able to access administration data for patients reviewed after 8

November 2004, even if the administration report was not filed in their medical record. We were not able to examine administration data for patients reviewed before this date unless a paper copy was available. This is unlikely to have affected the identification of prescribing errors, but had we been studying medication administration errors this would have been a significant limitation. Additionally, information entered on the ServeRx “patient notes” screen does not appear on the printouts filed in patients’ notes. Pharmacists use this field to record information on drug histories checked, interventions made and doses confirmed, which we were unable to view retrospectively. This type of information could easily be seen on the paper drug charts reviewed.

Finally, we identified other potential limitations with the retrospective interpretation of information. For example, it was often impossible to identify the date and time on which medication orders were initiated or discontinued on paper drug charts, and so the researcher had to use her judgement as to whether or not certain drugs were prescribed simultaneously. Medication orders may also have been written with information missing. However, provided this information was completed before the drug chart was filed, any such prescribing errors would not have been apparent to a retrospective reviewer.

### ***Discussion***

Using this retrospective method, we identified higher error rates than those identified using prospective methods (Chapter 4); in contrast, we did not see any effect of the introduction of electronic prescribing. This disparity will be explored in more detail in Chapter 6.

#### Did the introduction of electronic prescribing alter the data collected?

There were several ways in which data collection was changed following the introduction of ServeRx, although in this study we do not think these were a significant source of bias. There were some differences in the types of medication orders written, with more medication orders being classified as being transcribed onto ServeRx than rewritten onto paper drug charts, and fewer medication orders being classified as being written on admission post-ServeRx. This is likely to be because orders written on admission would be written on a paper drug chart, and then transcribed onto ServeRx on the study ward. This difference therefore reflects the system of work being changed, rather than any underlying changes in patient demographics.

Two issues were also raised relating to collecting comparable data on numbers of medication orders written pre- and post-ServeRx. First, for patients in the post-ServeRx cohort, we identified a small number of situations where two or more medication orders were written where only one would have been needed on a paper chart. For example, levothyroxine 75 micrograms could be prescribed in two ways on ServeRx. If one 50 microgram tablet plus one 25 microgram tablet are required, two separate medication orders have to be prescribed. Alternatively, three 25 microgram tablets could be prescribed, which would only necessitate one medication order. The number of post-ServeRx medication orders recorded may therefore be slightly inflated. Second, when counting post-ServeRx medication orders, it was often not possible to determine whether medication orders recorded as “stat” were prescribed by a doctor or represented nurses using this function to access medicines that had not yet been transcribed on to ServeRx. With the exception of warfarin, which is prescribed separately on paper charts and routinely accessed by nursing staff using the “stat” function, all of the “stat” medication orders were included in the count. Again, this may also have artificially inflated the number of medication orders written post-ServeRx. However, the overall number of once-only medication orders was very similar pre- and post-ServeRx, suggesting that this did not have a major influence.

Overall, it would appear that the two data collection periods were largely comparable, and any differences are likely to be due to differences in work patterns that arose following the introduction of ServeRx.

#### Was there any difference in the errors identified pre- and post-ServeRx?

We did not identify any impact of ServeRx on the incidence of prescribing errors, whether expressed per medication order or per patient day, using either the RRF or the trigger tool. However, being a pilot study, this aspect of our study was not powered to detect a difference and used less data than was used in the prospective study.

There was no difference in the proportion of errors rectified prior to administration, and error rates were similar with respect to the stages of patient stay in which they occurred. The sample size was not sufficient to have identified differences in the types of errors that occurred, but we did notice a potential reduction in errors involving provision of information for product supply. ServeRx appears to have

reduced errors involving failure to specify strength or formulation for products where more than one of these is available, as prescribers must choose from the options available.

A more general discussion of the issues relating to retrospective data collection appears at the end of this chapter.

### ***Conclusions***

Using the RRF, we did not identify any impact of ServeRx on the incidence of prescribing errors, whether expressed per medication order or per patient day. Errors were identified in 7.4% of medication orders pre-ServeRx and in 6.5% post-ServeRx. Four errors that resulted in harm were identified post-ServeRx, and none pre-ServeRx. None of the four appeared to be related to ServeRx.

## **5.3 Retrospective evaluation at Queen's Hospital**

### ***Methods***

Methods were very similar to those used at Charing Cross Hospital, as described above, however the sampling strategy was different. Since different versions of Meditech's electronic prescribing system had been introduced gradually over the course of a decade, we wanted our post-implementation sample to include a range of different versions of software. Throughout the rest of this chapter, "post-Meditech" refers to the data collected following the implementation of the Meditech electronic prescribing module; other modules of the Meditech system were already in place before the electronic prescribing module was introduced.

### **Sampling strategy**

This part of the pilot was designed to study the issues involved in evaluating well established systems which had often grown relatively slowly, usually starting with the less clinically challenging wards and then moving to more difficult environments more recently. We sampled patients from four different wards, one each from the specialties of general medicine, general surgery, paediatrics and medicine for the elderly, each of which had different versions of the software introduced at different times, as summarised in Table 23.

For each selected ward, data were collected for 25 randomly selected patients admitted in the calendar month six months before implementation of Meditech, and for 25 patients admitted in the calendar month six months afterwards (Table 23).

<b>Speciality &amp; Ward</b>	<b>Software version and date of implementation</b>	<b>Pre-Meditech sample</b>	<b>Post-Meditech sample</b>
Paediatrics (Ward 1)	version 4.8 June 2002	25 patients admitted in December 2001	25 patients admitted in December 2002
General Surgery (Ward 3)	version 4.6 November 1999	25 patients admitted in May 1999	25 patients admitted in May 2000
General Medical (Ward 8)	version 4.6 June 1999	25 patients admitted in December 1998	25 patients admitted in December 1999
Care of the Elderly (Wards A, B, C)	version 4.4 December 1996	25 patients admitted in June 1996	25 patients admitted in June 1997
Care of the Elderly (Ward 5, 6)	version 4.4 March 1997	25 patients admitted in September 1996	25 patients admitted in September 1997

**Table 23: Initial sampling strategy, based on implementation of different Meditech versions at different times**

#### Data collection

Inpatients admitted to the study ward in each specified month were identified from the hospital's information system, and 25 patients randomly selected. Where patients' notes could not be retrieved from the medical records library, additional patients were randomly selected in order to achieve the desired sample size.

For each patient whose medical notes were retrieved, a research pharmacist completed the retrospective review form (RRF) for the medication orders written throughout their entire stay on the study ward. This was a methodological difference compared to Charing Cross hospital, where we collected data only on medication orders written during a four-week study period. An additional difference was that laboratory data were examined for all patients in Queen's Hospital, regardless of the medication they were taking. All other methodological details were identical. Details were recorded of any prescribing errors identified, including any harm that resulted. The number of medication orders written for each patient during his or her stay on the study ward was also recorded.

#### Assessing the clinical severity of the errors identified

We assessed the clinical severity of all errors that caused harm and a 1 in 3 sample of those that did not, using the same methods as described for Charing Cross Hospital.

### Establishing the practical issues in retrieving information retrospectively

As for Charing Cross Hospital, we documented any problems experienced in retrieving information from both the paper-based records and the electronic prescribing system.

## **Results**

### Demographic data

We found that it was not possible to retrieve certain prescribing and pharmacy information for version 4.4, the version introduced on the medicine for the elderly wards; this was due to a reporting utility that had been removed. It was therefore not possible to include any patients from this specialty in the study, and data were subsequently collected only from a general medicine, a general surgery and a paediatric ward.

A total of 75 patients' medical notes were therefore reviewed pre-Meditech, and 75 post-Meditech, rather than the planned 100. The numbers of medication orders written for these patients are summarised in Table 24. Patient stays were longer post-Meditech for the general medical and paediatric specialties, and shorter for surgery. Similar numbers of medication orders were written for each patient pre- and post-Meditech. More details of the medication orders written are given in Tables 25 and 26. There was no difference between the pre- and post-Meditech periods in terms of the stage of patient stay in which medication orders were written ( $p = 0.12$ ; chi square test). However, the types of medication order differed ( $p = 0.03$ ; chi square test) with proportionally more "when required" orders being written post-Meditech. It is not known why this was the case.



	General Medicine		General Surgery		Paediatrics		Total Pre-Meditech	Total Post-Meditech
	Pre	Post	Pre	Post	Pre	Post		
Patients admitted in study month	82	71	190	187	209	221	481	479
Patients' notes reviewed (% of patients admitted in study month)	25 (30.5%)	25 (35.2%)	25 (13.2%)	25 (13.4%)	25 (11.9%)	25 (11.3%)	75 (15.6%)	75 (15.7%)
Medication orders written (mean per patient)	384 (15.4)	422 (16.9)	337 (13.5)	297 (11.9)	115 (4.6)	161 (6.4)	836 (11.2)	880 (11.7)
Patient days (mean per patient)	117 (4.7)	232 (9.3)	96 (3.8)	66 (2.6)	35 (1.4)	55 (2.2)	248 (3.3)	353 (4.7)

**Table 24: Summary of demographic data**

Stage of Patient Stay	General Medicine		General Surgery		Paediatrics		Total Pre-Meditech	Total Post-Meditech
	Pre	Post	Pre	Post	Pre	Post		
On Admission	146	149	106	84	35	43	287	276
During stay	160	171	196	164	53	90	409	425
Re-writing drug chart*	0	0	0	0	0	0	0	0
Writing Discharge Prescription	78	102	35	49	27	28	140	179
Grand Total	384	422	337	297	115	161	836	880

**Table 25: Medication orders written, presented according to stage of patient stay**

\*Rewriting the drug chart was not relevant at this site, as no examples were identified where patients' inpatient drug charts were re-written. Instead, a copy of the administration section of the drug chart was attached to the original chart for patients with longer lengths of stay.

Prescription Type	General Medicine		General Surgery		Paediatrics		Total Pre-Meditech	Total Post-Meditech
	Pre	Post	Pre	Post	Pre	Post		
Regular	239	272	129	97	45	47	413	416
IV infusion	67	65	104	76	4	9	175	150
Stat	29	33	27	28	12	19	68	80
When required	49	52	77	96	54	86	180	234
Grand Total	384	422	337	297	115	161	836	880

**Table 26: Medication orders written, presented according to type of medication order**

#### Prescribing errors identified using the RRF

Table 27 summarises the prescribing errors identified. A prescribing error was identified in 8.6% of all medication orders pre-Meditech, and in 8.8% post-Meditech. This difference of 0.2% is not statistically significant (95% CI -2.5 to 2.9%). When presented according to patient day, prescribing error rates were 0.29 pre-Meditech,

and 0.22 afterwards. Sample sizes for individual specialties are too small to permit statistical analysis.

	General Medicine		General Surgery		Paediatrics		Total Pre-Meditech	Total Post-Meditech
	Pre	Post	Pre	Post	Pre	Post		
Prescribing errors identified (% of medication orders written)	34 (8.9%)	29 (6.9%)	22 (6.5%)	17 (5.7%)	16 (13.9%)	31 (19.3%)	<b>72</b> <b>(8.6%)</b>	<b>77</b> <b>(8.8%)</b>
Prescribing errors per patient day	0.29	0.13	0.23	0.26	0.46	0.56	<b>0.29</b>	<b>0.22</b>
Prescribing errors that resulted in harm (% of medication orders written)	1 (0.3%)	3 (0.7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	<b>1</b> <b>(0.1%)</b>	<b>3</b> <b>(0.3%)</b>
Prescribing errors that resulted in harm per patient day	0.008	0.013	0	0	0	0	<b>0.004</b>	<b>0.0085</b>

**Table 27: Summary of results relating to prescribing errors**

We identified four errors that resulted in patient harm. All were in patients admitted to the medical ward, one was pre-Meditech and three afterwards; none of which appeared to be specifically related to electronic prescribing.

The errors were as follows:

1. A patient on regular aminophylline 225mg twice daily was prescribed clarithromycin, which inhibits the metabolism of theophylline and can result in raised theophylline levels. Two days later, the patient complained that his “heart felt funny”. Theophylline levels were not checked.
2. A patient admitted from a nursing home following a collapse and the onset of acute renal failure, was prescribed his usual dose of digoxin 125 micrograms once daily on admission without dose reduction. This resulted in a digoxin level of 2.7 micrograms/litre (desired range 1 – 2 micrograms/litre) two days later and the drug was stopped.
3. A patient was prescribed acitretin 25mg daily for the treatment of pityriasis rubra pilaris, in spite of having renal impairment (estimated creatinine clearance 27 ml/min). Acitretin is contraindicated in renal impairment as this can increase the risk of toxicity. The post-mortem report in the patient’s medical notes indicates that acitretin toxicity was thought to have contributed to this patient’s death, although further details are not given.

4. A patient was admitted on a dose of digoxin 250mcg daily with an estimated creatinine clearance of 11ml/minute. The digoxin dose was not reduced or stopped. When the digoxin level was checked the following day, it was reported as being 6 mcg/L (desired range 1 – 2 micrograms/litre).

Table 28 presents the prescribing errors identified according to the stage of patient stay, and Table 29 according to the stage of the prescribing process. There was no difference in the proportions of errors identified at each stage of patient stay ( $p = 0.66$ ; chi square test).

Stage of Patient Stay	Total Pre-Meditech	Total Post-Meditech
On Admission	29	27
During stay	33	41
Re-writing drug chart	0	0
Writing Discharge Prescription	10	9
<b>Total</b>	<b>72</b>	<b>77</b>

**Table 28: Prescribing errors identified according to the stage of patient stay**

Stage of Prescribing Process	Total Pre-Meditech	Total Post-Meditech
Need for drug	15 (1.8%)	22 (2.5%)
Selection of drug	0 (0%)	5 (0.4%)
Selection of drug dose	42 (5.0%)	46 (5.2%)
Selection of formulation	2 (0.2%)	2 (0.2%)
Instructions for supply	12 (1.4%)	1 (0.1%)
Instructions for admin.	1 (0.1%)	1 (0.1%)
<b>TOTAL</b>	<b>72</b> <b>(8.6%)</b>	<b>77</b> <b>(8.8%)</b>

**Table 29: Prescribing errors presented according to stage of the prescribing process**

Percentages are expressed as a percentage of all medication orders written

This suggests that there was a reduction in errors involving provision of instructions for supply following the introduction of Meditech, but few other differences. However, the sample sizes are too small to allow any firm conclusions to be drawn.

#### Clinical severity of the prescribing errors identified

The mean severity score for the sample of errors assessed pre-Meditech was 4.4; post-Meditech it was 5.0. This difference was not significant ( $p = 0.11$ ; t-test). There

were two errors with a score of more than 7 (representing a “serious” error), one of which was pre- and one post-Meditech. The four errors that resulted in harm were given scores of 5.4, 7.0, 4.0 and 7.2 retrospectively.

#### Practical issues in retrieving information from the medical notes and a computerised prescribing system

The mean time taken to complete the RRF was 46 minutes for the pre-Meditech patients and 57 minutes afterwards. This difference is statistically significant ( $p = 0.004$ ; t-test). Overall, the mean time was 51 minutes (range 10 to 145 minutes). These times are similar to those reported for Charing Cross Hospital (40 minutes and 46 minutes pre and post-ServeRx respectively). Again, this excluded the time taken to retrieve medical notes and other information; an average of four patients could be reviewed each day.

Various issues were identified in relation to retrieving information from both the paper-based and the computer-based records. Some of these were similar to the issues documented for Charing Cross Hospital; others were site-specific.

First, we could not retrospectively retrieve sufficient prescribing and pharmacy information from Meditech version 4.4, and were not able to sample any patients from the care of the elderly wards as initially specified in our sampling strategy. We therefore reviewed 75 patients pre- and 75 post-Meditech, rather than our target of 200 in total.

Second, for the 150 patients who were studied, not all of the medical notes initially requested could be retrieved. In total, 217 sets of medical notes were requested, of which 37 (17%) were not available as they were issued to other clinics or departments.

Third, for some patients whose notes were retrieved, not all of the required documents were available (Table 30). It is also possible that some additional drug charts may have been missing, as for the Charing Cross study, although a higher percentage of documents were retrieved at Queen's Hospital.

	General Medicine		General Surgery		Paediatrics		Total Pre-Meditech	Total Post-Meditech
	Pre	Post	Pre	Post	Pre	Post		
Initial Assessment	25	25	25	25	25	25	<b>75 (100%)</b>	<b>75 (100%)</b>
Medical Progress Notes	25	25	25	25	25	25	<b>75 (100%)</b>	<b>75 (100%)</b>
Nursing/ Midwifery Notes	25	24 (1N)	24 (1N)	20 (5N)	22 (3N/A)	23 (2N)	<b>71 (99%)</b>	<b>67 (89%)</b>
Laboratory/ Pathology data	25	25	25	21 (2N/A, 2N)	18 (6N/A, 1N)	23 (2N)	<b>68 (99%)</b>	<b>69 (75%)</b>
Current Medication Chart	25	25	24 (1N)	25	18 (5N/A, 2N)	23 (2N/A)	<b>67 (96%)</b>	<b>73 (75%)</b>
Discharge Prescription	19 (6N/A)	17 (8N/A)	17 (5N/A, 3N)	19 (6N/A)	13 (10N/A, 2N)	16 (9N/A)	<b>49 (91%)</b>	<b>52 (100%)</b>

**Table 30: Data sources retrieved pre- and post- implementation of electronic prescribing**

N = Not retrieved; N/A= Not applicable/Not required; percentages are calculated excluding those patients where data source was not applicable.

Finally, there were additional issues relating to the retrieval of electronic nursing notes and laboratory data from the main Meditech system, even for patients studied prior to the introduction of electronic prescribing. Nursing notes were not always accessible via the patient care inquiry system, although it was possible to retrieve them directly from the Meditech nursing module. Similarly, laboratory data had to be accessed from the hospital patient information system, which could not always be accessed. There were often problems retrieving information stored on the optical disk storage system, particularly when several individuals were trying to retrieve data at the same time. In many cases, several attempts were required to access the information required. Interestingly, for the pre-Meditech data collection period on the general medical ward, nursing notes were printed and filed in the paper notes in most cases, whereas this was not the case for any of the other data collection periods either pre- or post- Meditech.

### **Discussion**

In contrast to the Charing Cross Hospital study, there did not seem to have been any system-related changes in prescribing patterns at Queen's Hospital. This may be because the Meditech electronic prescribing system was almost hospital-wide at the time of our study, whereas ServeRx was a one-ward pilot.

### Was there any difference in the errors identified pre- and post-Meditech?

We did not identify any impact of Meditech on the incidence of prescribing errors, whether expressed per medication order or per patient day, using either the RRF or the trigger tool. However, the study was not formally powered to be able to identify a difference.

Error rates were similar with respect to the stages of patient stay in which they occurred. The sample size was not sufficient to have identified differences in the types of errors that occurred, but as for Charing Cross, we did notice a potential reduction in errors involving provision of information for product supply.

### Conclusions

Using the RRF, we identified prescribing error rates of 8.6% and 8.8% pre- and post-Meditech, respectively. Four errors resulted in harm.

## **5.4 Discussion**

As far as we are aware, these pilot studies represent the first retrospective study of prescribing errors in the UK for 30 years, and the only one to study errors before and after the introduction of electronic prescribing.

We found that it was possible to assess prescribing errors retrospectively using the RRF, although there were a number of practical issues encountered. These related to patient identification, retrieval of both paper-based and electronic medical records, and completeness of information filed in the medical notes. We also experienced a number of difficulties in retrospectively interpreting information. First, we realised that there had often been changes in clinical practice in the time period between a patient's hospital stay and the review of their medical records. For some of the patients at Queen's Hospital, this was almost ten years. We therefore tried to assess potential prescribing errors based on clinical practice at the time of the patient's stay; however, this was difficult in some cases. Second, it was often difficult to assess whether or not apparent harm had been caused by a prescribing error. Previous retrospective studies of iatrogenic injury have included an assessment of the likelihood of harm having resulted from a particular error; we would recommend that this be included in further retrospective studies of prescribing errors. Third, we intentionally used a broad definition of "harm"; it could be argued that some of the

errors classified as having caused harm resulted only in laboratory tests being outside of the desired ranges and would have had no consequences for the patient. Had the tests not been done, no “harm” may have been identified. In future studies, it may therefore be useful to define different levels of harm. Finally, our early inter-rater reliability tests, as described in Chapter 3, suggested that two different researchers identified different errors; more work is needed to explore the reliability of this method of error identification. As a result of such issues, we found that our research pharmacists could each only assess an average of four sets of medical notes each day.

Our results suggest that prescribing errors occurred in 7.4% of medication orders pre- and 6.5% post-ServeRx, and 8.6% pre- and 8.8% post Meditech. These retrospective studies were pilot studies and not powered to have been able to detect differences. However, our findings may be useful in performing sample size calculations for future studies of this type. Our data suggest that the only type of error that may have been reduced with electronic prescribing is the provision of instructions for supply of the correct product. This is perhaps not surprising, as the two systems studied both required medication orders to be complete and for specific dosage forms to be selected.

The error rates identified were higher than those previously reported using prospective reporting by ward pharmacists. The next chapter explores this discrepancy in more detail, and further discusses the advantages and disadvantages of different methods for identifying prescribing errors.

## **6. Comparing four methods of detecting prescribing errors**

### **6.1 Introduction**

This Chapter describes the comparison of four different methods for the detection of prescribing errors in the same set of patients at Charing Cross Hospital. Chapters 4 and 5 have already presented the results relating to prescribing errors before and after the introduction of ServeRx at Charing Cross, when studied both prospectively and retrospectively. Using a prospective method, we identified prescribing errors in 3.8% of medication orders pre-ServeRx, and in 2.0% post-ServeRx. In contrast, using the retrospective review form (RRF), we identified prescribing errors in 7.4% of medication orders pre-ServeRx and in 6.5% post-ServeRx. Furthermore, using the RRF, we identified four errors that resulted in some degree of patient harm. In this Chapter, we explore the potential reasons for the discrepancies in these results, as well as presenting and comparing the results obtained using two further methods: the trigger tool and spontaneous incident reports.

The objective of this part of the study was to compare, in the same set of patients, four methods of detecting prescribing errors:

- a) Prospective detection by pharmacists;
- b) Retrospective detection from medical notes using the retrospective review form (RRF);
- c) Retrospective use of the trigger tool;
- d) Spontaneous reporting.

### **6.2 Setting and subjects**

As explained in previous chapters, data on prescribing errors were collected on a surgical ward at Charing Cross Hospital during two four-week periods. The first data collection period was about three months before the introduction of ServeRx (April 2003); the second was six months after its introduction (November / December 2003). Where patients were on the study ward prior to the beginning of the relevant period, or remained on the ward at the end of the period, only those medication orders written within the study period were included. We collected data using each of the four methods for these same two periods.



## 6.3 Methods

Before describing how the methods were compared, we will give brief details of the four methods used.

### ***The four methods used***

#### **a) Prospective data collection by the ward pharmacist**

As explained in more detail in Chapter 4, the same ward pharmacist prospectively identified prescribing errors on the study ward during the two four-week periods, using methods published previously<sup>3</sup>. In addition, one of the investigators (BDF) checked for prescribing errors once a week to help identify any that had not been documented by the ward pharmacist.

#### **b) Retrospective data collection from the medical notes using the RRF**

As discussed in Chapter 5, we recorded details of any prescribing errors identified using the RRF in those patients whose medical notes were retrieved. The number of medication orders written for each patient during the study period was also documented.

#### **c) Retrospective data collection using the trigger tool**

For each patient whose medical notes were retrieved, we also applied the trigger tool, as described in Chapter 3, after completion of the RRF. Details of any prescribing errors identified in medication orders written within the study period were recorded.

#### **d) Spontaneous reporting**

The Trust operated a medication and blood transfusion incident reporting system, and all pharmacy, nursing and medical staff were encouraged to report any medication errors identified either electronically or via paper forms. About 1,000 reports are received each year, details of which are held in a central database. For the purposes of this study, we retrieved details of all reports relating to prescribing errors on the study ward in either of the two study periods.

### ***Establishing denominators***

We used two denominators, as explained in Chapter 3. The first was the number of medication orders written during the study period for the patients reviewed; the second was the number of patient days during the relevant study period for the

patients reviewed. Both of these were determined during the retrospective review of the medical notes using the RRF, as described in Chapter 5.

### ***Comparing the four methods***

For the purposes of this comparison, we included only those errors identified, by any method, in patients whose medical notes were reviewed for the retrospective part of the study. Only prescribing errors were studied. Separate comparisons were made for the pre- and post-ServeRx cohorts of patients.

Prescribing errors identified using each method were classified according to type, the stage of patient stay in which they occurred, and whether or not they were rectified before the patient received one or more doses. All errors identified were checked by BDF to ensure that they met the study's definition of a prescribing error and that they were classified correctly.

### ***Assessing the clinical severity of the errors identified***

We assessed the severity of all prescribing errors identified prospectively, all prescribing errors that resulted in harm, and a 1 in 3 sample of those identified by other methods but not prospectively. Errors were assessed by an expert panel, using the methods described in Chapter 4<sup>37</sup>.

### ***Specificity of the triggers within the trigger tool***

For each of the 23 triggers, we calculated the specificity of that individual trigger when compared to the prescribing errors identified by the trigger tool overall.

## **6.4 Results**

As reported in Chapter 5, we reviewed the medical notes for 93 (72%) of the 129 patients on the study ward during the pre-ServeRx data collection period, and 114 (78%) of 147 patients post-ServeRx. The remainder of these results relate only to those patients whose notes were reviewed.

A total of 1258 medication orders were written for these patients pre-ServeRx (mean 13.5 per patient), and 1614 post-ServeRx (mean 14.2). There were 438 patient days in the pre-ServeRx data collection period (mean 4.7 per patient), and 501 post-ServeRx (mean 4.4).

**a) Prospective data collection by the ward pharmacist**

In those patients included in the comparison, 48 prescribing errors were identified pre-ServeRx (3.8% of medication orders written), and 30 post-ServeRx (1.9% of medication orders written). Although in a smaller subset of patients, these percentage error rates are very similar to those identified for the entire population, as described in Chapter 4. Error rates per patient day were 0.11 and 0.06 pre- and post-ServeRx, respectively.

**b) Retrospective data collection from the medical notes**

Completion of the RRF took about an average of 44 minutes per patient, as well as the time taken to retrieve the medical notes. As presented in Chapter 5, we identified 93 prescribing errors pre-ServeRx (7.4% of all medication orders written) and 105 post-ServeRx (6.5% of all medication orders written). These figures both relate to 0.21 prescribing errors per patient day. In the pre-ServeRx data collection period, no errors resulting in harm were identified; there were four in the post-ServeRx data collection period, none of which appeared to be associated with ServeRx.

**c). Retrospective data collection using the trigger tool**

Application of the trigger tool following the RRF took about 4 minutes per patient. We did not identify any errors using the trigger tool in the pre-ServeRx data collection period. Two prescribing errors were identified in the post-ServeRx data collection period. These were two of the prescribing errors resulting in harm identified using the RRF (errors 1 and 2 as listed in Chapter 5). These two errors relate to an error rate of 0.1% of all medication orders written, or 0.004 errors per patient day, in the post-ServeRx study period.

**d) Spontaneous reporting**

For the patients included in the analysis, there was one prescribing error reported on the Trust's database in the pre-ServeRx period, and one post-ServeRx. The pre-ServeRx error was a medication order for modified release nifedipine with no start date; the post-ServeRx error was a prescriber's selection of metformin instead of metronidazole from the medication list.

Table 31 summarises the error rates identified using each method.

Method	Pre-ServeRx		Post-ServeRx	
	Per medication orders written	Per patient day	Per medication orders written	Per patient day
Ward pharmacist (prospective)	3.8%	0.11	1.9%	0.06
Retrospective review form	7.4%	0.21	6.5%	0.21
Retrospective use of trigger tool	0	0	0.1%	0.004
Spontaneous reporting	0.1%	0.002	0.1%	0.002

**Table 31: Summary of error rates identified using each of the four methods**  
Results apply only to those patients included in the comparative analysis

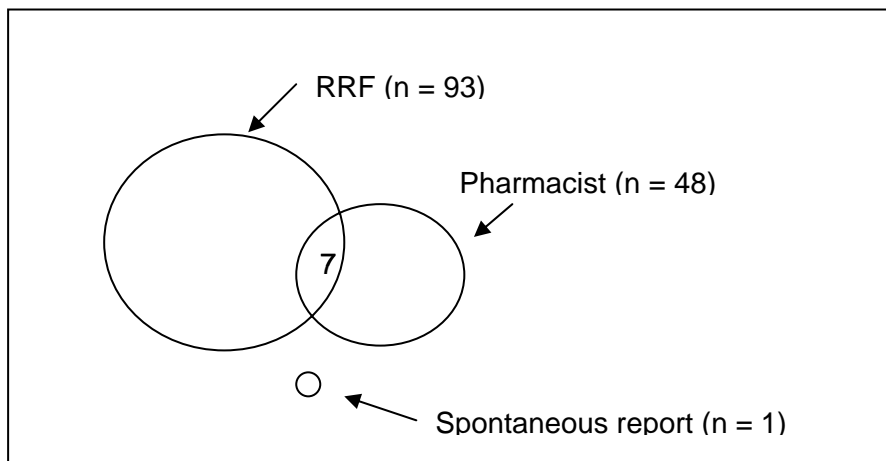
No errors resulting in harm were identified pre-ServeRx, and a total of four were identified post-ServeRx. Of these four, two (50%) were also identified using the trigger tool.

#### ***Total numbers of errors identified***

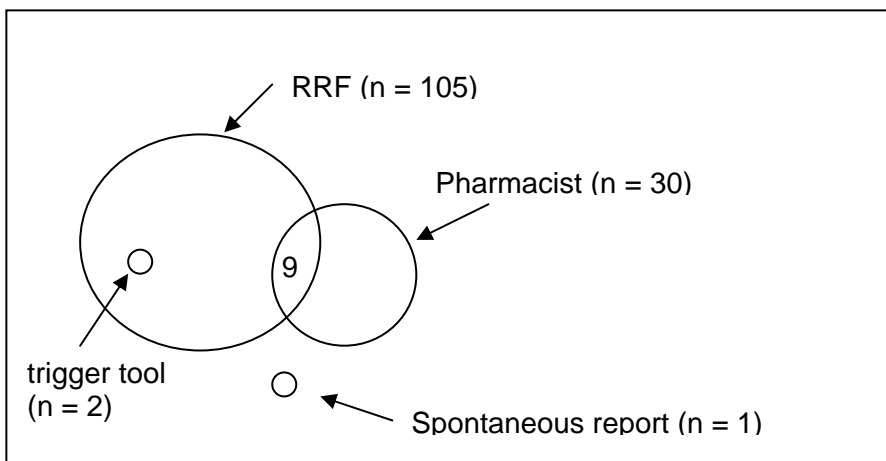
Using all four methods, a total of 135 different prescribing errors were identified pre-ServeRx (10.7% of all medication orders written; 0.31 errors per patient day), and 127 post-ServeRx (7.9% of all medication orders written; 0.25 errors per patient day). The difference in prescribing errors presented according to the number of medication orders written is statistically significant ( $p = 0.01$ ; chi square test; 95% CI for the difference - 0.6% to - 5.0%), while those presented per patient day are not ( $p = 0.07$ ; chi square test).

#### ***Comparing the four methods***

Figures 17 and 18 summarise the errors identified by each method and the extent of overlap between the different methods, for the pre- and post-ServeRx cohorts respectively. It can be seen that few errors were identified by more than one method.



**Figure 17: Prescribing errors identified in the pre-ServeRx cohort (n = 93 patients; 135 errors). No errors were identified using the trigger tool.**  
RRF = retrospective review form



**Figure 18: Prescribing errors identified in the post-ServeRx cohort (n = 114 patients; 127 errors).**  
RRF = retrospective review form

Tables 32 and 33 present the prescribing errors identified using each method, according to stages of the prescribing process, for the pre- and post-ServeRx cohorts respectively. Regardless of whether they were identified by retrospective or prospective methods, most errors related to the stages of “need for drug therapy” and “select specific dose”. The highest proportion of the errors identified using the RRF alone related to “need for drug therapy”.

Stage of prescribing process	Methods used to identify errors				
	Pharmacist alone	RRF alone	Pharmacist and RRF	Spont. report alone	Total errors detected
Need for drug therapy	9	39	0	0	48
Select specific drug	1	3	0	0	4
Select drug dose	17	28	6	0	51
Select formulation	1	2	0	0	3
Give instructions for product supply	6	8	1	1	16
Give administration instructions	7	6	0	0	13
<b>TOTAL (% of all errors)</b>	<b>41 (30.4%)</b>	<b>86 (63.7%)</b>	<b>7 (5.2%)</b>	<b>1 (0.7%)</b>	<b>135 (100%)</b>

**Table 32: Comparison of prescribing errors identified using each method or combination of methods, presented according to the stage of the prescribing process, for the pre-ServeRx cohort.**

RRF = Retrospective Review Form. No errors were detected using the trigger tool

Stage of prescribing process	Methods used to identify errors				
	Pharmacist alone	RRF alone	Pharmacist and RRF	Spont. report alone	Total errors detected
Need for drug therapy	10	44	1	0	55
Select specific drug	0	6*	0	1	7
Select drug dose	9	38*	5	0	52
Select formulation	1	1	1	0	3
Give instructions for product supply	0	1	0	0	1
Give administration instructions	1	6	2	0	9
<b>TOTAL (% of all errors)</b>	<b>21 (16.5%)</b>	<b>96 (75.6%)</b>	<b>9 (7.1%)</b>	<b>1 (0.8%)</b>	<b>127 (100%)</b>

**Table 33: Comparison of prescribing errors identified using each method or combination of methods, presented according to the stage of the prescribing process, for the post-ServeRx cohort.**

RRF = Retrospective Review Form.

\* In each case, one of these errors was identified by the trigger tool method as well as the RRF.

To further explore the differences in the types of error identified, a more detailed analysis of the types of error was carried out. The results are presented in Appendix J. In general the omission of medication on admission, from the discharge prescription and other types of omission were best identified by the RRF; duplication of medication and prescription of medication for which there was no indication was best identified by the pharmacist. Selection of the incorrect drug was best identified by the RRF; a range of different wrong dose errors were identified by the pharmacist and the RRF. Errors involving specification of correct strength and formulation on paper drug charts were identified equally by the pharmacist and RRF, although different errors were identified.

Tables 34 and 35 present the prescribing errors according to whether or not they were rectified prior to administration, for the pre- and post-ServeRx cohorts respectively. Perhaps not surprisingly, errors identified by the pharmacist were more likely to have been rectified prior to administration, particularly in the post-ServeRx cohort.

It was noted that for some RRF errors (16 pre-ServeRx and 11 post-ServeRx), there was evidence in the medical notes that the pharmacist had identified and rectified the error, but the errors were not reported as such by the pharmacist.

Was error rectified before patient received doses?	Methods used to identify errors				
	Pharmacist alone	RRF alone	Pharmacist and RRF	Spont. report alone	Total errors detected
Yes	18 (49%)	24 (35%)	2 (33%)	0	44 (39%)
No	19 (51%)	45 (65%)	4 (66%)	0	68 (61%)
Not known	4	17	1	1	23
<b>TOTAL</b>	<b>41</b>	<b>86</b>	<b>7</b>	<b>1</b>	<b>135</b>

**Table 34: Prescribing errors identified using each method or combination of methods, presented according to whether or not the error was rectified before the patient received (or should have received) one or more doses, for the pre-ServeRx cohort.**

Percentages are the percentage of errors identified using this method for which the outcome was known.

RRF = Retrospective Review Form. No errors were detected using the trigger tool

Was error rectified before patient received doses?	Methods used to identify errors				
	Pharmacist alone	RRF alone	Pharmacist and RRF	Spont. report alone	Total errors detected
Yes	12 (57%)	13 (22%)	6 (86%)	1 (100%)	32 (36%)
No	9 (43%)	46* (78%)	1 (14%)	0 (0%)	56 (64%)
Not known	0	37	2	0	39
<b>TOTAL</b>	<b>21</b>	<b>96</b>	<b>9</b>	<b>1</b>	<b>127</b>

**Table 35: Prescribing errors identified using each method or combination of methods, presented according to whether or not the error was rectified before the patient received (or should have received) one or more doses, for the post-ServeRx cohort.**

Percentages are the percentage of errors identified using this method for which the outcome was known.

RRF = Retrospective Review Form.

\* In each case, one of these errors was identified by the trigger tool method as well as the RRF.

Tables 36 and 37 present the results according to the stage of patient stay in which the error occurred. The RRF identified more errors at the admission and discharge stages. The pharmacist identified more errors on transcription of inpatient drug charts in the pre-ServeRx cohort, while the RRF identified more arising during transcription onto ServeRx. Similar numbers of errors arising during the patient stay were identified by the RRF and pharmacist pre-ServeRx, while the RRF identified more post-ServeRx.

Stage of patient stay	Methods used to identify errors				
	Pharmacist alone	RRF alone	Pharmacist and RRF	Spont. report alone	Total errors detected
Admission	17	49	3	0	69
During Stay	14	18	4	1	37
Transcribing on new drug chart / ServeRx	8	4	0	0	12
Writing TTA	2	15	0	0	17
<b>TOTAL</b>	<b>41</b>	<b>86</b>	<b>7</b>	<b>1</b>	<b>135</b>

**Table 36: Prescribing errors identified using each method or combination of methods, presented according to stage of patient stay, for the pre-ServeRx cohort.**

RRF = Retrospective Review Form. No errors were detected using the trigger tool



Stage of patient stay	Methods used to identify errors				
	Pharmacist alone	RRF alone	Pharmacist and RRF	Spont. report alone	Total errors detected
Admission	9	41	2	0	52
During Stay	9	27	5	0	41
Transcribing on new drug chart / ServeRx	2	13	2	1	18
Writing TTA	1	15	0	0	16
<b>TOTAL</b>	<b>21</b>	<b>96</b>	<b>9</b>	<b>1</b>	<b>127</b>

**Table 37: Prescribing errors identified using each method or combination of methods, presented according to stage of patient stay, for the post-ServeRx cohort.**

RRF = Retrospective Review Form.

### ***Clinical severity of the prescribing errors identified***

Table 38 summarises the clinical severity scores for the prescribing errors identified using the different methods. This suggests that there was no difference in clinical severity between errors identified by the ward pharmacist and the RRF, but there is some indication that those identified by the trigger tool were of a higher severity.

Method	Severity scores
Ward pharmacist (prospective) (n = 78)	Mean score 4.4
Retrospective review form (n = 57 in sample)	Mean score 4.4
Retrospective use of trigger tool (n = 2)	Mean score 6.0 (scores of 5.6 and 6.4)
Spontaneous reporting (n = 2)	Not assessed

**Table 38: Clinical severity of the prescribing errors identified using each method.** Prescribing errors identified both pre- and post-ServeRx are presented together

### ***Specificity of the triggers within the trigger tool***

Table 39 summarises the numbers of individual triggers that were positive for all 207 patients studied, the percentage of these that related to a prescribing error and their specificity. The specificity of each trigger is also shown in Table 39; this ranged from 0.54 (trigger T4) to 1.0 (triggers T7 and T9).

Overall, at least one trigger was positive for 127 (61%) of the 207 patients studied. Of these 127 patients, examination of the positive triggers led to the identification of two (1.6%) patients with prescribing errors that resulted in harm. There were a total

Drug chart data					
Code	UK trigger	Potential problem identified	Positive? (% pts; specificity)	Error? (% of +ve)	Notes
T1	Chlorphenamine / loratadine / hydrocortisone	Hypersensitivity reaction of drug effect	9 (4%; 0.94)	0	Some not needed; non-preventable ADRs
T2	Vitamin K (phytomenadione)	Over-anticoagulation with warfarin	2 (1%;0.99)	0	Prescribed for disease state, not warfarin-related
T3	Flumazenil	Over-sedation with benzodiazepines	0	0	
T4	Droperidol, ondansetron, promethazine, hydroxyzine, prochlorperazine, metoclopramide, cyclizine, granisetron or domperidone	Nausea/emesis related to drug use	101 (46%;0.54)	0	Prescribed for nausea following surgery or other reasons unrelated to drug therapy.
T5	Naloxone	Over-sedation with narcotic	0	0	
T6	Anti-diarrhoeals: loperamide, diphenoxylate, codeine or co-phenotrope	Adverse drug event	36 (16%;0.84)	0	Prescribed for analgesia and other underlying disease states.
T7	Calcium Resonium	Hyperkalaemia related to renal impairment or drug	1 (0.5%;1.0)	1 (100%)	Error number 2 as in previous section
T22	Unexpected medication stop	Adverse drug event	2 (1%;0.99)	0	Two ADRs (not preventable)
Patient notes data					
Code	UK trigger	Process identified	Positive? (% of pts)	Error? (% of +ve)	Notes
T20	Over-sedation, lethargy, falls, hypotension	Related to overuse of medication	3 (1%; 0.99)	0	Hypotension unrelated to medication error
T21	Rash	Drug related/adverse drug event	3 (1%)	0	Two were adverse drug reactions (not preventable)
T23	Transfer to higher level of care, such as ITU or CCU	Adverse event	2 (1%; 0.99)	0	
Biochemical / haematological / microbiological data					
Code	UK trigger	Process identified	Positive? (% of pts)	Error? (% of +ve)	Notes
T8	APTT > 3	Over-anticoagulation with heparin	2 (1%; 0.99)	0	
T9	INR >6	Over-anticoagulation with warfarin	1 (0.5%;1.0)	1 (100%)	Error number 1 as in previous section
T10	WBC < 3 x 10 <sup>9</sup> /L	Neutropenia related to drug or disease	1 (0.5%;0.99)	0	
T11	Serum glucose < 2.8 mmol/L	Related to insulin use or oral antidiabetics	0	0	
T12	Rising serum creatinine	Renal insufficiency related to drug use	4 (2%; 0.98)	0	Haemodialysis patient or underlying disease state
T13	<i>Clostridium difficile</i> positive stool	Exposure to antibiotics	1 (0.5%;0.99)	0	Cefuroxime stopped after positive result
T14	Digoxin level >2mcg/L	Toxic digoxin level	0	0	
T15	Lidocaine level > 5ng/ml	Toxic lidocaine level	0	0	
T16	Gentamicin or tobramycin levels peak >10mg/L, trough >2mg/L.	Toxic levels of antibiotics	0	0	
T17	Amikacin levels peak >30mg/L, trough >10mg/L	Toxic levels of antibiotics	0	0	
T18	Vancomycin level >26mg/L	Toxic levels of antibiotics	0	0	
T19	Theophylline level >20mg/L	Toxic levels of drugs	0	0	

**Table 39: Positive triggers and prescribing errors identified**

of 168 individual positive triggers, of which 137 (82%) were the result of two triggers and did not lead to the identification of any prescribing errors. These were T4 (prescription for anti-emetics) and T6 (prescription for anti-diarrhoeals).

## 6.5 Discussion

This is the first comparison of these four methods of identifying prescribing errors in the same patient cohorts. Our results are extraordinary in that they suggest that each method identifies different prescribing errors, with remarkably little overlap between them. Previous studies of adverse events in general<sup>50,51</sup> and adverse drug events in particular<sup>25</sup> have also concluded that different methods identify different things. However, our results, which relate specifically to prescribing errors, show even less overlap between the different methods.

Only 5-7% of prescribing errors were identified by both the ward pharmacist's prospective review and the RRF. More errors were identified using the RRF than by a pharmacist's prospective review, but the pharmacist identified many errors that were not identified using the RRF. Our results indicate that the ward pharmacist identified a smaller percentage of all errors post-ServeRx; this suggests that some types of prescribing error may be more difficult for the ward pharmacist to identify with the electronic system. This is important methodologically in that electronic prescribing may preferentially facilitate detection of prescribing errors by one research method but not others. In this study, ServeRx significantly reduced errors when measured prospectively, but not when assessed from the patients' notes. Perhaps not surprisingly, fewer errors were identified by the spontaneous reporting system and the trigger tool (each identifying less than 1% of all errors), but the trigger tool identified half of the errors that resulted in patient harm.

These results lead to a re-reading of the existing literature, and have major implications for the interpretation of data previously presented using prospective data collection by the ward pharmacist<sup>3,26,52</sup>. Our results suggest that we may need to multiply the error rates found in those studies by a factor of two or three.

When all errors identified by one or more methods are compared, the results suggest that ServeRx resulted in a significant decrease in the incidence of prescribing errors.

### ***Why do different methods detect different errors?***

There are several overlapping issues, however they can be simplified into three issues:

- Variability between pharmacists
- Collecting data “on the job” or solely conducting research
- The extent to which texts (drug chart and patients’ notes, computer records) represent reality

#### Variability between pharmacists

Different researchers and different pharmacists are likely to record different errors, because of differences in clinical knowledge, familiarity with the local prescribing paperwork and policies, and diligence in finding and documenting errors. To try to minimise this we used one of the team (BDF), who is also lead clinical pharmacist for the trust, to “sweep” for missed errors. Retrospective review has the same problems, particularly for a researcher external to the hospital, going back in time when policies and practice may have been different. Completeness of data collection may be more of an issue in prospective studies. We noted that for 16 of the pre-ServeRx errors identified using the RRF, and 11 of those post-ServeRx, there was evidence in the medical notes that the pharmacist had identified and rectified the error, but these errors were not reported as such by the pharmacist. There may be other errors that the pharmacist identified and rectified, but we did not discover in the patients’ medical notes. This discrepancy clearly relates to deficiencies in completion of the data collection form rather than error identification.

#### “On the job” versus dedicated research

Our prospective study was conducted by the ward pharmacist as part of her job, however the retrospective review was done by a full time research pharmacist. We estimate that the researcher spent about ten times longer than the ward pharmacist reviewing each patient. They also have the advantage of seeing the whole clinical picture; the disadvantage of this is that it may lead to some hindsight bias. Of the errors identified using the RRF but not the ward pharmacist, some were comparatively minor errors, such as not specifying the strength of co-codamol or the maximum doses for medication to be given when required. A pharmacist on the wards is likely to amend these prescriptions without consulting the prescriber, and may not consider them to be errors worth recording. Others were errors that the ward pharmacist may not have identified without reading the patient’s full clinical

background, something not routinely done as part of a ward pharmacy service. Such errors included drug history omissions, non-prescription of oxygen in patients for whom this was required, and prescribing too low a dose of prophylactic enoxaparin in patients with high-risk comorbidities. Others were errors that occurred during weekends and may not have been identified by the pharmacist before another member of the team rectified them or the patient was discharged.

### Texts versus reality

When the pharmacist is on the wards collecting data prospectively, they have access to more information than that present in the patients' notes, and hence can detect different errors. For example, the pharmacist identified some drug history omissions resulting from conversations with patients. In others cases, the ward pharmacist was able to identify medication that was no longer required, such as prophylactic heparin in a patient who she could see was fully mobile. These types of error are unlikely to be identified retrospectively. Finally, some of the pre-ServeRx errors related to unclear medication orders or incorrect doses that were subsequently rectified on the paper drug chart, meaning that no evidence of the error was available retrospectively.

### ***Advantages and disadvantages of the different methods***

Table 40 summarises the advantages and disadvantages of the four methods assessed.

Asking the ward pharmacist to prospectively record the prescribing errors identified during routine prescription monitoring requires little additional resource, however identified only about 30% of all prescribing errors. In contrast, retrospectively reviewing the medical notes using the RRF was the most productive, but also the most time-consuming method. In practice, only 4 patients could be evaluated each day. The RRF does have the advantage that it includes errors that appear to have resulted in patient harm, something required before economic evaluation can be achieved.

Method	Advantages	Disadvantages
Ward pharmacist (prospective)	Requires little additional resource	Identifies only about 30% of all prescribing errors; unlikely to identify errors resulting in patient harm as errors rectified.
Retrospective review form	Identifies the largest proportion of errors (70-80% of all prescribing errors); identifies errors that result in patient harm	Time-consuming (about 40 minutes per patient admission, plus time taken to retrieve medical notes; about 4 patients could be reviewed each day)
Retrospective use of trigger tool	Relatively quick to apply tool, plus time taken to retrieve the medical notes. Identifies harmful errors (although not all).	Provides information on a very small percentage (less than 1%) of all prescribing errors.
Spontaneous reporting	Requires little additional resource; engages staff in the reporting of errors.	Provides information on a very small percentage (less than 1%) of all prescribing errors.

**Table 40: Advantages and disadvantages of each method for the detection of prescribing errors**

This study also reports the first application of a UK version of the US trigger tool. Application of the trigger tool following the RRF required only an average of 4 minutes per patient; however, it would be expected that it would take considerably longer if this was done alone. A target time of 20 minutes had previously been proposed in the US<sup>24</sup>. The trigger tool method identified two of the four errors that resulted in harm in our sample, but identified 84 false positive triggers for every real case of error. However, most false positives resulted from two of the 23 items on the scale. The remainder may be useful as prompts for ward pharmacists, and/or incorporated into electronic prescribing systems in the future as reasonably good predictive prompts for further investigation. There has been little work comparing the trigger tool with other methods. Rozich et al<sup>24</sup> found that only 5 of 274 adverse drug events (ADEs) identified with the trigger tool were also identified by incident report and pharmacy intervention records; however they did not report the number of ADEs identified by these methods but not the trigger tool. We identified specificities for individual triggers ranging from 0.54 to 1.0; those previously reported in the US (in a larger sample) ranged from 0 to 0.77<sup>24</sup>.

Spontaneous reporting is probably the least time-consuming, but identifies a very small percentage of the total number of errors and cannot be recommended for evaluation of electronic prescribing.

***Limitations***

A potential limitation is that the same researcher carried out the trigger tool analysis immediately after the retrospective review form on each patient. This meant that the researcher would have already had some familiarity with the patient's medical records. As well as speeding the process, this could potentially have led to bias.

***Conclusion***

The incidence of prescribing errors is extremely dependent on the method of detection. Only prospective monitoring and retrospective monitoring seem usable for research purposes, however each technique identifies broadly different errors. The way an electronic prescribing system works may mean that it significantly reduces prescribing errors when measured by one method, but not by others.

## **7: A framework for evaluation of electronic prescribing**

### **7.1 Introduction**

This Chapter discusses the approach to evaluation of electronic prescribing developed and used within this project.

The first objective was to evaluate the evaluation framework. The more specific objectives of this part of the study, as specified in our original protocol, were to provide:

1. A descriptive account of practice within each system, including its implementation and changes in process and communications patterns
2. Staff reactions to the new system, both during its introduction and once it has become established
3. Staff views of the advantages and disadvantages associated with the new system
4. Patients' views of the new system.
5. Assess the project in terms of sustainability in the hospital environment, changes it foreshadows and contribution to policy.

Given the word limit for these reports, we have placed the qualitative evaluations of each system in Appendices A and B. In this Chapter we assess the evaluation framework, summarise the findings of each system and draw out the combined insights from having assessed both systems.

### **7.2 A Context of Evaluation of Electronic Prescribing**

Information systems programmes and initiatives in the NHS, from the local to the national, have become increasingly complex and technologically innovative as well as being increasingly expected to deliver substantial and transformative outcomes<sup>53,54</sup>. They come to directly and indirectly involve large numbers of people (stakeholders), to span institutions and professions, and may substantially reshape the processes of care giving. In this way the adoption of such technological innovations in health care are closely intertwined with, or even indistinguishable from, organisational change – some of which is planned and



intended, but much of which may be unintended and emergent, and indeed may often not be immediately recognised<sup>55</sup>.

Our approach to the evaluation of EP at QHB and CHX has been motivated by such an understanding, and has led us to apply a broad approach in data gathering as a means to capture the overall reshaping of work processes that occurs as EP is introduced and used within secondary care settings and to provide an essential context for more focused evaluation measures.

In any hospital, or even any ward within a hospital, the move to give up the established paper based methods for prescribing and administering drugs will inevitably be seen as a significant challenge that, at minimum, will draw concern (fears, hesitation) from managers, doctors, pharmacists and nurses, as well as patients. Each of these individuals and groups will approach the adoption of EP with some prior expectations, prejudices and probably many misgivings. But it is through these individuals' developed attitudes and perspectives on technology, on the incidence and causes of error, and on the need for change, that the EP system "in use", the actual new ways of working or experiencing care will come to be established and sustained over time.

Our evaluation studies in the two sites show in this way how, over time, people come to accommodate the new technical resources of EP within their working practices, and how the technical system itself and the care practices are shaped and changed. Thus one of the main results of the work reported here is to emphasise the significance of the local context and professional and patient attitudes to the way such systems are established and operate. To attempt to understand or assess EP without appreciating the significance of the challenges (and changes) its implementation implies is to risk missing the main point or failing to learn vital lessons.

Evaluation is essential to address directly focused outcome measures established prior to implementation - to assess quality and efficiency of prescribing and administration of drugs, including the critical area of error as discussed in previous chapters. But the perspective on evaluation used in this study goes further and adopts a wider remit. We acknowledge a need for a diverse range of evaluation activities to capture the dynamic and multi-faceted processes of change that are initiated when EP is implemented and which can capture how new ways of

working are experienced by various stakeholders. We deliberately speak here of evaluation activities in the plural, because we see the scope of change implied by electronic prescribing as overflowing the capacity of any one privileged evaluation technique.

As EP systems are brought into operation and used we should expect to see interesting consequences follow and should be able to capture them in evaluation. Some of these consequences will be planned for, expected, or predicted (for example, fewer dosing errors, faster drug rounds, better checking by pharmacists), but some will not (perhaps new demands for summary and audit data, loss of personal contact between HCPs, non-use of decision support). We may see changes in communication, regular tasks being performed in different ways, new medication regimes being established while established ones prove unable to be accommodated. Consequences may be seen for the hospital overall, or draw from broader organisational characteristics (relying on stable staffing to retain and pass on knowledge, or seeing enthusiastic staff staying in post longer to work within the EP environment). Indeed, in the sites studied each of these findings is reported.

Our experience also suggests that it is important to distinguish the aim and focus of evaluation, and to direct effort appropriately. We have seen the need for formative evaluations as part of an EP project, serving as an essential means of maintaining the impetus of the innovation – to provide input and direction in the specific context, to ensure that problems and bugs are identified, lessons are learned, successes are acknowledged, people feel involved and heard, and compromises and tactical changes essential to sustaining a system in use can be made.

The broad multi-perspective approach to evaluation also has value in allowing a more comprehensive (or more importantly comprehensible and sharable) understanding of the overall achievement from EP; one that can usefully serve the wider community of policy makers, health care managers, researchers, practitioners and patients. As Southon *et al*<sup>56</sup> suggest, evaluation of ICT in health needs to be more organisation focused, and in particular to be undertaken in ways that allow it to substantially support existing organisational decision making processes. Thus EP systems also require summative evaluations – evaluations that serve to communicate what has been achieved, what the enduring outcomes

are, and in such a way as to facilitate the understanding of other decision makers and stakeholders in other places, and to help them make informed decisions relevant to their own context.

### **7.3 Evaluation Perspective**

EP is one example of the contemporary trend to pursue reform in health care through the medium of information and communication technology (ICT). But as is widely acknowledged, such technical systems and innovations based around them are difficult to evaluate<sup>57</sup>. Both formative and summative evaluation poses practical problems and raises questions of what should be evaluated, based on what data, the perspective from which technology, work processes and services delivered are to be assessed, appropriate means of collecting data, and the criteria of judgement to be used. As Symons<sup>58</sup> suggests, for any evaluative activity we need to carefully consider the context of evaluation itself (who is evaluating and why), the process (how) and the content (what)

In the medical tradition the answers to such questions are usually found in randomised controlled trials (RCT), often proposed as the gold standard of evaluation. However, their applicability to evaluation of information and communications technology (ICT) based innovations is often questioned for theoretical and practical reasons<sup>57,59,60,61,62,63,64,65</sup>. The RCT assumption that different factors or parameters (such as hardware performance, training, social arrangements and institutional history) can, through experimental design, be disentangled from the social processes and wider cause-effect relationships established around a system in use is often critiqued as limited or inappropriate for ICT based innovations<sup>65</sup>.

The wider information systems discipline is less influenced by the medical/scientific model. As organisational information systems have become more pervasive, ambitious, flexible, complex and interactive, evaluation emphasis in this field has, to a degree, shifted. It has moved away from simple cost and benefit approach, or narrow questions of “user satisfaction”, to new concerns with how, and to what extent, information systems innovations serve ambitions of organisational change, innovation in process and the development of strategic agendas. This in turn has led to political, cultural and organisational aspects being seen as necessarily playing a major role in shaping evaluation activity<sup>66</sup>.

Thus, issues of alignment with business goals and institutional interests, the support for knowledge work and knowledge workers, understanding of existing work practices in formal and informal senses and the ability to transform them, have all been given attention in the IS field<sup>58,67</sup>. Ethical questions, to what extent and in what way a new information system may effect peoples' legitimate interests for example for professional discretion, privacy or information stewardship, also no longer appear to be irrelevant or simple to accommodate<sup>68</sup>.

In both the IS and medical informatics fields there is increasing agreement that evaluation should be seen less as a process of judgement, and more as an essential component of the learning/changing processes that are a fundamental part of the use of innovative technologies. Evaluation activity is a necessary attribute of these technologies, a means by which collective insights can be assembled and fed into current and future implementations, essential to "steering" the technology (creating it in use) and leading to increased organisational knowledge and capacity for change.

Evaluation, in these terms, is not an activity undertaken outside of a new systems development activity, as a means of judgement, but is an essential part of it. Thus, increasingly formative evaluation is seen as more appropriate than a narrowly summative approach. This is particularly true, as Farbey et al.<sup>69</sup> argue, in a changing or dynamic environment, where evaluation must allow for a proactive search for unexpected benefits (achieved or potential) as well as unexpected barriers. Such evaluation must be re-integrated into the change processes and reflect the complexity and contextuality that drives the worked out "success" (or otherwise) of any innovative information system, revealing the complex processes that contribute to outcomes (to show *why* outcomes come about), and how relationships *between* system characteristics, individual and organisational characteristics operate (a process focus)<sup>70,71,72</sup>

Extending this point, we argue that evaluation of electronic prescribing systems should seek to capture the process of their enactment; that is the way this technology is understood and configured in use, and in-turn the way users and organisations are (re)constructed by their engagement with the technology. What needs to be evaluated is not a moment in time or an isolated set of one dimensional outcomes (prescriptions written, drugs administered), but a dynamic and active socio-technical ensemble at work.

Such an evaluation should also reflect ethical perspectives, concerned not only with efficiency and effectiveness but also with broader implications of EP, looking towards changes to the way medicine and health care are conceptualised and practised, and are experienced by both health professionals and patients. Thus, for example, in the studies reported here, we have addressed patient attitudes and opinions at some length when assessing electronic prescribing.

Accepting that evaluation activities for EP must include the evaluation of how they come to be embedded in their social, organisational and wider context necessarily implies different evaluation methods and perspectives, ones that can complement rigorous quantitative analysis of system functions and outcomes. We have used qualitative methods in the ethnographic tradition, including observation (on wards, in pharmacy and at managerial meetings) and various form of semi-structured interviews to gain an insight into how people experience and relate to EP in their daily tasks and routines, how they perceive it and assess it, and in this way to understand *why* certain outcomes happen – what Hirschheim and Smithson<sup>73</sup> term an understandings zone of evaluation.

Another method employed in the study at CXH was a group meeting (loosely termed as a focus meeting) attended by professionals from different groups (nurses, doctors, pharmacists and management). The meeting had a defined aim and agenda (evaluation of the system), and was facilitated by two researchers. Such a focus meeting allows evaluators to explore how different people interact, reacting to and influencing each others' views, and how group agendas are built or expressed. Such an approach based on negotiation and consultations, has immediate formative potential if it re-enforces collective understanding and responsibility for a system as it becomes established. Such a collective evaluation process can also, usefully we would argue, help participants to question the validity of initial objectives and to reshape them based on shared experience<sup>74</sup>.

Finally, these evaluation activities for EP must be reflexive. Any evaluation is ultimately a non-objective, political process that is established and resourced by particular interests. Evaluators, and those that use their outputs, should understand this and it should lead them to question their own and other participators interests, beliefs and assumptions, and consider how these might influence the choice of criteria and methods, the evaluation process and its

findings. In this spirit the *Requirements for Preparation of Final Reports for the Patient Safety Research Programme* suggests that:

*Qualitative research should include the researcher's perspective, areas of potential bias / influence, justification of data collection and analysis tools and choice of setting, participant information.*

This critical and reflexive stance is just as relevant for quantitative evaluations.

#### 7.4 SPO evaluation framework

Taking the various points made above we now describe the framework we have applied in this study (Figure 19).

	<b>Systems functions</b>	<b>Human Perspectives</b>	<b>Organisational Context</b>
<b>Structure</b>	<i>Technical detail</i>	<i>Work conditions and implied requirements</i>	<i>Sustainability, opportunity costs, management needs' skills requirements</i>
<b>Process</b>	<i>Information processing; correct and valid</i>	<i>Human participation in tasks; social interaction</i>	<i>Altered delivery and practice</i>
<b>Outcome</b>	<i>Relevant, applicable, reliable</i>	<i>Quality of service, and outcomes</i>	<i>Effect in the world</i>

**Figure 19. The evaluation framework** (Based on Cornford *et al.*<sup>21</sup>)

A structure, process and outcome model was initially proposed by Donabedian<sup>75</sup> for evaluating quality of care from the perspective of different stakeholders, notably physicians and patients. Donabedian's ideas were developed further by Cornford, Doukidis and Forster<sup>21</sup> to produce a matrix of structure, process and outcome as one dimension and system functions, human perspectives and organisational context on the other.

This model addresses Donabedian's three classic aspects from the perspective of the technology used, the people involved in the work process, and the institutional setting. The framework thus encompasses technical, individual, team and organisational perspectives and serves to address the long-term prospects of a system - its sustainability within a technical, social and organisational context - as well as changes to the means for the delivery of care and to established work practice. Use of the framework has helped in this study to focus on organisational consequence of EP ("effect in the world"), and has led our evaluation activity beyond a few narrow or decontextualised measures.

The advantage of this framework for studies of EP, we argue, is that it frames a broad set of evaluation activities and perspectives that combine social and technical perspectives and that encompasses qualitative and quantitative approaches. It must, however, be understood as just a framework within which specific data gathering approaches can be located, and we certainly do not claim that it alone offers the elusive integration of the technical and social, qualitative and quantitative elements. The framework can however, as shown here, guide evaluation activities and the choice of criteria, serving as a flexible template within which specific evaluation criteria and methods can be located, and related one to another in analysis. The framework is particularly relevant to the study of the key goal of reducing medication error through its compatibility with Reason's model that sees errors as having roots in technical, individual, group and organisational failures, with the emphasis directed towards the latter end <sup>76</sup> .

As a simple primary route through data the model allows consideration of how technical structures link to human work process and create organisational outcomes – a simple diagonal. Such a reading of data might produce a clear understanding, but it is more likely that tracing such a simple chain of understanding will raise questions or pose contradictions (for example, how come "good" technology did not lead to "good" human process, or vice versa; how was a fragile and incomplete technology accommodated and made useful by human participants?). Resolving such a contradiction will then require a shift of attention to some other aspect of a system – perhaps in technical outcomes (for example, non-use of certain functionality), or be found in the prior attitudes of certain stakeholders. Considering the interaction (interrelations) between the conceptual cells achieves a deeper level of understanding (a hermeneutic reading of research

data) by moving from understanding parts to understanding wholes and back again.

In the next section we apply the framework to the two hospitals. A summary of the findings is presented first (Tables 41 and 42).



	<b>System Function</b>	<b>Human perspectives</b>	<b>Organisational context</b>
<b>Structure</b>	<ul style="list-style-type: none"> <li>• ServeRx is a stand alone technical system that includes support for electronic prescribing, scheduling, automated dispensing and electronic administration, as well as elements of stock control.</li> <li>• Includes computerised drug trolley and automated cabinets for storage.</li> <li>• Installed on one ward and with no substantial connection (other than basic data) to the Hospital's other information systems.</li> <li>• Initial technical problems and the system needed tailoring to CXH/UK requirements.</li> <li>• Many problems rectified with subsequent versions but some hardware and software shortcomings remain.</li> </ul>	<ul style="list-style-type: none"> <li>• Training provided to doctors, nurses and pharmacists but on-going support (including the physical presence of a trainer on the ward) was found to be necessary.</li> <li>• Doctors had little involvement in shaping of the system and some considered this as not appropriate.</li> <li>• Nurses hesitant about the system at the outset.</li> <li>• System driven forward by pharmacists, other professionals felt that it reflected most strongly pharmacists' interests.</li> <li>• Pharmacists clearer at the outset what the system was for and what they wanted from it.</li> <li>• Patients unsure of what to expect, with a number of concerns about computerisation.</li> </ul>	<ul style="list-style-type: none"> <li>• A pilot project, envisaged as an opportunity to learn from this system and inform future initiatives.</li> <li>• Initiated and managed by Pharmacy department</li> <li>• Enjoyed extra resources.</li> <li>• Substantial commitment from many staff members.</li> </ul>
<b>Process</b>	<ul style="list-style-type: none"> <li>• The system reached stability and became well integrated into work of the ward.</li> <li>• Once stable, the data processing functioned well.</li> <li>• Inbuilt structuring of core work processes of prescribing, dispensing and administration of drugs performed satisfactorily for most but not all drugs.</li> </ul>	<ul style="list-style-type: none"> <li>• The system influences how, when and where prescribing is done and checked, shaping work processes of doctors, nurses and pharmacists.</li> <li>• Experience of using the system over time and over its many versions has meant that the attitudes towards it have evolved and shifted.</li> <li>• Nurses administering drugs bound by a sequence of procedures embedded in the system.</li> <li>• The way different professionals communicate with each other changed.</li> </ul>	<ul style="list-style-type: none"> <li>• Experience emphasised the challenge that comes when the working practices of professional groups and interdisciplinary teams are reshaped by introducing a powerful and structuring technology.</li> <li>• Technology can be explicitly used to enforce a 'good' process, but some aspects of practice do not neatly fit, or are incompatible with, the system.</li> <li>• This is apparent on one ward, but across a hospital the effect could be magnified as different specialities are considered.</li> </ul>

<b>Outcome</b>	<ul style="list-style-type: none"> <li>• A usable technology (hardware and software) that was over time shaped and integrated into ward practice.</li> <li>• Facilitates safe or safer prescribing and administration processes</li> <li>• Provides data which is of an appropriate quality and available for all participants in the care process.</li> <li>• Continuing mismatch between system characteristics and the use of certain drugs.</li> </ul>	<ul style="list-style-type: none"> <li>• A system which pharmacists, and perhaps more reluctantly, nurses came to accept and many would miss.</li> <li>• Doctors' opinions more varied; identified shortcomings but believed in benefits an ideal system might bring.</li> <li>• Restructuring effects on the way different professional groups work, varying opportunity to exercise a degree of autonomy.</li> <li>• Generally perceived as safer or at least potentially safer, reducing some errors but also acknowledged as introducing new risks.</li> <li>• Patients had less concerns about computerisation after the introduction of ServeRx than before it.</li> </ul>	<ul style="list-style-type: none"> <li>• Plans for the system's future are still being discussed, but in the immediate future ServeRx is not going to be transferred to another ward after the closure of Ward 8N.</li> <li>• The pilot has led to valuable lessons; benefits and drawbacks of EP; scope of impact; the processes involved in 'hosting' such a system; project management and implementation strategies.</li> </ul>
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**Table 41: Charing Cross Hospital: ServeRx system**

	<b>System Function</b>	<b>Human perspectives</b>	<b>Organisational context</b>
<b>Structure</b>	<ul style="list-style-type: none"> <li>• EP implemented as a custom-built front end for Meditech pharmacy system.</li> <li>• Developed as part of a whole-hospital HIS, interfacing with other HIS modules.</li> <li>• Accessed via wireless laptops, static PCs and dumb terminals.</li> <li>• A number of technology problems including competition for laptops, short battery life and sometimes unreliable wireless connection,</li> <li>• DOS interface perceived as initially difficult to learn and requires complex combinations of keystrokes. However perceived as more stable and safer than Windows systems.</li> </ul>	<ul style="list-style-type: none"> <li>• Formal on-going training program with dedicated system trainers supported by informal staff mentoring by more experienced colleagues.</li> <li>• Individual professional groups are willing to work through initial problems and adopt a new way of working that may not always provide their own group with obvious benefits.</li> <li>• View of computers as part of natural and desirable progress.</li> </ul>	<ul style="list-style-type: none"> <li>• Hospital has had a long-term commitment to computerisation and an established, generally good, relationship with software supplier.</li> <li>• From its earliest involvement with HIS developed a strong focus on workable solutions for whole hospital.</li> <li>• A stable workforce helps embed new ways of working</li> <li>• Developed resources, skills and managerial competencies to maintain the technical components of the system.</li> <li>• A belief that they can get things right.</li> </ul>
<b>Process</b>	<ul style="list-style-type: none"> <li>• Few problems reported with data processing and reliability.</li> <li>• Facilitates rapid availability of test results, accurate medication history on transfer to another ward, and legible, timely discharge letters containing a complete list of current medication.</li> <li>• Enables co-ordination of work across the hospital to support the patient care process and allows different health professional groups to share data, communicate and justify decisions.</li> <li>• Technical capacity of the system is not seen as significant hindrance to clinical activities.</li> </ul>	<ul style="list-style-type: none"> <li>• Legible, standardised, complete patient medication records which are always available make prescribing a more distributed activity with some decisions made remote from the patient.</li> <li>• Offers health care worker (in particular doctors and pharmacists) an opportunity to restructure their work and to choose to do things differently e.g.; multitasking for junior doctors on call, pharmacists new opportunities to change the way work is organised (but less pharmacy work done on the wards), availability of information may empower nurses to check and challenge doctors.</li> <li>• Both improves and diminishes inter-professional communication; may reduce direct communication with patients.</li> <li>• Potential risk of “deskilling” prescribers balanced by opportunity to learn new drug information.</li> </ul>	<ul style="list-style-type: none"> <li>• An organisational and professional alignment with technology and its suppliers supported by enthusiasts and champions.</li> <li>• EP (as a part of HIS) facilitates the establishment of a data driven practice that seeks to maximise the benefits of inter-professional working.</li> <li>• EP facilitates enforcement of Trust prescribing policies.</li> <li>• Organisation policy and practices have tried to foster the preservation of relationships between professional groups.</li> </ul>

<ul style="list-style-type: none"> <li>• <b>Outcome</b></li> </ul>	<ul style="list-style-type: none"> <li>• A stable, usable, continuously evolving system which supports the complex workflows surrounding medicines use</li> <li>• Most data collected is judged as of good quality (more complete, legible, accessible) and is sharable among multiple users.</li> <li>• Generally meets local user needs, though lack of data reporting facilities noted.</li> </ul>	<ul style="list-style-type: none"> <li>• Doctors and nurses perceive as their system, not a system designed for and controlled by pharmacists</li> <li>• Perceived by staff and patients as more efficient and probably safer, with a better audit trail than paper.</li> <li>• Patients see EP as more secure and confidential, but recognise possibility of new types of “picking” error when prescribing.</li> <li>• Changes in working practice for all health professionals, helping them manage and use time more efficiently and effectively.</li> <li>• Practice of all health professionals more visible, highlights variation in practice, and makes mistakes more visible and accountable.</li> </ul>	<ul style="list-style-type: none"> <li>• A sustainable EP system that operates as just one part of a hospital wide HIS.</li> <li>• A system that attracts staff and may contribute to low staff turnover.</li> <li>• Staff and patients perceive QHB as a modern, advanced organisation that embodies state of the art technology.</li> <li>• Often reflect on why, despite their sense of success, they have received relatively little attention by policy makers.</li> </ul>
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**Table 42: Queens Hospital: Meditech System**

## 7.5 Applying the framework to Electronic Prescribing

Each case study is presented in depth in the Appendices, here we give an overview in Tables 41 and 42 to briefly present the main findings of the studies reported within the adopted framework – for the full account of each study see Appendices A and B.

In this Chapter we elaborate the framework further and apply it for a more detailed and integrated analysis of the two cases. Drawing on Donabedian's distinctions, the three aspects of structure, process and outcome are presented in turn, seen in each case from the perspective of the technical, the human and the organisation.

***Structure: The established characteristics of the situation under study. "The things we have".***

Structure is sometimes referred to as "the causal past" <sup>77</sup>, representing significant initial conditions that an innovation such as EP must relate to - current resources and actors and the characteristics of the work setting and hospital - and with which it must combine to become embedded.

### System Functions

In the case of EP we consider the technical components used to implement EP, both as already established and as introduced as part of the implementation. Technical elements offer specific functionality, and may displace others, for example in both studies displacing the old style paper drug chart and in the case of CHX the old style drug trolley. EP is thus an innovation in structure, the introduction of new technical resources.

In both the sites studied, the technical components proved problematic. Computers crash and hang, batteries go dead, data transmission is not always reliable, data are not always preserved. In both cases the technologies used started out as alien to the particular context with poor structural compatibility, for example because of their origins in other health care systems (Israel and US) and the embedded assumptions that they carried. There was also in both cases some suggestion that there was simply not enough technical resource, for example a lack of computer workstations.

Technology is also a physical element and, for example, issues of ergonomic design were raised in the CHX case as nurses used automated cabinets and computerised trolleys. The different screen interface technologies used, Windows-like and mouse driven in the case of ServeRx and DOS based for Meditech, also proved significant in the minds of our respondents, with a general preference, or at least acceptance, that the Windows paradigm would prevail and serve better the needs of new users (drawing on their general IT skills) notwithstanding the accumulated experience of old hands with the function keys.

As a physical element of structure, the drug chart too, although being displaced by EP, was seen to play a quite important role. In purely technical terms, both systems attempted to provide some analogue for the drug chart, both on screen and as an articulation of ward based activity. But in both cases, particularly CHX where the system was directly related to previous and parallel practice in the hospital, what technology offered was not perceived as quite replacing what had been lost. Many people thus referred to the “overview”, the quick update, that a drug chart offers and felt a sense that care practices had been fragmented through the new technology.

### Human Perspectives

Here we identify the various stakeholder groups who come to use or experience a new EP system, principally doctors, nurses, pharmacists and patients. Among the most significant elements of structure that they bring are their professional formation and training, their ethical tradition, as well as attitudes, desires and expectations in the face of change in general, and technology led change in particular.

Our findings, in this respect, identified the training and support regimes established in both cases, as an essential structural element for successful implementation. Indeed, in the case of ServeRx, the quantity and duration of this support had to be expanded to maintain the system in operation. At QHB the confidence of users, and of new users in particular, was essentially linked to the good training facilities offered, and the high level of informal and ad-hoc support that people felt to be available. Indeed in both cases it was found that training was really an “on-the job” activity that helped people to accumulate

their knowledge on a “*need to know now*” basis and relied on many informal supportive relationships across professional boundaries.

Another aspect of structure that human actors provide is their commitment to EP as a means for professional and institutional development and part of a vision for their hospital or their professional specialism. Thus at CHX senior nurses identified EP as an essential element of a programme of modernisation and a useful challenge for their staff. Meanwhile other more junior nursing staff showed a more ambivalent attitude, and expressed concern that EP was to a degree coming between them and their patients – violating their professional tradition.

Doctors too exhibited a range of prior attitudes and expectations in relation to EP. At QHB senior doctors were involved in the acquisition and build up of the use of the Meditech HIS from the start, and many (though not all) identified themselves as proponents of EP. As might be expected, in both sites junior doctors expected to bring their knowledge of IT in general to the EP system, and in general they found it easier therefore to learn the system, appreciate its benefits and foibles, and to keep a general faith in EP as an almost inevitable and desirable part of their future work practices.

The prior formation and training of pharmacists and the established pharmacy systems were seen to be strongly supportive of EP in both sites in that pharmacy culture is about order and sequence, exercising control, structured communication and working as part of a team. All this is broadly compatible with the inscribed systematisation that comes with EP technology. Pharmacy work is also, at times, quite routine, and the potential to “automate away” such aspects was appreciated. Similarly pharmacists have perhaps the most concrete sense of error around drugs, and can make the most a direct link between EP and error reduction. EP, potentially, might become a means to enhance or empower pharmacy interests, to embed them in a stronger way into practice though, as reported in the studies of both sites, achieving this is not so easy in operational terms (for example, problems in Decision Support Systems), nor is it necessarily wise in organisational terms if it results in EP being seen as a “pharmacy” system imposed on others (see section below).

### Organisational context

Here we consider the formal management structures through which EP is developed as well as the established culture and working style of the hospitals.

In the cases studied here, in particular in the QHB case, we find that the establishment of EP and its hospital wide implementation, draws strongly from the distinctive computer focused managerial strategy pursued over 10 or more years, itself linked to the relocation of the hospital to a new purpose built site. The organisation is the Meditech system and many people suggested that without it work would stop. EP was just a part of “the HIS” and was very much a taken for granted resource, an every-day matter. This had practical consequences for the research in that it was hard to keep any conversation focused on EP. Discussion swiftly slid away to some other part of the HIS. Put another way, this prior experience of technology had built a strong legitimacy for EP and smoothed the roll out into the various specialities across the hospital.

In contrast, at CHX, the ServeRx system was a pilot, and the project was managed and sponsored by the Pharmacy department with degrees of support from other operational areas. As a large teaching hospital it is research led in many areas, and has considerable IT experience drawn over a number of years. One aspect of the hospital’s engagement with technology was its recent experience of a successful pioneering hospital wide PACS system that affected some people’s generally positive views of technical innovations and their potential to deliver tangible benefits. The small scale of the pilot at CHX – one ward – also prompted some respondents, notably doctors, to reflect on EP in terms of “*all or nothing*”. If it was an institution wide initiative, and resourced at that scale, they saw more benefits, but in a pilot they saw more the disjunctions and extra work.

***Process: The way things work and are worked out; how parts interact or operate to perform individual and collaborative tasks. “The things we do”.***

Process here is concerned with the activities that occur within the hospital setting as they relate to drugs and their management. This process is to some degree under the influence of human participants through their professional



training and experience, but is equally conditioned by the structural characteristics of the technology employed.

Most significantly for these studies is our simple finding that process changes as a result of EP, being negotiated and worked out as a part of the extended implementation activity. Indeed, our findings suggest that the real significance of EP for each site was found not in the technical characteristics of the supplied technology, but in the activity of accommodating it and negotiating it into use.

### System Functions

Our study here focused on the way that the technical components worked together as a system, how they manipulated and processed data, and how correct, valid and trustworthy they were in day to day use.

From both studies we find that EP systems are not stable or given as operational technology, but demand constant attention to bring the technical process up to the desired level of performance and the full range of functions. Similarly they need attention to become acceptable within the social environment. For example, in the CHX case, throughout the period of use of Serve Rx there was constant attention to assessing and pursuing the required functionality such as discharge prescriptions, as well as to monitor the reliability and safety of the technical system.

At QHB a similar route had been followed, though as a more substantial system with a longer history, some of the issues that CHX faced had been already resolved. Still, there was more similarity in their situation than might at first be expected. For example, both sites had problems with accessing and using summary, audit and overview data and it is surprising at first sight that neither system seemed to offer usable and flexible reporting systems to allow access to the data. Similarly, both sites continued to struggle with certain drugs and prescribing practices that did not quite 'fit' the inscribed logic of the software.

### Human perspectives

Here the framework led to a focus on four main stakeholder groups: doctors, nurses, pharmacists and patients. Each group, taken alone presented their

own distinct account of what it means to work with and through the new system, which we briefly summarise here. More significantly perhaps is the ways in which EP changes the relations between the various stakeholders.

In both the studies we have seen how EP influences how, when and where prescribing is done, how it is checked, and how drugs are administered. In this way we see EP as shaping new working practices for doctors, nurses and pharmacists as well as other health care professionals who interact with patients.

For doctors, particularly junior doctors, the principal of EP was broadly welcomed even as some aspects of the systems in use were viewed as problematic, particularly so in CHX with its 'project' status and interface problems to other parts of the hospital. At QHB, in contrast, both junior and senior doctors reflected positively on the ability to work away from the ward or bed-end, and to access data and prescribe remotely. In this way EP, or more generally the QHB HIS, supported junior doctors in their dominant mode of working – always prioritising and shifting rapidly from one task to another.

In a similar way pharmacists too had used the system to restructure their working practices, for example performing more reviews remotely at QHB, and in both cases using the EP system to help prioritise and schedule their work.

For nurses EP is probably a more constraining development. For example, the CHX system imposed a distinct discipline on nurses as they loaded drug trolleys, administered drugs and completed a round. Nevertheless, they did over time come to find positive resources within the system upon which they could rely on in their work - and which helped to improve the systems image - for example, the lack of need to find keys and lock a trolley, or the swifter preparation for a drug round.

Of course, shifts in time and place and the ability to reorganise work or rely on technical resources may have negative consequences. Both doctors and pharmacists at QHB recognised this, reflecting at times on how their relationships were perhaps weaker and how much of their interaction was mediated through the technology. Even nurses, who work for the most part within a ward, were aware of the technology's potential to add distance to

work, reflecting on how computers could come between them and their patients if they looked at screens rather than faces.

At both CHX and QHB the study asked patients for their attitudes to EP as key participants in the process. The findings reflect perhaps a more general sense in society that computers are on balance a good thing, and can offer many benefits in terms of efficient and reliable service delivery – a sort of “Tesco effect”. For some patients it represented an expression of the “modern” hi-tech care process that they desired. Still, they are not blind to the failings of computers and the potential fragility of a technical system when compared to the human. Nor were they wholly sanguine as to the nature of the new services they will be receiving, fearing that they may be less personal.

### Organisational Context

Here we considered EP as an intervention or contribution to the overall organisation and to its operational development.

The studies at both sites emphasise the challenge that any particular hospital must face when adopting EP and the long and extensive (almost unending) implementation that it requires. Getting from “here” – which for most hospitals will be an established, functioning, well understood and tolerably safe system based on paper and the accumulated years of experience of all the main actors (doctors, pharmacists, nurses, patients) - to “there” - a brave new world of electronic prescribing with effective decision support and ‘information at our fingertips’ must be understood as a significant process in itself.

In these terms EP is not an end state that is achieved after a discrete effort, but is more suitably understood as an enduring process of change and for which the organisation must be prepared and committed.

Reflecting on the experience of both sites, very different in scale as they are, the overall impression is to reinforce the conventional wisdoms of IT projects; the need for high level commitment, shared ownership and active management, and for an overall incremental perspective that is resourced to support systems as they develop over extended periods.

***Outcome: The consequences of an innovation, what endures, how care is experienced. “The things that happen”.***

Traditionally outcome is associated with measures of patient’s health status as a consequence of process, but here outcome is extended to include the enduring state of technology, of professional interests and for the health care organisation itself.

### System Functions

For the technical components outcome is expressed principally in their ability to continue to operate within the environment, to be considered to maintain their status as relevant, applicable and reliable participants in the health care setting – allowed to stay. This is of course not the usual use of the term “outcome” in health care, but in the case of EP, as with other new and challenging technologies, it is indeed a primary consideration.

One way of expressing the relations between the human world and the technical has been in terms of the traditions of hospitality, the rules that govern the entertaining of guests and the conventions that retain some distance between the host and the visitor<sup>78</sup>. There is then a subtle shift if or when a guest becomes a regular member of the family – when a technical visitor becomes “domesticated” and finds a taken for granted place within the household.

In these terms the two technical systems studied here achieved rather different outcomes. In the case of CHX it was hosted for a while but never became taken for granted to the degree that it could not be dispensed with.

Interestingly some similar metaphors were used by nurses when talking about the system and its alien status. As one said, “this is not our baby”. In the case of QHB, in contrast, there is ample evidence that the EP, or more generally of the MediTech HIS has become domesticated and found a natural place in the hospital.

### Human perspectives

Once again, we consider the four main stakeholder groups: doctors, nurses, pharmacists and patients. For each group we asked what their overall feelings were about their work with the new system, their sense of achievement or satisfaction in doing their job or receiving care. It is here that a more traditional

notion of “outcome” can be found – with outcome reported in terms of patient satisfaction, protocol adherence, and overall satisfaction with prescribing and administration. In these terms the two cases studied here offer some compatible findings, and some distinctive ones.

These systems were generally perceived as usable and most professional groups expressed a general sense that they were safer or at least potentially safer, reducing some errors, catching others and refining aspects of process. When asked, and towards the end of the study, most people said that they would want the system to stay and would prefer to work with it – even initially sceptical nurses at CHX whose attitudes changed over time and as the difficult period of initial implementation passed. From the perspectives of patients, interviewed at both sites, the general sense was that the computerised system they saw was desirable and should be more efficient and safer. They generally preferred it to other systems, and thus wished it to stay.

In the case of CHX, as a pilot system operating on one ward and therefore inviting a critical more reflective response, the health care professionals, in particular doctors and pharmacists seemed to express their understanding of outcome through a multi-layered perspective. There was for them the “ideal” EP system which they understood in their own way and even enthused about, and then there was the actual ServeRx they used day-by-day. The tensions between these two EPs that are reflected in their comments provide a useful choice of perspective from which to assess outcome. Is it the day-to-day and messy incomplete and troublesome EP we consider, or is it the (possibly reinforced) vision that we should pay attention to?

### Organisational Context

The organisational outcome reflects the institution wide response to the use of EP.

The two sites studied are in this respect very different. QHB has 10 year’s experience with a comprehensive HIS, and for them EP was just one part of a broader commitment to a particular use of technology. As such EP had indeed become just “one of the things we do”, having the status of an embedded characteristic of the hospital. Seen in the wider context though, as was appreciated by some staff, the future is not perhaps so clear. As NHS policy

develops and the National Programme moves towards EP the status of the existing systems in use at QHB may come into question. Nevertheless, from the hospital's own perspective, their long experience of EP would seem to set clear standards against which any future strategy will be judged. In this way, one clear outcome for the hospital is their detailed level of understanding that probably exceeds almost any other similar UK site.

At CHX, in contrast EP was operating as a pilot experiment on just one ward and its status within the organisation was as something new and different, reflecting a commitment to innovation. The system was publicised in these terms within hospital publications, and featured in a BBC programme. In this way and, despite the pilot ending as wards were reorganised, it did represent within the hospital a means for expressing its commitment to a proactive policy for medicines management. In outcome terms then, one of the significant aspects of the pilot was the opportunity it provided for learning about ward based systems in general and EP in particular, and bringing new knowledge and skills to the hospital.

## **7.6 Lessons for EP policy and practice.**

We have presented a structured, theory driven evaluation of two novel electronic prescribing and drug administration systems that have been implemented in hospital settings. Both these systems can be seen as successful in that they were adopted and used over an extended period and the users of the systems are generally positive about them and they have been shown to reduce prescribing and drug administration errors. Drawing on the findings and analysis reported above, and reflecting on the overall insights that have emerged from this aspect of the work, this section summarises the key lessons for EP policy and practice that emerge.

### ***Address EP as socio-technical innovation***

EP is a socio-technical innovation that is achieved over time and through engaging various different stakeholders in a collective effort to reform the ways in which drugs are used and to exploit the potential of technology in this. Reducing error is of course an essential part of the motivation for EP, but this motive should be balanced with other more general requirements for improved or reformed practices and to allow better use of resources. Adopting EP will

have many consequences for all manner of people and health care professionals and not all effort can be simply directed to, or assessed as a contribution to, isolated error producing practices.

***EP is not a technical solution there for the taking***

EP is not the substitution of one way of working by some fully formed and superior version, and it certainly does not arrive as a suite of software applications or databases that can immediately displace established ways of working. Rather, even as technology, we must expect it to be shaped and formed in the local context, adapted to meet particular needs and priorities. It is notable that most of the successful computerised prescribing systems in hospitals (renal unit at Birmingham, Brigham and Women in Boston) are systems developed in house, a situation in which the relationship between the technology and the users has the greatest potential for interaction. The experience at QHB and CHX is broadly compatible with this observation.

***Expect and respond to emergent change***

Our findings suggest that the change that is experienced through EP goes beyond the planned and is manifest in a number of shifts in the way work is organised, where it is performed and how it is prioritised – emergent changes. We have found in both sites studied that the use of EP will change the work process of individual health care professionals as well as the ways that they work together, changes that go beyond the particular functionality for individual tasks built into a system. It is fundamental to EP, as a tool that people appropriate in their own ways for use in their individual tasks, that the outcomes observed will be shaped along the way; for example, as pharmacists use computer screens to review prescribing data and to locate and prioritise particular prescribing events for scrutiny, or doctors prescribe from formularies and in standard ways. EP also allows subsequent related reforms of practice at the organisational level to be considered and pursued, for example how discharge prescriptions are prepared and dispensed, and these future possibilities should be recognised within EP projects.

***Support human interaction***

EP both connects and disconnects health care practitioners and patients within the care process. Shared prescribing data (at the individual patient level or in summary) can connect a pharmacist and a doctor and be supported by other

computerised media such as email. But if the technical mode degrades the interpersonal relations, for example keeping pharmacists in their office and off the ward, or on the ward but at the nurses station workstations, then some important element of the care process may be lost. Similar arguments can be made in respect of other relations between nurses, doctors and patients. Such effects must be anticipated and managed, with all stakeholders aware of the issues and contributing to their resolution and the trade offs required.

### ***Resource an extended implementation***

This essentially local or situated construction of EP practices and procedures means that any technology which is successfully implemented and used in one setting might have different “impacts” or even be rejected in another. This is precisely because technology does not work in isolation but is intertwined with the social (for example, organisational and wider political context) and is appropriated in different ways, over different time scales and to different degrees by different people. To succeed in this process, as we have seen in our studies, requires adequate resources being devoted to sustaining and adapting systems during an extended period of implementation and learning.

### ***Adopt a broad approach to evaluation***

One part of resourcing the extended implementation is to incorporate a range of formative evaluation activities to help maintain and refine the EP agenda. The use of our evaluation framework can help to ensure that such work is more complete and useful than isolated measures of selected outcomes. The evaluation framework can provide an opportunity to contextualise the findings from more quantitative studies, and help focus on stakeholder attitudes and behaviours and how they play a part in the ability of EP to become integrated into day-to-day activities.

### ***Work to develop better technical systems***

Studies such as this should also provide vital information for the developers and suppliers of EP systems. It is notable that both the technical systems studied here originated outside the UK, and we have seen how such imported systems developed around other traditions of practice need extensive efforts to align them and their suppliers with the needs of UK hospitals. Some of the recurring issues that we have identified, such as basic understanding of UK practice, the need for flexible data reporting functionality or careful attention to



all the formal and informal roles of the drug chart, must be better addressed in research and evaluation studies, and the results communicated to the supplier sector.

## 8. Discussion

The purpose of this research was to develop, and pilot, a range of methodologies relevant to the evaluation of electronic prescribing in hospitals. Hence, we have structured the report around methodological issues, rather than presenting an evaluation of a system in the round. In this Chapter we report the key findings of the previous chapters, and integrate them. We briefly set these against the literature before going on to raise the resultant policy issues and research agenda.

Our original aim was to show “the feasibility and practicability of the proposed framework of evaluation, and of methods used to conduct prospective and retrospective studies.” We believe we have met this aim. Our evaluation framework brings together qualitative and quantitative assessments of an EP system, and we have shown it is applicable at any stage of implementation, from a prospective study of a single ward pilot to a retrospective study of a well established, hospital wide system. Another way of viewing this is that the framework allows assessment of outcomes, and sets them against a rich understanding of context. As we described in Chapters 1 and 7, the outcome of an EP system depends heavily on the setting, the process of introduction and embedding in practice (one estimate from the USA is that success with CPOE is only 20-30% about the technology<sup>79</sup>). By describing this context it helps others understand the generalisability of the findings, and helps them plan for successful implementation.

It is noticeable that most other evaluations of EP in hospitals, in the UK and USA, do not provide the necessary context, and just provide a limited number of quantitative findings. “Lessons learned” about the best way to implement EP tend to be published much later. Many of these articles do not come from academic researchers, but from focus groups and committees formed from those who have had practical experience of implementation; they are not directly related to the quantitative evaluations. The advantage of a prospective evaluation of EP using our framework is that these lessons emerge early on, give a rounded view, and are directly linked to the quantitative findings.

We have also provided a tool kit of definitions and methods which can be used for prospective and retrospective quantitative measurements of patient safety and harm. We have explained ways of defining and measuring both prescribing error and

medication administration error (Chapter 3). For retrospective evaluations, we have defined the required dataset and had it converted into an Access database for direct entry in the field (Chapters 3 and 5). We have also adapted the trigger tool method to reflect UK practices (Chapters 3 and 6). One of the difficulties in drawing general conclusions from medication error studies is that the definitions and methods used can alter findings by one, two or three orders of magnitude. In another report<sup>80</sup> we note that there is a need to standardise definitions and methods so that studies in several settings can be meaningfully compared.

### ***Methodology***

There were several surprising findings in our comparison of methodologies:

- Prospective and retrospective methods of detecting prescribing errors usually detect different errors.
- Electronic prescribing systems, in our study, mainly reduce the prescribing errors that pharmacists detect when visiting a ward. When these errors are corrected, they usually leave no trace in the patients' notes. Hence EP systems, as they currently function, need to be evaluated prospectively rather than retrospectively. The prospective evaluation of ServeRx showed a significant reduction of prescribing errors from 3.8% to 2.0% (Chapter 4). Retrospective evaluation (while not powered to detect a difference) showed the introduction of ServeRx reduced errors from 7.4% to 6.5%, and following the introduction of Meditech prescribing errors moved from 8.6% to 8.8% (Chapter 5).
- Trigger tool detected two out of four cases of harm at Charing Cross Hospital; however, in studying 205 patients it was also triggered on 166 occasions in which it did not identify a prescribing error or harm. However, two triggers caused most of the false positives (Chapter 6). If they were removed the resulting triggers could at least be worked into a checklist for ward pharmacists, and there is the potential to have them interrogate an electronic patient record in the future.
- Spontaneous reporting proved very insensitive to prescribing errors and is not recommended as a research tool.
- There are still issues to be resolved to improve the inter-rater reliability in assessing prescribing errors, and assessing the extent of harm. The inter-rater reliability is recognised as a problem in the international literature; in practice it at least means the same person(s) would ideally be assessing

prescribing error in both strands of an intervention study. The definition of harm depends to some extent on the purpose of the research. For example, an economic evaluation may wish to know whether any extra resources were used (extra drugs? extended length of stay?) and whether the quality of life was reduced.

- Contrary to the expectations of many, after the introduction of EP it was neither quicker to access patients' notes for research purposes, nor were all patients' notes available. EP systems can not usually cope with all medicines, and hence paper based notes are also stored and need to be accessed, even with a comprehensive HIS system such as Meditech. The long experience of the system at Queen's Hospital also illustrated two other problems. First, that software may no longer be able to access very old records (over 10 years old in this case), and second that electronic records are still not immediately available if there is more demand on the server than it can cope with. At each site, before or after EP implementation, it was still only possible to retrospectively evaluate about four patients a day (Chapter 5).

We also explored methodological issues by commissioning two expert essays, one on the economic evaluation of electronic prescribing (by Professor Buxton of the Health Economics Research Group, Brunel University) and the other on statistical issues in the evaluation of EP (by Dr Carpenter of the Medical Statistics Unit, London School of Hygiene and Tropical Medicine). These are presented in Appendices C and D, and the key points presented below.

### ***Economic Evaluation***

Professor Buxton notes that our studies provide some important indications of the possibilities and challenges for undertaking a formal economic evaluation of an electronic prescribing system. As regards cost estimation, it emphasises the need to realistically estimate the initial costs which need to include not just the capital costs of the system and its installation, but also the costs of the time of key staff involved in the development of the system/implementation of the project. Measurements undertaken in this study show that it is feasible to estimate the time implications for staff involved in tasks associated with prescribing/administration of medication, but this report emphasises that it may be more appropriate to establish the actual opportunity cost of marginal changes in staff time.

Much more difficult is the appropriate valuation of the errors avoided. Two approaches have been identified, and both merit further exploration. It needs to be established whether key stakeholders have a concept of an “intrinsic” value for error reduction, or whether a “consequential” valuation is more appropriate. If the latter, then a substantial programme of work is needed to establish a robust method of valuation and provide mean estimates of the value of avoiding different types of error.

We need robust estimates of the reduction in error rates for different types of errors, particularly for significant errors which, because of their relative rarity, are not well characterised in relatively small studies. It needs to be explored whether it is possible to use aggregated experience or alternative data bases to establish robust and generalisable ratios of different types of error that occur in different settings.

The problem of lack of generalisability of individual studies needs to be recognised. For the purposes of estimation of the cost-effectiveness of future implementations a decision-analytic framework will need to be used that can incorporate parameter values from studies of particular past implementations such as this, as well as estimates of the value of avoiding different types of error. For this to be achieved requires that all such studies collect a set of consistently-defined key parameters that can be used in modelling.

### ***Study design and analysis***

Dr Carpenter discusses study design and analysis. Regarding study design, if possible randomisation should be used to ensure “cause” (electronic prescribing) can be definitively linked to any “effect” (hopefully reduced prescription error). In practice, we realise that for many smaller studies, randomisation may not be practical. For such cases, informed by the ideal randomised study, Dr Carpenter highlights factors that should be taken account of in the design and describes methods for choosing an appropriate sample size; he has derived an appropriate formula and illustrates its implementation. For example, a sample size of 107 patients in each group could show a reduction in prescribing error rate from 8% to 4% (alpha 5%, beta 10%).

The analysis of data from such studies needs to take into account the hierarchical structure of the data, using multilevel modelling or generalised estimating equations. This is because patients have typically 10 prescriptions during their stay, yet the length of stay, severity of illness and hence number of prescriptions can vary widely. Failure to take into account this patient level information (for example, by analysing

the data using contingency tables) could be misleading, as the conclusions are vulnerable to bias from atypical patients. Evaluations of EP in the literature have not taken this into account and hence will provide p values that are smaller than they should be.

Secondly, he discusses the relative merits of a logistic versus a Poisson model for data, preferring a logistic approach. Finally, he describes how “propensity score” methods can be used, in the absence of randomisation, to provide a check on the similarity between the control and intervention groups and can be used in the model for estimating the effect of intervention.

### ***ServeRx and error reduction***

ServeRx is not just an EP system, it also provides new technologies in the form of a computer controlled store cupboard, an intelligent drug trolley with electronically controlled drawers for each patient, all linked to a bar coded patient identification system, required to release a specific patient’s drugs. In addition to reducing prescribing errors from 3.8% to 2.0% ServeRx also reduced medication administration errors significantly, from 7.0% to 4.3% (excluding IV errors), while markedly increasing identity checking from 17% to 81%. Other markers of “good process” were also measured, including the nurses observing more doses being taken and more doses being given nearer the target time. These are significant changes; however, they were achieved at an increase in staff time. The pharmacy department increased its service to the ward to keep belief in the new service, and it took doctors longer to prescribe and nurses longer to conduct medication related activities outside of drug rounds.

In UK hospitals about half the MAEs are because drugs are not on the ward when required, something that can be ameliorated by extra resource, so the question of whether this reduction could have been produced by other means still arises. On the one hand, there was a feeling that now the system had bedded in, and with some relatively simple software changes, the extra resources required by ServeRx could have been reduced. On the other hand, the ward (before the intervention) used the traditional drug trolley system. It has been argued that a better system is a Patients’ Own Drugs (PODs) system; the Audit commission recommend this <sup>11</sup>, although the evidence base that it is better is, in our view, weak. However, the ward already used significant elements of the PODs approach, including pharmacists providing admission and discharge services, and using the patient’s own drugs (if available) in

the patient's drawer of the drug trolley. Hence, we would expect the reduction in MAE caused by ServeRx to be similar in a PODs ward.

It is notable that bar coding, while markedly increasing identity checking, did not lead to 100% patient identification before administration. This is partly because of the way in which "as required" drugs were administered (outside the normal drug round), partly in cases such as barrier nursed patients, in which the drug trolley would not be taken into the room, and the patient's bar code would be stuck to the wall outside the room, and partly due to the adoption of "work rounds" whereby new bar codes were printed, scanned and then discarded if the bar-code on a patient's wrist band did not scan easily.

### ***Limitations of EP systems***

EP and associated technology rarely seems to be able to cope with all aspects of hospital prescribing, and it is important that exceptions are sought and captured, as they may create new errors, or may not deal with difficult situations which are inherently more error prone: for example, prescribing of high risk variable dose drugs such as warfarin or insulin, or certain IV drugs, or uses in specialist areas such as neonatal ICU or A&E. Automated drug cupboards/trolleys may not be able to deal with bulky drugs, and bar coded identification systems will not be used to identify patients for all drug administrations. People often have expectations that EP systems will work in all cases; their limitations in normal use need to be publicised more. The evaluation framework needs to seek and capture these exceptions. It would be expected that these exceptions will diminish if there is a good working relationship with the supplier.

New causes of errors were introduced with ServeRx, such as picking the wrong drug from a list of products when prescribing. For example, "Paracetamol Soluble 500mg" appeared alphabetically before "Paracetamol Tablets 500mg" on the screen. There was an unintended increase in the prescribing of soluble paracetamol tablets until the product was renamed "Paracetamol Tablets (soluble) 500mg", moving it below "Paracetamol Tablets" on the picking list; unintentional prescribing then stopped. This is a simple example of how people can adapt the system to reduce errors. While prescribing soluble paracetamol would just have produced inconvenience, there was a more serious problem caused by a similar issue of doctors picking the first product on a list rather than the right product. In this case imipenem, a powerful antibiotic, appeared as "injection i.m." (intramuscular) before "injection i.v."

(intravenous). IM and IV formulations are different and should not be confused. There were several cases in which doctors prescribed the IM formulation when meaning to prescribe IV. Luckily, the ward only used the drug intravenously, so nurses ignored the IM instruction. However, in other settings and with other drugs it could be a dangerous error.

When drugs or routes of administration can not easily be dealt with by an EP system a great deal of scrutiny needs to be applied to the exceptions. The relationship between prescribing error and harm is not a simple proportion. Some errors are much more likely to cause harm than others, and some of the drugs and routes of administration most likely to cause harm to others are those that some EP systems find difficult to handle, such as drugs that have their dose changed regularly (warfarin, insulin) or IV drugs. We need to ensure that EP is not predominantly reducing the probability of events happening that are only weakly associated with harm.

### ***Harm from errors***

Our study has provided a basis from which the extent of harm produced by medication errors can be estimated. We have provided the data set and definitions required, written an Access database for data entry in the field, and estimated the time taken and the extent of recovery of patients' notes. As the introduction of EP did not have any obvious effect in the cases of harm we can pool the data, and we find 8 cases of harm from 356 patients – a 2.2% error rate. The sample is not across all specialities, and is biased towards surgical patients at Charing Cross Hospital, however this gives the best estimate yet of harm from prescribing in hospitals, covering a teaching hospital and a general hospital. Although Vincent *et al*<sup>34</sup> reviewed 1000 patient admissions in the UK for medical error, they did not specifically search for prescribing errors, and did not review the drug chart.

We took a fairly wide definition of harm, so, for example, a laboratory value (for example, serum potassium, INR, digoxin concentration) outside the recommended range as a result of therapy was considered harm, even if subsequently detected, corrected and there was no adverse consequence to the patient. A more rigorous definition, which may be of interest for economic evaluation, may have reduced the cases of harm to 3 or 4 – around 1% of patients. Taking our figures in the round, it could be said that for every 100 admissions, 1000 -1500 items will be prescribed, there will be 100 -150 prescribing errors and one patient will be harmed. While 1% of



patients harmed is a small proportion, the sheer volume of patient admissions means there could be expected to be a large number of harmed patients across the country. As pointed out by Professor Buxton, there is a real need to estimate accurately the extent of harm which results from prescribing errors in hospital. Our report for the NPSA on the Heinrich ratio <sup>80</sup>, (which assumes a fixed relationship between non-harm accidents, minor harm and major harm) has debunked its validity for medication errors. We point out that there is an urgent need to explore the relationship between medication error and harm. Both these reports point to the need for a large scale review of notes to establish the extent of medication error and harm in the UK.

### ***When to evaluate***

A significant factor in the evaluation of an EP system is when that evaluation occurs. We felt that when we studied ServeRx, around six months after introduction, it, and the humans working with it, had reached a reasonably stable level of activity. However, earlier assessment may have been a poor predictor of performance. It takes time for an EP system and the people using it to find and reach what they perceive to be an acceptably safe and efficient way of working. Early assessments of the Brigham and Women's system found little improvement in their target variables, and that the system introduced a potentially fatal IV potassium chloride error; it took several years to remove the error and improve the target variables <sup>8</sup>. More recently Shulman *et al* <sup>41</sup> also reported an initial increase in errors after the introduction of EP; errors eventually fell to below pre-implementation levels.

There should be a need to regularly review the effectiveness of an EP system as it, or the human systems around it, or the technology it intersects with, continue to develop. Even with a well established system such as the Meditech at QHB, the move in drug distribution/administration systems in the UK towards Patient's Own Drugs systems means changes to the way the EP and pharmacy systems are used. Meditech will benefit from a re-evaluation when PODs has been implemented.

We would also expect some of the measures of ServeRx to improve over time, such as the amount of nurses' time on medication related activities, which would be expected to be reduced following a new software release. Human systems could also be changed in the way they work with the EP. Following the current evaluation, showing the errors the pharmacist misses, there could be a revision of the ward pharmacists' ways of working with EP, which could in turn be expected to reduce prescribing errors, and would then need to be re-evaluated.

One advantage of the evaluation framework is that it gives sufficient understanding and context to not only describe and explain the effectiveness of the system, but also to predict ways in which it could be developed, could be improved, or is/could be used in such a way that it increases the risks to patients.

### ***Decision Support***

Decision support is not as simple as many think. There are reviews that show it can (but does not necessarily) improve decision making and reduce length of stay<sup>81,82</sup> However, many of these evaluations are of stand alone systems for a limited range of decisions, and often have been tested in the “lab” rather than in routine use in clinical practice. Our study of decision support (Appendix E) showed that QHB had a clear and overt policy on decision support – the prescriber remained responsible for the decision, and hence most of the decision support was ensuring that drugs were on the formulary, in doses and formulations that could be supplied. At CXH there were similar restrictions, but prescribers and nurses made assumptions about decision support which were not true, such as that allergy checking and drug-drug interactions were in place. However, the pharmacy had not activated these as they felt they were not sufficiently developed. This mismatch of assumptions and reality could be dangerous and an overt policy of stating the extent of decision support must be part of the training.

There are also some issues about what is usually considered as decision support in medicine. In reality, most “decision support” is decision constraint or decision removal, for example having chosen a drug, choice of dose is constrained, or choice of route may be removed. This is sensible, and a reasonable way of reducing error, analogous to fly-by-wire technology in aircraft, or anti-lock brakes in cars – they ensure actions are not excessive, and give ordinary users the same performance as more advanced practitioners. However, there are three issues that need to be addressed

1. Does automatic removal of elements of decision making reduce the skills of practitioners, so they become more dangerous when not using a system with decision support? When EP is ubiquitous this is not a problem, but over the next 10 years requires serious consideration by professions.
2. Another view of decision support would be that it presents relevant information in such a way that better decisions can be made. For example, the Meditech system includes biochemistry results. Several cases of harm in

our study were a result of renally cleared drugs being given in normal doses to patients with reduced renal function. Using decision support to inform the prescriber that a drug they are prescribing is renally cleared, and giving the creatinine clearance, and the formula for dose adjustment, would alert prescribers to a potential problem, and support them in their decision of which dose to give. This sort of decision support could be developed in the Meditech system and would seem a development QHB may wish to consider.

3. Finally, the focus of decision support at present seems to be the individual. However, in safe practices the role of the team and its various members is important – utilising their combined knowledge and perceptions makes for better and safer decisions, as shown with techniques such as crew resource management. We also know that the role of the patient in decision making is extremely important, yet often not enacted in practice. A decision support mechanism which supported these ways of practice may be a suitable development. One theoretical approach which may support these ends is “distributed cognition”<sup>83,84,85</sup>. In our view this approach is worthy of exploration.

There has been a literature on technology providing decision support in medicine for over 30 years, however it is significant that it is little used in practice. There is a risk that over use of drug-drug interaction warnings, for example, lead to staff ignoring them. Even at Brigham and Women’s Hospital drug-drug interaction warnings are only for those combinations that “you would virtually never prescribe together” (David Bates, personal communication). Another issue is that, even in a well established area, such as drug-drug interaction checking in GP prescribing systems, there have been problems with the software handling the functions correctly<sup>12</sup>. Decision support is assumed by most people to be an important way of reducing errors; the gap between expectation and reality is important and potentially dangerous. There is a need to alert practitioners to this, and seek new solutions. One approach would be to identify the problems that are most likely to cause harm and focus on decision support in those areas.

### ***Qualitative findings***

The qualitative research describes the settings and shows the development of the relationship between the social and the technical. Despite the EP systems, their settings and their stages of development being very different, there were common

lessons to be drawn about the implementation and effects of an EP system. Chapter 7 draws out the general lessons, and a more detailed description of each system is given in the Appendices A and B. A novel aspect of our assessment of the systems has been asking the opinion of patients. They generally liked the use of the systems, while being aware of the potential for new error that computers bring.

The general lessons are that EP needs to be addressed as a socio-technical innovation. It is not a technical solution “there for the taking”, which can just be “plugged in” to a ward or hospital; it needs to be shaped and formed locally. A consequence of this is that there will be emergent, and potentially very important, changes in the way work is organised; these can to some extent be anticipated and a national debate will be beneficial in some cases. An example is the way EP both connects and disconnects health care practitioners within the care process. Communication between professionals can be improved by access to a common and unique data set for each patient, however there is a significant risk that this may degrade interpersonal relations, for example keeping the pharmacist in their office, off the ward. Instead of patients being seen, they may become objectified – existing as a list of drugs and measurements – this is counter to the way good care is conceptualised: recognising the patient as an autonomous individual. However, being able to concentrate on a patient’s drugs in an office or at night in a residency may also improve the quality of “technical”, pharmacological care. A balance needs to be struck between two.

There are also lessons for implementation. First, a good relationship with the supplier is important, and, as many suppliers are not from the UK, they need a thorough understanding of the UK system, and how we wish care to be enhanced. Second, the supplier and the hospital need to commit resources to a prolonged period of implementation, in which both sides are working to sort out and work through hardware and software problems, and develop new skills and working practices. Constant support and on-the-job training are required. Finally, the EP system needs to be evaluated, using the framework we describe; this can be applied with varying degrees of intensity. Pre-implementation studies can be very useful. One valuable benefit of each EP system was to make errors more visible to professionals, however this led one consultant at CXH to think the system was dangerous. He thought many more drug administrations were being missed and demanded that the system be withdrawn as it imperilled patient safety. It was only

because we had pre-implementation data that we could show that there were indeed fewer (but more visible) omissions and the system was safer in this respect.

### **Literature**

In any report of this nature it is usual to set the findings into the context of the literature on the area. Any RCT of a new medicine would be integrated into such a knowledge base. However, Information and Communication Technology (ICT) is fundamentally, ontologically, different to a medicine. A molecule does not change, however ICT does change, and can be used in very different ways. Hence, the benefits, and risks, of any system may not be transferable to different organisations or systems of work within them. Here are some reasons why the literature is of limited benefit in this field:

- A major source of repeated error in the USA is transcription of the prescription by an inadequately skilled person; once this error is made the drug is repeatedly given to the patient, and hence is more likely to cause harm. EP, as usually implemented, markedly reduces these errors in the USA, and this is why EP is so successful in US trials. In UK hospitals there is far less transcription, and it is done by doctors or pharmacists, so transcription errors are a small part of UK practice, and hence, other things being equal, one would expect EP to be less effective in the UK.
- Virtually all studies are conducted in one hospital, and often on one ward, reducing the generalisability even more.
- The commonest source of the studies comes from Brigham and Women's Hospital in the USA, from a system they have developed to their own needs over more than a decade. Even the best home developed UK system, from Birmingham, has been specifically developed for the needs of renal wards; its effects on other wards are unknown.
- Literature from the USA is affected by their structure of health care. For example, private hospitals target their marketing at doctors, as they bring in the patients, who bring the money. Hence, they will not want to implement a system that deters community physicians. As one hospital information officer lamented, she needed to bring in a system acceptable to 1,000 voluntary (community) doctors<sup>79</sup>. The successes and failures of US systems need to be interpreted against this sort of context.
- The literature, particularly on practical issues of implementation and usage, goes far beyond the traditional academic literature. It includes on-line

journals and magazines, reports of meetings and fora from a range of organisations and professional groups, and chat room entries and blogs from (often discontented) users.

These problems of interpretation are partly due to the nature of ICT and partly due to EP being at a relatively early stage of development internationally. However, it should be noted that the points we have made are not generally recognised and come from our past experience of ICT and US health care. Had the past evaluations adopted the evaluation framework we have described, there would be far more context against which to understand them, and it would be easier to draw out the lessons, benefits and risks that would be more likely to transfer to EP in UK hospitals.

As in the USA, the UK literature on electronic prescribing is very varied - from accounts of experiences in professional journals to more formal evaluations in academic journals. The accounts exhibit various degrees of partiality, often give little detail, may use unusual methods, and usually only assess one or two aspects of the performance of the system. Of the three hospitals which used EP from the 1990s onwards, Arrowe Park Hospital has published several accounts and evaluations, as has Queen's Hospital.

The eight most academic evaluations<sup>40,41,42,86,87,88,89,90</sup> are summarised in tabular form in Appendix K. Of the studies which we can interpret in a similar way to our own (Table 43) we see some similarities:

Study	% prescribing errors pre-	% prescribing errors post-	% error reduction
ServeRx	3.8	2.0	1.8%
Pharmakon	7.4	4.7	2.7%
QS 5.6 (ICU)	6.7	4.8	1.9%

**Table 43: Prescribing error reduction following electronic prescribing in UK studies**

One study<sup>40</sup> besides our own has measured medication administration error (MAE) reduction as a result of linking EP to an administration system. The studies show a similar reduction in errors. ServeRx reduced non-IV MAE by 2.7% (from 7.0% to 4.3%). Fowlie *et al*<sup>40</sup> found a reduction of 3.6% (from 9% to 5.4%).

Overall, these findings are remarkably similar and may give some indication of the reduction in prescribing errors that EP can provide in the early stages of implementation.

We finish by outlining what we see as the policy implications and research agenda that follow from our research.

### ***Policy Implications***

- All EP programmes should first be tested “in vitro” on a set of patient data which will explore an EP system’s competence in realistic prescribing situations. This will improve quality assurance and add confidence to the “signing off” of the software before it is used on patients.
- All new systems should be evaluated in several settings. Our evaluation framework and methods are a good basis for others to use.
- Professions need to engage early with some of the likely consequences of EP. For example, how can patient contact be maintained? How can pharmacy improve its error monitoring?
- Long term relationships are required with suppliers.
- Software must be able to be adapted locally.
- Data needs to be structured so that it can easily be accessed and interrogated.
- Decision support should be kept simple and overt from the start.
- Before adopting EP, individual professionals need to have an understanding of the benefits to themselves, as well as patients as a whole and the NHS.

### ***Research Agenda***

- A patient database needs to be constructed to test EP systems “in vitro”.
- We need to capture information from current EP experiments in the UK, including failed and withdrawn systems, to identify good and bad practice and system features.
- Further work is needed on reliability of assessing errors and their consequences.
- Future summative evaluations should recognise the hierarchical structure of data, should use logistic modelling and, given the difficulty of conducting randomised trials, propensity score methods should be used.

- The relationship between error and harm needs to be fully understood. This is a substantial and important piece of work.
- A large study of patients' notes is required to establish the frequency of harm and to cost that harm. From this the basics of an economic model for future interventions can be built.

### **Conclusion**

Our aim was to pilot methodologies for the evaluation of EP. We have provided a robust evaluation framework that can be used in any setting, and establishes the quantitative changes in the incidence of error as well as contextualising to give insight into generalisable lessons for the future. We have also highlighted the issues to do with experimental design of future quantitative and health economic studies.

Taking all our quantitative results into account, and recognising that the study was designed to pilot methods, we make the following tentative statement. We think that in hospitals doctors make errors in 10-11% of the prescriptions that they write, and that the first implementation of an electronic prescribing system will reduce prescribing errors by 2-3%.



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## List of Appendices

	<b>Page</b>
Appendix A. Qualitative evaluation of electronic prescribing with the ServeRx system at Charing Cross Hospital	147
A.1 Introduction	147
A.2 Methods	148
A.3 Evaluation results	149
A.4 Patients' views	166
A.5 Summary of evaluation: key findings	173
Annex Ai Agenda for focus meeting	177
Annex Aii Questions: aide memoire	179
Annex Aiii The ServeRx patients' opinion survey	182
Appendix B. Qualitative evaluation of electronic prescribing with the Meditech system at Queen's Hospital	188
B.1 Introduction	188
B.2 Methods	191
B.3 Evaluation results	193
B.4 Patients' views	212
B.5 Summary of evaluation: key findings	219
Annex Bi Analysis of initial scoping interviews	224
Annex Bii Staff interview guide for Queens Hospital Burton	225
Annex Biii The Queens Hospital patients' opinion survey	227
Annex Biv Medication errors with EP: two views of the same picture	234
Annex Bv Reflections on qualitative methodology	239
Appendix C. Issues for the economic evaluation of measures to reduce/avoid errors in the prescribing/administration of medicines on hospital wards	242
C.1 Introduction	242
C.2 Identifying, measuring and valuing the net costs of the intervention	243
C.3 Identifying, measuring and valuing the main benefits of the intervention	245
C.4 Implications for sample size and study design	248
C.5 Generalisability of results and the need for modelling alternative future scenarios	249
C.6 Conclusions and recommendations for future reasearch	249

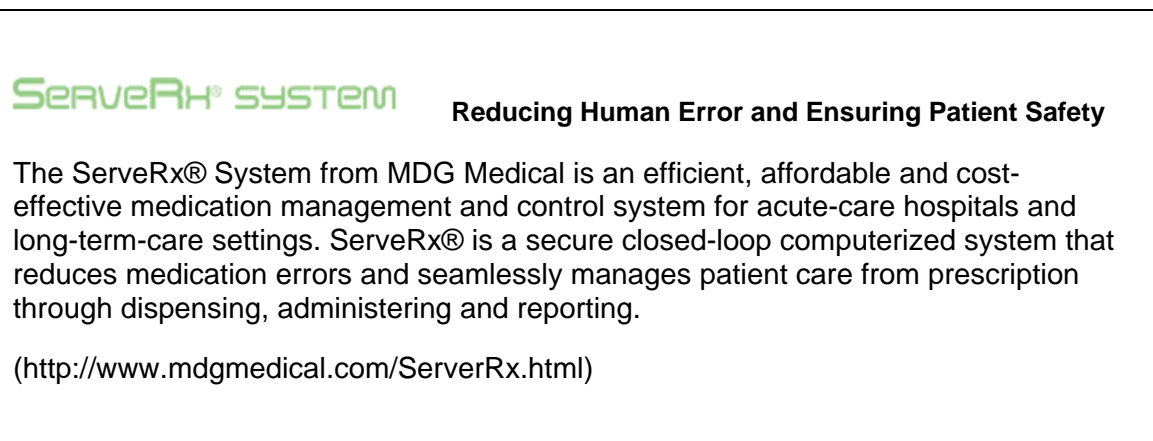
Appendix D. Statistical issues in the evaluation of electronic prescribing	251
D.1 Introduction	251
D.2 Design issues	252
D.3 Analysis issues	258
D.4 Discussion	262
Appendix E. Clinical decision support features of the two systems studied	263
E.1 Introduction	263
E.2 Defining decision support	263
E.3 Methods	264
E.4 Results	265
E.5 Discussion	269
E.6 Conclusion	270
Appendix F. Retrospective Review Form (Chapter 3)	272
Appendix G. Trigger tool review (Chapter 3)	284
Appendix H. Types of medication orders written during the pre- and post-ServeRx prescribing error data collection periods (Chapter 4)	287
Appendix I. Detailed work sampling results (Chapter 4)	288
Appendix J. Analysis of types of prescribing error (Chapter 6)	290
Appendix K. UK studies evaluating electronic prescribing systems in hospital inpatients (Chapter 8)	292

## Appendix A. Qualitative evaluation of ServeRx

### A.1 Introduction

This Chapter describes the qualitative evaluation of the ServeRx system. Together with Appendix B it supports and elaborates on findings discussed in Chapter 7. The findings are analysed and reported using Cornford's *et al.* framework.<sup>21</sup>

The ServeRx electronic prescribing system, as briefly introduced in Chapter 2, was installed on a 28-bed general surgery ward at the Charing Cross Hospital (CHX) in 2003 and includes electronic prescribing, scheduling, automated dispensing and electronic administration, as well as elements of stock control. The technical system (the hardware and software) comes from a small and specialised supplier (ServeRx: MDG Medical, Israel) (Figure 20). It is one of just three trial implementations in the world. The system is a “closed loop” system, joining electronic prescribing with a forced choice of the correct product in dispensing and bar-coded identity checking of the patient at the time of administration. A principal aim is to reduce prescribing and administration errors, but this needs to be understood within a broader desire to improve (or not degrade) the overall level of patient care, and to free resources for other productive care activities.



**Figure 20: The ServeRx system (supplier's description)**

The project to pilot the ServeRx system was initiated in January 2003 following initial contacts between the Hospital and the technology vendors. It took six months to complete preliminary work, including preparing an operational outline, refitting a

treatment room on the ward to hold the equipment, installing the equipment, and system testing. The system went live on the ward in June 2003 following brief training undertaken using hardware and software different to that actually implemented.

The system was quickly integrated into the ward's working practices, though not without many issues emerging through the early period. It has operated in a live mode for just over two years at the time of writing, having taken about nine months from initial live running to a situation in which a stable system was in everyday use on the ward and covering basic functionality (Figure 21).

<b>2002</b>	
December	CHX Contract with MDG for 6-9 month beta test on surgical ward
<b>2003</b>	
May	Original proposed implementation date; Electronic discharge prescriptions and usable remote terminal in pharmacy promised for September
June	Limited system goes live on 8 North
August	Software stability problems (8N and in Israel)
August/Sept	Software patches to fix bugs; system become more stable while MDG reworking code
November	Date of release of stable software given as 15 January; no date given for discharge and pharmacy terminal (version1.13)
<b>2004</b>	
January	Release of 1.13 proposed by MDG for May 2004
February	Intermediate version of software installed
June	Release 1.13 implemented

**Figure 21: Implementation timetable, ServeRx**

## A.2 Methods

As a complement to the before and after design used at CXH and described in Chapter 4, this element of the research was based on an ethnographic approach and

included interviews with relevant stakeholders including nursing staff, consultants, junior doctors, pharmacists and pharmacy management, as well as periods of observation on the ward and at project steering group meetings. A focus group session was also held, nine months after the system went live (April 2004), at which doctors, nurses, pharmacists and hospital managers discussed their experiences and attitudes to the system. (See Annex Ai for an agenda for the focus group session.)

Formal interviews, undertaken between March 2003 and February 2005, were taped and transcribed and the focus group was supported by a dedicated note taker. (See Annex Aii for an interview guide.) If tape-recording was not feasible, or interviews were very brief, written notes were made. Information was captured by two experienced researchers (TC, EK), who compared findings and produced a rich account which acted as the source for the main section of this Chapter. A separate methodology and researcher team undertook the patient related research reported in Section A.4

This element of the research was motivated by a desire to understand how such an innovative set of technical components (computers, bar codes, mobile devices, smart cupboards) came to be established within the working practices of health care professionals as they prescribe and administer drugs and how their attitudes to the system developed throughout the period of planning, implementation and use.

### **A.3 Evaluation Results**

In this section we report the findings from the interviews and observation using the structure of the Cornford *et al.* framework. The analysis is presented first for the system function, then the human perspectives and finally from the organisational view. In each section the analysis is reported first in terms of structure, then process and finally outcomes, though we acknowledge that these sub-headings are at times hard to strictly adhere to.

### A.3.1 System functions

#### **Structure**

At CXH the ServeRx electronic prescribing and administrations system with automated dispensing is installed on only one ward. It has no substantial connection (other than basic patient data from patient administration system) to the Hospital's other information systems (for example, PACS).

After an initial period of instability and slow running, and with the release of patches and new versions of the software, the technical system became generally stable from about September 2003 (three months after implementation). The principal elements of the technical system implemented are described in Figure 22.

Central ward based server computer holding patient and pharmacy databases and supporting data backup procedures.
Automated cabinets to hold ward stock and individual non stock drugs in computer controlled drawers.
Central console for drug selection and trolley loading, used by nurses and pharmacists via a touch screen interface.
Workstation at nurses' station, available for all tasks including prescribing and review, using a conventional keyboard and mouse.
3 * portable and dockable pentablets (Pentabs), available for prescribing with stylus input.
2* computerised and dockable drug trolleys, each with touch screen and bar code readers.
1 * bar code printer to produce wrist straps for all patients on the ward

**Figure 22: Principal elements of technology within the system**

The technical elements all started life with some operational problems: The Pentabs had limited battery life, and some data loss problems were observed on docking. At one point they were taken out of use, later they were replaced with a new version. Their screens too were small and not as bright as desired making it hard for two or more people to review data simultaneously. In practice, much prescribing was undertaken using the two fixed workstation computers where the windows interface was generally found to be easy to use and provoked little comment.

The server computer was often slow and would hang - a problem associated in part with its data backup routines. Other problems noted were the small size of the trolley drawers and the lack of suitable handles, and initially trolleys broke down. The automated drug cabinet too, while functioning well, raised design issues associated with the ergonomics of its use, particularly when it was being restocked. Finally, in the initial periods, the sheer quantity of demand on the system for all types of functionality meant that there were often queues for access – particularly to the workstations.

A number of desired system functions were not available at the start of the period of use, for example the ability to generate and despatch discharge prescriptions, though this was added during the project. Equally almost all aspects of decision support including allergy alerts were not implemented, not being judged to be of appropriate robustness for operational use (see Appendix E).

Although doctors and pharmacists who were only occasionally working on the ward found the system difficult to use, overall those using the system frequently found the interface intuitive.

*“Initially I thought it was quite confusing but that was because I wasn’t using it all the time. [...] Since I have been doing the ward, I think it is quite good”.* [Ward Pharmacist]

### **Process**

Since the system has reached some form of stability (about three months after implementation) it has become almost totally integrated into work of the ward. Once stable, the data processing functioned well. The inbuilt structuring of the core work processes of prescribing, selection and administration of drugs performed satisfactorily for most drugs, but some aspects of this work were found to be incompatible with the system (for example, prescribing of warfarin and intravenous fluids), and not all drugs could be safely prescribed through the system because their protocols do not fit easily into the structures embedded in the software – regular dose at set times - and these remained on the system only as a prompt to consult a subsidiary paper chart. Some related problems arose in respect of antibiotics in that the system set duration to the hospital norm (five days), and this could lead to their being omitted thereafter if the prescription was not renewed.

Prescribing takes place at the bedside, with doctors in theory using portable and dockable pen tablets that are not wireless enabled, and which update the central ward database only when docked. These Pentabs provide doctors with a structured prescribing form and access to patient medication history, with pull down menus for selecting drugs, selecting doses (including defaults), and timing and some relevant alerts, for example for allergies. However, as noted above, these devices were often not used, with doctors often reverting to the fixed workstations.

Following prescribing by Pentab or at a workstation the prescription data is uploaded to a database held on a ward based server computer. The prescribing data can then be systematically reviewed, checked or changed by pharmacists, and they can do this from any terminal on the system with certain access to the prescribing data. During the study period review was principally undertaken on the ward but also, in the later stages, included one terminal located off the ward and in the central hospital pharmacy. Where once almost all pharmacist intervention was located on the ward, based around the paper drug chart (if and when available), there was now the potential for review remotely.

Dispensing and administration of drugs is achieved by the use of two computerised drug trolleys for ward drug rounds, rounds being undertaken in parallel for each side of the ward. Rounds start with loading the trolley, which is done while it is docked to the main console (touch sensitive screen) and automated cabinet. An individual patient's drugs are loaded into an individual drawer of this trolley at the start of a drug round. The scheduling software allows the patient to be identified and their relevant drugs are indicated based on the recorded prescriptions. Item-by-item drugs are drawn from the automated cabinet that holds the majority of the ward stock. The system is designed such that only one drawer on the trolley (the individual patient drawer), and one drawer of the automated cabinet can be open at any one time. Preparation for a drug round is then a more structured activity for a nurse, and one in which the individual patients are considered one by one, and their medicines are systematically collected together.

During the ward drug round administration to the patient is initiated by reading a patient's bar-coded wrist strap. Reading this bar code triggers the opening of the appropriate drawer of the trolley for this patient and thus allowing access to the appropriate drugs. The possibility of giving drugs to the wrong person should thereby



be greatly reduced. Administration is then recorded on the trolley's computer screen (again a touch screen), which updates the main record when it is re-docked with the main system. Undertaking a drug round is equally a more structured activity, with a specific activity of identification and a more comprehensive scheme for recording administration.

This description of the process embedded in the technical apparatus is of course summarised and at each step of the process there are alternative routes (for example, bar codes may be on room doors or furniture, as in side room isolation nursing when trolleys are not brought into the room). In some case the system has to be circumvented, as when too many drugs are needed and they cannot fit in the patient drawer.

### **Outcome**

*"It was a living hell for 6 weeks. Not just because of the change process but because of unstable technology. We were completely unprepared for the degree of change although we tried to prepare..... It is a complete change of practice".* [Senior Nurse in focus meeting]

The most significant outcome for the technical system is that, after a period of intense frustration and technical failures, it was made to work and has been able to remain in continuous use for over two years. In part this is attributable to the maintenance of working relationships between the hospital and the supplier, with errors, bugs and conflicting issues of practice worked out and to a degree resolved through time. But even after two years of use, some issues of appropriate functionality within the technical system remain to be resolved, for example, how the prescription of oxygen should be handled within the system.

As shown in Chapter 4, ServeRx has significantly reduced prescribing and drug administration errors, but has increased the time taken for these activities. These outcomes can partly be understood as an outcome of the functionality inscribed in the technical system. However, as addressed below, they also need to be seen as a consequence of how people came to use it.

In summary, the following outcomes of the technical system were identified by interviewees:

- A usable technology (hardware and software) that was over time shaped and integrated into ward practice.
- The maintenance of prescribing and administration data to an appropriate quality and available for all participants in the care process.
- Continuing mismatch between system characteristics and the use of certain drugs.

### **A.3.2 Human Perspectives**

*“It was surprising ... we thought we had thought about everyone else who needed to be trained ... but we forgot about many people who had been involved in drug prescribing practices for years... e.g. dieticians, they weren’t trained, we didn’t think about it. There are more people involved in drug management than we expected”.*

[Senior Nurse]

*“A single biggest change we had in this ward in 30 years”* [Consultant in focus meeting]

ServeRx was implemented on a single surgical ward and operated as a system for only a specific part of the care activity with no integration with other information systems. Nevertheless, many human participants were drawn into the system and used it. At the core these include doctors, nurses and pharmacists, though almost anybody who came onto the ward to contribute to care was a potential participant (for example, dieticians, physiotherapists etc.). The following section presents the views of the three main stakeholder groups, nurses, doctors and pharmacists. The views of patients are reported separately in section A.4

#### **Structure**

##### Initiation and training

As an experimental project that was piloting a range of new technologies and new ways of working the system was supported by a dedicated trainer who provided formal and informal support and spent much time on the ward and supporting the various users. This support has proved vital to the nurses’ satisfaction with the system, and the period in which the trainer was continuously present on the ward had

to be extended. In the initial stage the pre-implementation training undertaken shortly before the launch used a system that was not identical to that implemented. In effect, training for the main user groups was undertaken in the initial period of use, during which a brief parallel running approach was used. Thereafter training was offered to people as required, though for doctors in particular the training was not generally well received and some avoided it or undertook it with little commitment - they expected to learn on the job, expected to apply their general IT knowledge, and to develop their use in interaction with colleagues.

*"I haven't had a formal training but I picked it up, it is fairly user friendly. And nurses help you a lot... you can ask them questions".* [HO in focus meeting]

*"But you learn on the job, it takes time to learn. This is not the system you can learn from manuals".* [Pharmacist]

*"A lot of doctors didn't come to training. Even if they did, they didn't pay much attention".* [Sister]

### Doctors

This system seems at first sight to have had fairly minimal structural impact on doctors. As one would expect, it was the more junior doctors who had most direct contact with the system, and for them it was just one among a number of immediate concerns that they faced as they worked through rotations and moved from post to post. What the system demanded from them, in terms of computer skills or new work practices, was seen as generally within their competence, if at times rather irksome. As one of the trainers reflected, junior doctors prioritise all the time and this project was not a top priority for them.

*"There should have been more involvement from clinicians".* [Consultant in focus meeting]

Some doctors reflected on the structure of the system in terms of its lack of a reflection of their interests. Put another way, they looked for a greater involvement in the design of such systems, and felt that their participation in both design and implementation planning was the only way to achieve really useful, appropriate and usable systems. Whether this is true or not (and whether it is achievable), such

comments do reflect a general sense that in the case of ServeRx the level of involvement of doctors was not really appropriate to the task being undertaken.

### Nurses

Nurses had to use ServeRx as the only way to administer drugs and as such the structural aspects of the system impinged on their work extensively. Nurses were hesitant about the system at the outset, and often feared letting go of familiar structures within their work environment such as the bed-end drug chart and the old style drug trolley. They also expressed a lack of knowledge about computers (some had not used a mouse before) and some fear and resistance to computers becoming a more substantial part of their job.

*"I avoided it [ServeRx] because I'm here for the patients. My job is looking after patients".* [Staff Nurse]

*"Without previous knowledge of computers it was difficult".* [Staff Nurse]

*"Computers do not feature much in nurses training".* [Junior Nurse]

### Pharmacists

This system was to a large degree driven forward by pharmacists, the project being led by the Chief Pharmacist, and this emphasis was reflected in comments by both doctors and nurses who saw the whole system as reflecting most strongly pharmacy's interests. Unsurprisingly then, pharmacists when interviewed had the clearest understanding as to what the system was for (reduce errors, save time, improve service), how it operated, and the perceived additional benefits for pharmacists (more time for patient contact, taking drug histories, discharge counselling etc.).

Pharmacists interviewed in the early stages of the study and before the system was in live use could immediately appreciate the potential for more comprehensive review, of more legible entry and more coherent detail drawn from pull down menus and better adherence to the hospital formulary. The more enthusiastic persons interviewed at the start of the research came up in the end with a sustained and positive account of expectations for the system:

*“It will enable us to capture our practice, e.g. asking ‘tell me all the changes done in the last 48 hours’ this will be a huge benefit. It will make audit possible, e.g. listing all the patients on drug X.” [Pharmacist]*

Asking if the system would serve the interests of Pharmacists elicited a number of feelings. The wish for an ideal ServeRx could be quickly conjured up, principally in terms of freeing time and “eliminating routine things”. What would be done with this time? Three ideas emerged 1. spend more time with patients, 2. liaison with GPs and “the community”, and 3. thinking about the processes and “keeping up-to-date with the latest developments”.

This last point was elaborated by a pharmacist remarking that junior staff have little discretionary time and little opportunity to think about their work. Our interviews also indicated that for most pharmacists “working with patients” was the goal, for example in taking drug histories (doctors are not good at this they suggested), and advising patients about their drugs. They then linked this back to an ideal ServeRx by asking how the new system would support such goals.

## **Process**

### Doctors

Junior doctors, who do the majority of prescribing, use pentablocks to prescribe at a bed site or workstations on the ward. As one doctor noted the workstation now provides a focal point where different professionals gather, and doctors can ask pharmacists questions. However, others pointed out that with a drug chart it was easier to get a quick overview of drugs and, whenever necessary, discuss it with a consultant.

Doctors generally understood that a system such as ServeRx has the potential to change processes within the care setting and could make a significant contribution to improved medical practice and in principal to the elimination of a significant general class of error. They however maintained a strong distinction between *this* system with, as they saw it, some significant failings and problems, and an ideal system. For example, doctors often expressed the opinion that such a system would be more appropriate and desirable if it was implemented across the hospital, which would result in fewer problems of transition of their working practices between the study ward and the rest of the hospital.

*“Either everywhere or nowhere”* [HO in focus meeting]

*“But .. if everyone in the country was using it this would presumably solve most of the hurdles”.* [Consultant, focus meeting]

*“It shouldn’t have been introduced in a surgical ward. Would have been better in a quieter ward with less prescriptions”.* [Consultant, focus meeting]

Junior doctors noted often the extra work they thought it created, for example transcribing drug charts of patients coming on to the ward (a task shared with pharmacists), having to deal with some drugs outside the computerised system (and thus as they indicated “having to do two rounds”), the need for training as they rotated, and the queuing for access to terminals.

However, over time there were some more positive comments made and, for example, a comparison drawn with the Hospital's PACS system, which was seen as a success for technology.

*“It is very positive, it has eliminated paperwork. This can be compared with PACS. PACS is very successful, it is a model for such projects.... This system will spread. If, like PACS can be accessed from any computer”* [Spr]

However, others indicated that EP is rather more complicated to implement than PACS, emphasising the way in which EP systems shift the complex relationships between different health care professionals and articulate the work process:

*“PACS is not a system that is of the same immediacy than the drug management system like ServeRx. Can’t compare it. This is a fundamental process, many people are involved in it not like in PACS when it is 1:1”* [Consultant]

### Nurses

The way the nurses prepare for drug rounds and administer drugs has changed significantly. In the task of loading the drug trolley, the nurse is bound into one sequence of events which may seem to fragment the work – a per patient, by drug process of loading the trolley drawers, and one which splits off some aspects of the work, such as preparation of IV fluids, or may leave some untidy aspects to be dealt with, for example referral to paper charts, or uncertainty as to whether oxygen

should or should not be prescribed through the system. Undertaking a drug round is equally a more structured activity, with specific attention to identification and a more comprehensive scheme for recording administration. The system demands passwords and pin numbers along the way to establish a definitive record of who has done what and when. Prescribing or administration not undertaken as part of regular drug rounds, for example when a nurse gives a “stat”, occasional or elective dose, requires another work flow to log and administer, and this involves walking to and from the computer twice to obtain the drug and then to record administration.

Thus, perhaps not surprisingly, and as noted above, nurses were hesitant about the system at the outset often reflecting on their perceived role as a nurse.

*“I spent less time on a drug round but it doesn’t help me to do a better job as a nurse. Before nurses could pick up a chart and at a glance see what is there, what happens. In 20 seconds you could see what they’ve got there (on what drugs a patient is)”.*  
[Staff Nurse]

*“I’m here for the patients. My job is looking after patients.”* [Staff Nurse]

The nurses’ perception was in general that there might be less medication errors being made or at least there should be less errors in the future if or when the system became more established. Their notion of error was generally related to others activities, principally doctors.

*“Doctors make less errors.”* [Nurse]

*“Biggest problem is mis-prescribing of drugs because doctors might have clicked on a wrong drug (from drop-down menu). Before, when they had to write down the drug, there was less scope for error, they might have prescribed wrong dosage but at least drug was right”.* [Nurse]

However, nurses too could reflect upon their own practice and see some potential for error reduction in the system.

*“Coming from different wards using traditional trolley, and trying to find different drugs in the trolley and maybe finding a drug isn’t there – something that wouldn’t happen with ServeRx – in that respect I find it very beneficial”.* [Nurse]

*“When I had to do a night shift it definitely helped, it was quicker, and as you are so tired there is less chance of errors”.* [Staff Nurse]

*“The system hasn’t reduced medication incidents but in the future it should (now there are hiccups). Still the system highlights that drugs were not given, gives reminders of drugs to be given outside normal drug rounds”.* [Nurse]

More senior nurses, and those who had had more information during the build up to the implementation by participating on the project team, were generally more positive. They saw the future in this system, with a better more careful and error free regime of care with time saved becoming available for more creative nursing activity. They anticipated and kept faith with these promised benefits, even at the times when the system was at its most problematic, as one quote given above says, *“The system hasn’t reduced medication incidents but in the future it should...”*

Through the interviews we can see that nurses attitudes towards the system shifted over time, from “non-involvement” at first (except for senior nurses), to some interest (on seeing ServeRx room and equipment being established), to feeling somewhat uncertain and lacking confidence (after receiving the first part of training), apprehension and disgruntlement (during the turbulent first weeks or rather months) to guarded acceptance of the system or at least acknowledgement that *“the system is better now than it was before”*.

All nurses considered the implementation process and the time the system took to stabilise as very stressful. Indeed, some nurses saw their attitude as a part of the problem, for example referring to *“my technophobia”*. Getting through the difficult period, and learning to work with the new system evoked a sense of satisfaction in some nurses. Indeed one of the senior nurses commented on the system as being a way to engage more junior staff and to give them a challenge that would spur them on to develop new professional competencies.

*“They will survive it... this project helped to build resilience”.* [Sister].

*“We have a personal sense of satisfaction now as we are up and running. It is getting there, becoming part of routine”.* [Nurse]



Still, for some nurses the overall feeling from the experience was of being made to do something that they would not have chosen to do, and which they still, to a degree resented as an imposition.

*"It wasn't our baby so we don't feel a sense of achievement. We have done well but we know it wasn't ours. Not that I would have wanted this to be our baby, even if I could have made it my baby."* [Nurse]

### Pharmacists

Pharmacists can to some extent choose how and where they do their work. While previously they visited each patient and checked their drug chart if available, now they can check through the computer and assess each patient's chart for changes, then visit patients whose drug records indicated a pharmacy related problem. However, they can (and the ward pharmacists does) continue to see all or most of the patients on daily basis.

Pharmacists attitudes and responses, as they developed over time, are significant in understanding not just what they understood the system to be intended for, but also how the system became a reality for them as it started operations and was embedded into their working practices. Thus pharmacists who used the system generally reported positive responses:

*"I think overall I would say I would rather it was here and I wouldn't want to go backwards and take it out".* [Ward Pharmacist]

*"I didn't actually know what to expect so I guess that's probably a good thing. I mean I thought it would be high tech and very nice to look at but I didn't know what the absolute plus points would be from it. [...] Well I like it because everything is on one screen, it's all there. You don't need to go around looking for the different bits and pieces and if you want it you have the sort of power, as it were, to change something and its all easily readable, you know there are no qualms about mistakes being made".* [On call Pharmacist who has used the system as cover]

*"It is easier to spot problems. Also, it seems that everyone is thinking a bit more about drugs, there is a greater 'visibility' of prescribing and that's good".* [Trainer and Support Pharmacist]

The question of working with patients and maintaining patient contact was, as indicated above, a central concern of pharmacists and some comments indicated some questioning of the extent to which this system was serving that goal.

*“On this ward you are very computer focused. All the prescriptions are done at the computer. Before drug charts were by patients’ beds and that’s when you used to talk to patients, see them in their whole environment”.* [On call pharmacist who has used the system as cover in focus meeting]

The disappearance of drug charts was a common theme commented on by pharmacists as well as doctors and nurses. They all emphasised the quick access to a general overview that the chart provided, usefully placed at the end of the bed, even if in the same sentence they would acknowledged the frustration of physically locating charts and the problems of incomplete, incoherent and illegible entries.

### **Outcomes**

One of the outcomes of the project are the peoples’ attitudes towards ServeRx and computerisation in general. The pharmacists interviewed generally shared a positive opinion about ServeRx and most of them did not oppose computerisation. Junior doctors’ opinions about the system varied widely, ranging from very enthusiastic (“very good”, “quicker”) to rather negative. However, the majority of those we had spoken to considered the “ideal” computerised system as generally worth pursuing. Senior doctors tended to be more sceptical about this particular system and the computerisation process in general, although again they did not necessary dismiss an idea of EP system that is all pervasive and shared between wards and different hospitals. After the initial turbulent implementation effort most nurses have come to accept the system, with some becoming reliant on it, as the above quotations suggest:

*“I have come round to it in more ways than I thought I would but still I’m not 100% convinced....I am a pretty hard person to satisfy.”* [Staff Nurse]

*“I like the system. I am now worried about going to the old system, I prefer this to paper drug charts”* [Sister in focus meeting].

The majority of interviewees felt that the system was safer due to:

- Legible and complete prescriptions;

- Easier and more timely access to prescribing data;
- Access to patients' history;
- Automated dispensing of drugs;
- Checking patients identity (by scanning bar codes on patients' wrists)
- Greater visibility of prescribing and ability to audit.

However, the system introduced new risks. The problem most commonly noted was a picking-up error, where doctors would choose a wrong drug from a list. Many also worried about computer failure and its implications for practice (how to proceed without records) and potential risks of administering wrong drugs or not administering on time. As one of the doctors noted, ServeRx has resulted in house officers having the main responsibility for updating the system and has reduced the involvement of others in the process of prescribing.

Many of the participants mentioned that they missed the drug chart. Its use in practice goes beyond its "official" purpose - it is used as a quick method of assessing the clinical state of a patient while standing at the bedside, particularly by nurses coming on shift or pharmacists visiting the ward. Senior doctors also missed the ability to use a drug chart as a communication "device" between themselves and junior doctors or visiting consultants.

*"Now I am thinking about what I can and cannot do with a drug chart. [...] I appreciate paper drug chart more". [Junior doctor]*

It seems that one of the outcome of the way the system was used was "shifting of time" when activities are done; for example, when prescribing takes place and when it is checked. Perceptions about implications for time taken to do different activities varied amongst professionals. Junior doctors, although acknowledging that they did not need to look for a physical record or re-write paper records, generally felt that the ServeRx system has introduced extra activities (for example, the need to transcribe records for patients moving between wards) or made some of the activities more cumbersome (for example, prescribing on the computer and viewing records). Nevertheless, as stated before, most of their problems tended to stem from particular limitations of the system and its confinement to one ward. All nurses pointed out that some activities took longer and some shorter when using the new system. However, their perceptions of time taken for different activities differed. For pharmacists the

introduction of ServeRx resulted in new activities, for example providing support for nurses and doctors on Ward 8N (for example, answering their queries about the system, helping out with some system-related problems) and transcribing of prescriptions. However, it has also made the process of reviewing prescriptions easier.

The system has imposed changes in practice on all those who work with it; most were seen as beneficial and appropriate. Nevertheless, the system is seen as more structuring and at times constraining for those who work with it. To varying degrees the system sometimes poses irksome duties and enforces a unique sequence of activity. This is particularly visible in the way the nurses prepare for and conduct drug rounds, considering each patient one by one. Pharmacists' work process has changed as well. Because they can check each patient's chart at a terminal in pharmacy, eventually this might result in some pharmacists choosing to spend less time on wards or seeing patients for whose charts they have identified a problem. Such a development might not be welcomed, as explained to us:

*"The system with its protocols and alerts is not enough. Doctors can ask pharmacists different things"* [Junior Doctor]

However, we have noticed that this is not necessarily the case. The ward pharmacist for Ward 8N continues to visit the ward regularly and speak to doctors on the ward, as well as see most of the patients on daily basis. Furthermore, by virtue of the project itself, we observed more interaction between participants on the ward, particularly around prescribing. For all of the period of implementation the ward had a constant presence of a trained pharmacist to work with other staff as they became familiar with the system and as they encountered problems. Pharmacists and their work gained visibility. Moreover, in the face of the new system certain solidarity emerged, with nurses and doctors helping each other, showing a shared sense of being in the front line.

### **A 3.3 Organisational Context**

#### ***Structure***

Implicit in the qualitative evaluation of ServeRx is a question: "If it is demonstrated that ICT used in this way does reduce errors, then how might we build upon this experience to inform any wider scale deployment of the system?" Through the

expressed opinions of the participants, and discussion with pharmacy managers, we present here some of the relevant issues that emerge.

It is significant that this was a pilot project. It was undertaken with a general understanding that what was being attempted was new, innovative and potentially worthwhile but was still an experiment or pilot. It was also understood as being demanding of extra resources and effort, including in technical and organisational design, dedicated space, and individual commitment. The system was supported by the constant availability of support staff to answer questions, collect problems and issues for resolution, provide training and reassure users. This “project status” allowed some lee-way, and it was generally understood as an opportunity to shape this system and potential future systems. Even so, it was a considerable shock to some staff that a system such as this did not arrive “fully functioning”.

If the system were to be more widely implemented, to further wards or across the hospital, this special status would not remain. For managers contemplating any wider deployment the consequence of uncertainty or lack of trust in the technical components and the active support for them is important.

### ***Process***

Experience on this ward has emphasised the inevitable challenge that comes when the working practices of professional groups and interdisciplinary teams are interfered with, as they inevitably are, by introducing a powerful and structuring technology.

The structuring itself poses a dilemma. On the one hand in addressing the aim of reducing errors in prescribing and administration the technology is explicitly used to constrain and enforce a “good” process. But, as the process is developed and codified it reveals aspects of practice that do not neatly fit, or which are mutually incompatible. This is apparent on one ward, but across the hospital the effect would be magnified as different specialities are considered. For example, a paediatric ward or care of the elderly. Equally, computerised prescribing and administration is not the only potential strategic initiative in this area; for example, in this hospital PODS has also been under trial on other wards, but the question remains as to the compatibility of the system as worked out with PODS.

## **Outcome**

At the time when we began to write this report the study period had come to its end and the future of the system, both on this ward and in some potential larger roll out, was under active discussion. Initially, it was decided that the system would stay on Ward 8N but would not in its present form be rolled out to other wards. It was considered that “the system in its current configuration was neither robust enough or flexible to contemplate extending to other wards”. More recently, due to the re-organisation of the hospital, which will result in Ward 8N being closed, a discussion centred around feasibility and desirability of transferring ServeRx to another ward. As the supplier was not able to commit to a date when new version of the system would be ready and more generally has shown diminishing interest in the UK’s market, the final decision was not to transfer the system at present. However, discussions continue whether ServeRx might be used on a Day and Stay Unit.

Despite this outcome, the pilot has led to valuable lessons regarding benefits and drawbacks of EP, the processes that are involved in “hosting” such as system, as well as project management and implementation strategies. It has also led to the staff involved with ServeRx acquiring new skills.

## **A.4 Patients Views**

*“They say: “Here comes Tesco again”. They are intrigued, want to see it, especially the younger patients are interested in it. Patients don’t voice negative comments”.*  
[Nurse]

### **A 4.2 Methods**

Patients on the study ward were interviewed to obtain their views on possible advantages and disadvantages of the ServeRx system. A structured interview schedule was used (see Annex Aiii). This consisted of a small number of questions with 5-point Likert scales to measure satisfaction and agreement, and a series of open-ended questions to explore patients’ views in a qualitative manner. The interviews included the same topics pre- and post-ServeRx, but the questions were reworded as appropriate for use before and after its implementation. Specific questions were included relating to the use of when required (PRN) medication; this

was because of concerns that PRN medication might be less accessible to patients during post-ServeRx drug rounds.

All patient interviews were conducted by a research pharmacist. A convenient sample of patients was obtained by asking nursing staff to nominate patients who they considered to be well enough to be interviewed. All interviews were carried out in a relaxed manner, and any questions that appeared difficult for the patient to answer were omitted so as not to put undue pressure on the patient. Patients' responses were recorded by hand in as much detail as possible. Pre-ServeRx interviews were conducted at convenient times during April and early May 2003; post ServeRx interviews were carried out on various dates between 25 February and 6 December 2004.

Responses obtained on the Likert scales were summarised using the median and range. The qualitative data were analysed by identifying and comparing general themes.

## **A 4.2 Results**

### ***The patients interviewed***

Eight patients were interviewed pre-ServeRx, and twelve post ServeRx. The patients were broadly similar in terms of demographic details (Table 44), with the exception that only one female patient was interviewed pre-ServeRx and five post-ServeRx. Patients were similar in terms of age distribution and length of stay at the time of interview. All except one patient (interviewed pre-ServeRx) had been in hospital before.

	Pre ServeRx	Post ServeRx
<b>Length of time in hospital</b>	<b>Number of patients (%)</b>	<b>Number of patients (%)</b>
0-4 days	1 (12.5%)	2 (17%)
5-9 days	2 (25%)	4 (33%)
10-14 days	4 (50%)	4 (33%)
15-19 days	0	0
>20 days	1 (12.5%)	2 (17%)
<b>Total</b>	<b>8</b>	<b>12</b>
<b>Age band of patients interviewed</b>	<b>Number of patients (%)</b>	<b>Number of patients (%)</b>
21-25 years	0	0
26-30 years	1 (12.5%)	0
31-40 years	1 (12.5%)	2 (17%)
41-50 years	1 (12.5%)	2 (17%)
51-60 years	0	1 (8%)
61-70 years	1 (12.5%)	4 (33%)
>70 years	4 (50%)	3 (25%)
<b>Total</b>	<b>8</b>	<b>12</b>
<b>Gender of patients</b>	<b>Number of patients</b>	<b>Number of patients</b>
Female	1 (12.5%)	7 (58%)
Male	7 (87.5%)	5 (42%)
<b>Total</b>	<b>8</b>	<b>12</b>
Whether first time in hospital?	Yes, 1 (12.5%) No, 7 (87.5%)	Yes, 0 No, 12 (100%)

**Table 44: Demographic details of the patients interviewed**

***Patient satisfaction***

Before the introduction of ServeRx, the median level of patient satisfaction with the paper-based system was 4 (range 3 - 5, where 5 was the most highly satisfied). The median level of enthusiasm regarding the proposed Serve-Rx system coming to the ward was 3 (range 2 - 5).



After the introduction of ServeRx, patients' median level of satisfaction (median 4.5; range 3 – 5) was very similar to that pre-ServeRx. The median level of enthusiasm for a return to the paper system (median 3; range 1 – 5) was also very similar to the previous level of enthusiasm for ServeRx.

With respect to the administration of PRN medication, six of the eight pre-ServeRx patients interviewed (75%) were aware of the PRN system and 75% all reported that they had requested PRN medication during their stay. Post-ServeRx, 11 of the 12 patients (92%) were aware of the PRN system and 10 (83%) had requested a PRN drug. Pre-ServeRx, the median level of satisfaction with the PRN system was 5 (range 4-5); post-ServeRx it was 4.5 (range 2-5).

### ***Pre-ServeRx qualitative results***

In response to an initial open question about their general impression of the current paper-based system, patients' comments were mostly positive and upbeat.

*“Very good. Nurses are very hard working. They rely on reading the prescription chart and then going to the cabinet (which is double the work)”.*

*“Current system is very intensive. It takes up a great deal of nurses' time. Particularly in view of the fact that NHS contracts bank nurses; all the time bank nurses must spend on administering medicines. Nurses do long days and therefore definitely room for errors to creep in”*

Several patients referred to the paper-based system being labour-intensive. Two less positive comments were made. These were a perceived concern that there was no check of whether prescribed medication was still required, and a concern that 10pm medication was sometimes given at 10:30pm, which was perceived to be too late.

When informed that "a computerised system of prescription and medication administration" was going to be installed on the ward, patients gave a wide variety of responses. Some were very enthusiastic, saying that it "sounds brilliant", for example, but without giving more details as to why. Others were very sceptical. Two patients mentioned "Big Brother", but this phrase was used in relation to a fear of

computers failing, rather than in relation to being watched from afar. One patient referred to other computer systems that had received bad publicity, another was concerned that staff would blame the computer for any errors that occurred, and another that there would be a loss of “the personal touch”.

In terms of the practicalities of how the system would operate, some patients described spreadsheets, bar codes, scanning, and inputting data, suggesting a good understanding of what the system would be like. Others talked of cylinders, a system resembling an automatic cat-feeder, and a robot moving around the ward. One patient thought of the system as a replacement for the pharmacist's ward visit. Some raised very relevant concerns, such as whether a computerised system would be able to handle intravenous drugs, and how unwanted doses would be managed, and system crashes, reflecting problems that did arise when the system was put into place. Most patients referred to “time-saving” at some point during their interview, clearly assuming that the aim of introducing the new system was to save time and increase efficiency. Three also referred to error reduction.

*“Computers will decrease mistakes and bring benefit. Can't see a cost saving though”*

*“Save nursing time. Save money for NHS in the long term. Very happy to see progress in the right direction.”*

When patients were asked what they thought the effect of the computer system would be on the administration of PRN medication, one patient expressed the view that it might help the nurse to find the appropriate medication quicker. Another hoped that the computer would not hinder the process “since it can't hear a patient screaming for painkillers”.

### ***Post-ServeRx qualitative results***

When asked for their general impression of the current system post-ServeRx, patients' comments were again very positive in general ranging from “*excellent*”, “*good*” to “*generally OK*”.

*“Good idea. Only one nurse needs to go round doing the drugs. Safer. Only goes to the person with the wristband. Wristbands are clear - survived a shower. Scans easier”.*

However, there were some exceptions. One patient said: *“Computers aren't always right”*. He was concerned that nursing staff did not know what medication they were giving, possibly referring to the fact that tablets are not identifiable individually once they are dispensed and placed in the drug trolley. Another noted that nursing staff sometimes scanned a barcode from a strip of barcodes, rather than the one on the patient's wrist. One commented that doses were sometimes given late, and another referred to a problem whereby they had been waiting for a drug to be supplied for five days. During the course of the interviews, several patients referred to language and/or cultural issues, suggesting that the computer system may have advantages for staff for whom English is not their first language.

When post-ServeRx patients were asked what they perceived the paper-based system of medication administration to have been like, their responses suggested that they had a good understanding of how the system actually worked in practice. This is probably because all had been admitted to hospital previously. The majority of patients had some safety concerns with the paper-based system. These included its perceived time-consuming nature, illegible doctors' handwriting, losing “bits of paper”, communication, and drug trolleys left unattended. Some simply expressed the opinion that the computer system was safer.

When asked about any advantages that they could think of with the paper-based system the majority of patients interviewed with ServeRx in place could not think of any or only mentioned its disadvantages.

*“The computer is a better way of doing it. Paper could get lost”*

*“Not in terms of speed because you have to go through files searching for doctors instructions. With a computer you simply press a button and it's there on screen - you get a printout saying what's given. Modern technology is better if all the info is there”.*

Some thought that there were advantages with a paper-based system but couldn't specifically name any. One patient thought that the paper system retained flexibility. Other pointed out:

*“The human is always the best. The system looks pretty good, but I didn’t like it when my bar code wasn’t read. It has been read, but not all the time. It [paper system] stood the test of time. Whether the paper system is better depends on the rules for both systems and whether those who use it abide by them”.*

When asked about the perceived impact of the new system on administration of PRN medication, three patients thought the system was beneficial, five considered it to be detrimental and four were unsure or thought it made no difference. The three positive comments related to speed, and nurses no longer having to look for written medication records. Two of the negative comments concerned the perceived extra time needed if nursing staff had to check the drugs prescribed on the computer; the other comments were more general concerns about computer systems.

*“With the paper system the doctor can write it up there and then. Where do they go with this current system? Computers can go wrong, e.g. when I came in for an OP visit I was told to come straight in as an inpatient. They were looking for a bed. I needed to phone my relative and the computer came up wrong. I don’t believe in computers”.*

*“Hopefully [the new system] makes nurses lives easier. To scan your bar code or look up on the system when you had your last dose. Not having to look for written records”.*

*“They take longer now because they have to check on the computer first. If the computer is going slow it takes them longer to check what each patient can and cannot have”*

### **A 4.3 Conclusions**

Our interviews suggest that patients have a range of views on the computerisation of medication prescribing and administration. There was little difference in median satisfaction scores before and after computerisation, although our sample size was very small. It was interesting that the median score for enthusiasm for the “other” system was at least one point less than the median score for satisfaction with the ‘current’ system during both study periods.

Prior to computerisation, patients were very unsure of what to expect, with a number of concerns about computerisation. Much of this was based on what seemed to be an inherent mistrust of computer systems. Following the implementation of the new system, patients voiced these concerns less often and instead commented on perceived disadvantages of the previous system.

It was of interest that patients assumed that the main reason for computerisation was to save time, when this has not proved to be the case in practice. Interestingly, two also felt that the computerised system would be beneficial for staff for whom English was not their first language. Patients varied in terms of which system they perceived to be safer.

Our findings suggest that patients may be slightly less satisfied with the system for requesting PRN medication with the computerised system, but a larger study would be required to substantiate this.

Finally, our results raise some useful points about patients' perceptions of what is important, such as 10pm doses being given at 10:30pm. This would be considered to be accepted practice amongst hospital staff, and therefore highlights a mismatch between patients' and staff expectations. Patients were also aware of some important safety issues such as scanning barcodes from a list rather than the one on the patient's wristband.

## **A 5 Summary of evaluation: key findings**

### **A 5.1 System Functions**

#### ***Structure:***

- ServeRx includes electronic prescribing, scheduling, automated dispensing and electronic administration, as well as elements of stock control.
- Installed on only one ward and has no substantial connection (other than basic data) to the hospital's other information systems.

- Initial technical problems and the system needed tailoring to CXH requirements.
- Many problems have been rectified with subsequent versions but some hardware and software shortcomings remain.

***Process:***

- The system reached some form of stability and is almost totally integrated into the work of the ward.
- Once stable, the data processing functioned well.
- The inbuilt structuring of the core work processes of prescribing, selection and administration of drugs performed satisfactorily for most, but not all, drugs.

***Outcome:***

- A usable technology (hardware and software) that was over time shaped and integrated into ward practice.
- Facilitates prescribing and administration processes and provides data which are of an appropriate quality and available for all participants in the care process.
- Continuing mismatch between system characteristics and the use of certain drugs.

## **A 5.2 Human perspectives**

***Structure:***

- Training provided to doctors, nurses and pharmacists but on-going support (including the physical presence of a trainer on the ward) was found to be necessary.

- Doctors had little involvement in shaping of the system and some considered that this was not appropriate.
- Nurses hesitant about the system at the outset.
- System driven forward by pharmacists, other professionals felt that it reflected most strongly pharmacists' interests. Certainly, pharmacists were clearer at the outset what the system was for and what they wanted from it.
- Patients unsure of what to expect, with a number of concerns about computerisation.

***Process:***

- The system influences how, when and where prescribing is done and checked, shaping work processes of doctors, nurses and pharmacists.
- Nurses administering drugs are bound by a sequence of procedures embedded in the system.
- The way different professionals communicate with each other changes.
- Experience of using the system over time and over its many versions has meant that the attitudes towards it have evolved and shifted.

***Outcome:***

- A system which pharmacists, and perhaps more reluctantly, nurses have come to accept and many would miss.
- Doctors' opinions were more varied, but generally they felt the system had many shortcomings but they still believed in benefits an ideal system might bring.

- The system had restructuring effects on the way different professional groups work, although some could exercise a degree of autonomy.
- The system was generally perceived as safer or at least potentially safer, reducing some errors but also acknowledged as introducing new risks.
- Patients' views varied but they had less concerns about computerisation after the introduction of ServeRx than before it.

## **A 5.3 Organisational Context**

### ***Structure:***

- A pilot project, envisaged as an opportunity to learn from this system and potential future initiatives. It enjoyed extra resources in terms of money and time and required substantial commitment from many staff members.

### ***Process:***

- Experience on the ward emphasised the challenge that comes when the working practices of professional groups and interdisciplinary teams are interfered with by introducing a powerful and structuring technology.
- Technology is explicitly used to enforce a “good” process, but some aspects of practice do not neatly fit, or are incompatible with the system. This is apparent on one ward, but across a hospital the effect would be magnified as different specialities are considered.

### ***Outcome:***

- Plans for the system are still being discussed, but in the immediate future ServeRx is not going to be transferred to another ward, after the closure of Ward 8N. The pilot has led to valuable lessons regarding benefits and drawbacks of EP, the processes that are involved in “hosting” such a system, as well as project management and implementation strategies.



## **Annex A i: Agenda for focus meeting 30 June 2004**

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Department of Information Systems, London School of Economics

In the first part of this meeting we would like to discuss ServeRx's performance and how it might be judged. Then we want to discuss the process of implementation of the system and how change has been experienced and handled. Finally, we would like to ask what can be learned from the project. Our aim is to pose these questions and to identify and explore areas of agreement and debate.

### **Part 1. Is ServeRx successful?**

How would you define success, i.e. what criteria should we use to measure this (content) and how can we assess them (process)?

Has the system had an effect on the incidence of medication errors?

Has ServeRx had substantial effects on working practices and professional roles?

Can you identify changes in the relationships *between* different professional groups/patients, at the ward level and against the hospital wide context?

Has the system influenced practices, expectations or attitudes elsewhere in the Hospital and Trust, e.g. in other wards, specialisms?

Would you like the system to stay on Ward 8N, be discontinued, or perhaps extended to the whole hospital?

### **Part 2. The Change Process**

Has ServeRx been experienced as a substantial change process? If so, change in what areas and experienced in what ways?

Considering the full duration of the ServeRx project, how would you describe the changes in attitudes and responses to the system over time.

What aspects of the project have been most influential in shaping these attitudes?

### **Part 3. Lessons Learned – beyond ServeRx**

Considering the issues discussed so far, what can be learned about:

-The process of medicines management, i.e. manual and computerised and across the clinical settings. Have we learned anything about the way medicines are prescribed, dispensed, administered and managed, and the way different professions work together?

-The potential of computerised drug management systems, e.g. should they include additional functionalities, support other aspects of medical practice, be more integrated with other hospital information systems or should such moves be abandoned?

-Appropriate implementation processes for innovative information systems within a clinical setting; how can the implementation of such systems be best approached, what could have been done differently?

How might this knowledge be put to use in future projects?

## Annex Aii: Questions: aide memoire

This is just a sample of questions asked. Questioned varied depending on the person being interviewed and the time of the interview (e.g. before, during and after the implementation of ServeRx))

(Check current job title and where they work)

- How long have you been working at QHB?  
(*interviewer to clarify this in terms of timeline of the HIS project*)

How often do you use the system? For what tasks?

What was it like, learning to use the system? Did you have any problems when you first started? How were these resolved?

Is the system easy to use?

Have you ever experienced the system crashing/going down when you've been using it or needed to access it? (*Lead on to ask about other critical events, risky situations – do they remember any specific events, what have they learnt from incidents like that?*)

Has the system met your expectations?

What do you see as the main potential benefits from having the system?

What would you miss most about the system if it went?

What would you like to change about the system? (*prompts: reporting facility, allergies pop-ups, insulin etc*)

In your opinion, does the use of the system result in reduction of medication errors?

What is the biggest problem?

Is the system successful? How would you define its success, i.e. what criteria would you use to measure it (content) and how would you assess it (process)? How would other groups define its success?

Prompt for :

- a) measures of success,
- b) work practices supported, enabled or removed,
- c) other people (groups) who will define this

What do you do if there is something you think could be improved? Are there procedures in place to deal with system improvement? E.g. User groups? (*probe: how easy is it to get things changed- feeling of involvement in the system development over the years*)

As a pharmacist how do you see the system influencing

- Your role in provision of healthcare
- Your working practices on a day to day basis
- Your working style as part of a team or as a professional

Has your behaviour/practice been changed by the system? If so, in what way?

- do you think the system makes you think more or less about what you do compared to the paper-based system? (*prompts: are things sometimes too easy? Or does it encourage people to think, to “engage the brain”?*)
- Have you ever felt constrained in what you want to do by the system? (*explore dosing flexibility; timing of doses etc*)
- Has the system ever pushed you to make a certain decision? (*prompt: ever had to do something that was against your professional judgement?*)
- Has the system affected the amount of time you spend with patients? (*if no experience of other system, ask if system helps or hinders time for direct patient contact*)
- Has the system affected the amount of time you spend with other health care professionals? (*prompts: better or worse relationships compared to using a paper-based system. If no knowledge of other system, ask if system helps or hinders time for direct patient contact*)
- Who is more in control – you or the computer?
- Does the system make you feel safer?

How are your professional interests as a pharmacist represented in the system? (I.e. does this system mainly support pharmacists in their work, or perhaps nurses or doctors?). What group may benefit most from the system and why?

What are the attitudes of clinical staff (doctors, nurses) towards ServeRX?

Have the attitudes changed over time? In what way?

Are nurses and doctors confident in using the system? Do they find it easy to use?

Do they find it useful?



**Q. 3** When required, nurses can also administer medication outside of the scheduled 'drug round' (i.e. if a patient has been prescribed a pain killer, this can be given out when the patient is in pain instead of waiting for the 'drug round').

**A.** Were you aware of this system?

- |            |                          |     |
|------------|--------------------------|-----|
| Yes        | <input type="checkbox"/> | . 4 |
| No         | <input type="checkbox"/> | . 5 |
| Don't know | <input type="checkbox"/> | . 6 |

**B.** Have you been prescribed any 'when required' medication?

- |            |                          |     |
|------------|--------------------------|-----|
| Yes        | <input type="checkbox"/> | . 7 |
| No         | <input type="checkbox"/> | . 8 |
| Don't know | <input type="checkbox"/> | . 9 |

**C.** If yes, have you actually asked for a medication outside of the 'drug round' (i.e. when you have required it)?

- |            |                          |      |
|------------|--------------------------|------|
| Yes        | <input type="checkbox"/> | . 10 |
| No         | <input type="checkbox"/> | . 11 |
| Don't know | <input type="checkbox"/> | . 12 |

**D.** How would you rate your satisfaction with this system of giving medication 'when required', on the following scale?

Very satisfied	Indifferent	Very unsatisfied	
_____  _____  _____  _____			. 13
☺	☹	☹	

**E.** Do you have any other comments to make about this, perhaps give a reason for the above rating?

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. 14

*[F. PRN status (i.e. researcher to list PRN drugs, if any):*

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\_\_\_\_\_  
\_\_\_\_\_ ] . 15

**Q. 4** Previously, there was a paper-based system of prescription and medication administration on this ward.

**A.** Do you have any experience of this paper-based system (as a patient or otherwise)?

Yes  . 16

No  . 17

Don't know  . 18

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ . 19

**B.** What images come to mind when you hear this?

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ . 20



**C.** How do you think such a system worked?

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. 21

**Q. 5** The system worked as follows. Details of all medication were written on a paper drug chart. The ward had a conventional drug trolley, which contained all the medication in alphabetical order. There was no one compartment designated to you and the wristband you are currently wearing was not bar-coded and would not be read.

When the nurse reached your bedside, she/he would read the drug chart and select your medication from the drug trolley.

**A.** What do you think of such a system?

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. 22

**B.** Do you have any reservations about that system?

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. 23

**C.** Do you think that such a system would have had any advantages over the current computerised system?

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. 24

**Q. 6** The nurses were still able to give 'when required' medication outside of the scheduled 'drug round'.



21-25	<input type="checkbox"/>	. 33
26-30	<input type="checkbox"/>	. 34
31-40	<input type="checkbox"/>	. 35
41-50	<input type="checkbox"/>	. 36
51-60	<input type="checkbox"/>	. 37
61-70	<input type="checkbox"/>	. 38
>70	<input type="checkbox"/>	. 39

**Q. 12** [Interviewer to indicate gender:]

Female	<input type="checkbox"/>	. 40
Male	<input type="checkbox"/>	. 41

## **Appendix B. Qualitative evaluation of electronic prescribing with the Meditech system at Queen's hospital Burton on Trent**

### **B 1 Introduction**

This Chapter describes the qualitative evaluation of the Meditech system. It is structured round Cornford's framework (Chapter 7). It illustrates how the framework can be applied to a well established system, and provides valuable lessons. Given the novelty of our involvement of patients, we report and reflect on this information at length. Finally, we reflect on the methodology.

Queen's hospital Burton upon Trent (QHB) is a 460-bed district general hospital providing acute care plus a range of community-based and outreach services to around 200,000 people living in Burton-on-Trent and surrounding areas.

The vast majority of wards and departments at QHB operate on a "paperless" basis via the Meditech Hospital Information System (called "the HIS" by staff), which can be accessed from anywhere in the hospital. Paper medical notes are still maintained but most prescribing, recording and communication throughout the hospital is now electronic. ITU and HDU, theatres, the private patients ward, outpatients and part of A&E are the only departments not to use electronic prescribing (EP).

Geographically, QHB is located on two adjacent sites, separated by a public road. Acute in-patient services, A&E, pathology laboratory, pharmacy, therapies, and majority of outpatient clinics are housed in the modern two-storey block on the main site. All wards have access to a vacuum tube system for the delivery of urgent small items which can be transported safely by this method. These include inpatient and "to take home" medicines.

Three care of the elderly wards, plus a "half-way-house" ward are on the Outwoods site, which is a short up-hill walk from the main hospital entrance. The Outwoods site also houses dietetic services, the diabetes centre, plus training and education facilities for nurses, doctors and other staff. These wards use a traditional portering service for delivery.

The origins of the Meditech HIS project, of which EP is now an established part, coincided with a time of great change for hospital services at Burton.

The hospital now occupies a 26-hectare site roughly two miles west of its former site in Burton town centre. Development of the present site started in 1973 with the construction of the Outwoods wards which provide intermediate care facilities. Until 1993, acute services remained at the old Burton General Hospital and pharmacy services operated on two sites. By September 1993, all wards had moved up to QHB, the old hospital closed and pharmacy services were consolidated in one enlarged department at Queen's Hospital.

In the late 1980s, initial discussion on upgrading the existing patient administration system stimulated research into better technology options and resulted in the selection of the Meditech from the USA. To fund it, the hospital borrowed £2m from the health authority and pledged medical equipment money for two years. At that time, the pharmacy was looking to upgrade its own Cortex computer system and wanted access to patient data, with the possibility of electronic prescribing in mind.

Phased introduction of individual modules in the Meditech HIS package began in 1991. By December 1993 the master patient index had been set up and tests could be ordered and results reported electronically. Several other modules, including Patient Care Inquiry (PCI) which collects all the reports, letters and notes for a patient, followed.

Electronic prescribing was the last facility to be introduced. The original Meditech Order Entry module was not suitable for an NHS hospital because it required pharmacists to enter in patient orders, as they do in the USA. In the words of one pharmacist who saw that early system : *“Apparently, the doctors just write on a slip of paper and then the pharmacist enters it in and makes sense of it. So we said we just haven't got the time and why duplicate work?”*

Instead, an EP front end was developed, in which medication orders were entered directly into the pharmacy module. Staff involved at that time recalled Meditech *“bending over backwards”* to develop a product suitable for the NHS marketplace. One nurse said: *“They [Meditech] work in Canada and USA and other countries but they didn't really understand how the NHS works. So they had to work closely with us at that point to understand the fundamentals”*

The first trial of EP was carried out on one medical ward in April 1994. This followed the Arrowe Park model of prescribing using static PC terminals and paper printouts for medicine administration recording. The pilot was terminated after 2 weeks because of concerns that, in the words of one project team member, that *“what was at the end of the bed was not the same as the computer”*

Full implementation had to wait until suitable and affordable mobile technology became available. In November 1994 QHB became a demonstration site for the NHS EPR (Electronic Patient Record) project and gained the funding needed to purchase 20 Toshiba laptops and associated wireless technology. In December 1996: EP (Meditech version 4.4) was successfully piloted on 3 Outwoods site care of the elderly (COE) wards<sup>91,92</sup> with subsequent roll-out across the hospital site as shown in Figure 23 below. The Queen’s project team have presented and reported their work on EP<sup>93,94</sup> and an independent evaluation of EPR was carried out in 1997<sup>95</sup>

<p><b>April 1994:</b> First trial on medical ward using Arrowe Parke method (static terminals for prescribing and paper printouts for medication administration)</p> <p><b>Dec 1996: Mobile technology pilot</b> on Outwoods COE wards <b>Meditech version 4.4</b></p> <p><b>March 1997:</b> Wards 5 and 6 (acute COE) plus A&amp;E emergency admissions unit</p> <p><b>June 1997:</b> Ward 11 (ophthalmology)</p> <p><b>Nov 1997:</b> Wards 19 and 20 (orthopaedics)</p> <p><b>June 1999:</b> Wards 6 and 8 (acute medicine). <b>Meditech version 4.6</b> : Separate screens for medicine prescribing and administration</p> <p><b>July 1999:</b> Elective surgery ward 11 (gynae) and ward 14 (ENT)</p> <p><b>Nov 1999:</b> Wards 3 and 4 (acute surgical wards and theatre recovery areas) Order sets being developed: to simplify complex prescribing (eg for ENT)</p> <p><b>March 2000:</b> Wards 15 and 16 and delivery suite (maternity)</p> <p><b>May 2001: Meditech version 4.8</b> . Facility for inserting take home (TTO) drugs automatically into discharge letters for GPs</p> <p><b>April 2002:</b> ward 1 and 2 (paediatrics) and neonatal unit</p>
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**Figure 23: EP roll out at Queen’s Hospital**

## **B 2 Methods**

The study at Queen's Hospital Burton (QHB) was the retrospective arm of the project to pilot the prospective and retrospective evaluations of electronic prescribing (EP) in hospitals. The evaluation framework is Cornford's (Chapter 7). The principal research objective was to determine if it is feasible to quantify the effect of EP on medication errors using retrospective review of patient notes. The purpose of the qualitative work (primarily interviews with key stakeholder groups plus some observation) was to put the quantitative findings in context. Stakeholder groups were defined as those who took part in the decision making process regarding the system; those who use the system or its outputs; and those who are in some way affected by it. The intention was to interview a broad range of clinical and non-clinical staff at senior, middle and low grades, plus a small number of inpatients.

### ***Approach and data sources***

Informed consent was obtained from all participants before interviews commenced. The vast majority of interviews were tape recorded, with the subject's consent. If tape-recording was not feasible (for example, because of the setting), written notes were made. All interviews were fully transcribed and written notes typed up.

### ***Initial scoping visits Jan-June 2004***

Initial contact with Queen's Hospital Burton (QHB) was made through the Head of Pharmacy Services, who was designated the primary contact point for access to the site and for the local provision of information about the study to potential participants.

The initial scoping visit took place in January 2004. The research team met QHB staff who had been involved in the hospital computer system from the start (the "core team"), observed a medicine round on a surgical ward, and carried out a preliminary interview with a junior doctor.

Further in-depth scoping interviews with three core team members (two pharmacists; one nurse) and two users of EP (one senior and one junior clinician) were done in June 2004. These interviews explored understanding of, and participation in, the system; assessment of key benefits and problems; and how the system influenced professional working practices. They also clarified the research team's own understanding of the

system. Questions were tailored to the respondent's professional group and to their role in system establishment.

Two researchers (IS and SC) independently read and re-read the interview transcripts and notes, then met to discuss and agree emerging themes. (see Annex Bi for detail). These initial data were used to develop a topic guide for subsequent interviews (see Annex Bii).

***Staff interviews and observations November 2004 –March 2005***

The majority of follow-up interviews with staff were done at QHB over a three-day period in November 2004. The interview guide used is shown in Annex Bii

Pharmacy staff and the majority of senior clinicians were identified and approached by the key contact; other clinical and ward staff were mainly recruited by senior pharmacists responsible for the relevant wards. A small number of interviewees were identified by the research team during interviews and department visits. Researchers visited QHB again in early 2005, after an announcement had been put out on the HIS asking staff with issues or comments about the EP to contact the research team. No further interviewees were identified in this way.

All staff interview data (see Table 45) has been included in the analysis. Initial charting was done using the framework developed from the scoping interviews<sup>96</sup>. Three researchers (TC, EK and IS) independently read and re-read the interview transcripts and notes, then met to discuss and agree emerging themes. The Cornford framework was then applied systematically to the data by EK and TC, and reviewed by IS.



	<b>Senior</b>	<b>Mid</b>	<b>Junior</b>	<b>Total</b>
Pharmacy	2	5	1	8
Clinical	3	1	4	8
Nursing	2	3	1	6
Other				4
<b>Observations</b>				
Drug administration	2			
Pharmacy (clinical check)	1			
Pharmacy (dispensing)	1			
Prescribing	1			
Prescribing training	1			

**Table 45: Staff interviews and observations (all data)**

### **B 3 Evaluation Results**

In this section we report the findings from our staff interviews using the structure of the Cornford framework <sup>21</sup>. The analysis is presented first for the system function, then the human perspectives and finally from the organisational view. In each section the analysis is reported first in terms of structure, then process and finally outcomes, though we acknowledge that these sub-headings are at times hard to strictly adhere to.

#### **B 3.1 System Functions**

##### **Structure**

At QHB electronic prescribing (EP) is an integral part of the hospital-wide information system (HIS), as described above. It is present as one of the HIS modules, but it seamlessly interfaces with other modules. From the perspective of users “the system” they use for prescribing activity includes multiple parts of the Meditech suite including prescribing, patient index, nursing notes, tests etc.

EP was the last clinical ordering module to be implemented in the hospital. As described earlier, the EP module was written specially for QHB. Small modifications have been done continuously (either by the internal staff, or when necessary by

Meditech); major system upgrades happen approximately every two years. A new, Windows-based upgrade is expected soon.

The technical elements of the system include a mixture of dumb terminals, PCs and laptops. The laptop computers used for prescribing and administration on wards are capable of accessing the hospital-wide wireless LAN. Each EP ward has two laptops and three static computer workstations. It has been suggested that some departments (for example, therapies) do not have enough PCs, and there can be competition between nursing and medical staff for laptops at ward medicine round times. However, this is not perceived as an important problem, and generally the hospital seems to have extensive and adequate access points. More commonly, lack of laptops and their short battery life is mentioned as a problem - while one laptop is charging, there is only one available to doctors, nurses, pharmacists and others on a ward.

The hospital wide system uses a DOS interface which is perceived as initially difficult to learn. Our findings suggest that most people get used to this quite quickly, indeed many grew up with the system, only know this interface, and fear a move to the new windows/mouse interfaces. Even some young doctors who have grown up with Windows systems seem to like the interface. They consider the system safer - it very seldom crashes - and one suggested that the structured key stroke driven interface *imposes* a sequence of steps which have to be followed. Some people also reported it as easier not to have to use a mouse in certain conditions (i.e. where there is no space for a mouse, for example on a laptop attached to a drug trolley) For those familiar with the system it is quick to execute commands and to move between screens. Others, however, are eagerly waiting for a Windows interface, because the current interface seems to them very old and outdated, ("*rubbish*" as described by one of the interviewees), reporting that it is difficult to remember how to access certain functions (complex combinations of key strokes), and the interface (key placing and combinations) are different on different machines.

The impression conveyed through the interviews is that the HIS is a very stable system, seen as much more reliable than the usual Windows-based applications. For example, we were told that it only crashes about once a year, although, as one would expect, more problems tend to arise after a major upgrade. However, interviewees indicated that the wireless connections were not always reliable, and terminals sometimes break down halfway through prescribing (freeze). Generally, people interviewed were satisfied with the system's structure, and although they would have

liked to see some improvements, the technical capacity of the system was not seen as significantly hindering their activities.

### **Process**

Few problems were reported with data processing and data reliability. Authorised users can access relevant modules and read and update information that is shared between different professionals. Pharmacists and doctors regularly access patients' history, nurses' notes and tests results etc, and indeed expect such functionality to be available to them as they perform their duties. Pharmacists, doctors and nurses all spoke of the system in this way:

*"You have got a lot more information at your fingertips"* [Pharmacist],

*"We can all see the patient as a whole"* [Nurse]

*"Look that's my hospital!"* [a Consultant, pointing at the computer screen]

Prescribers access EP screen to prescribe medications (regular medicines, "stat" and single doses). They can also mark medications for discharge, which are later dispensed by the pharmacy. During drug rounds nurses go around patients' beds with a conventional drug trolley equipped with a laptop, through which they can access the drug administration screen. Pharmacists can access the system and review patient medication orders from anywhere in the hospital, although they tend to check them in the pharmacy.

In addition to the functional elements described above, the system also serves to provide a structure that allows the coordination (articulation) of work within the hospital, and to a large degree, around the patient, supporting the patient care process:

- It allows for different professionals to access each others data and to communicate, for example to justify their decisions; pharmacists can make a note as to why and in what way they have changed a prescription, nurses can state why they have not administered a drug.
- Test results are available faster, and can reach all authorised persons. Data are in this way more available for use than in a paper-based system. (However, the system does not easily support the provision of group summary data to clinical users within a speciality.)

- Accurate medication history can be provided on transfer to another ward.
- GP receive legible discharge letters with lists of patients medications automatically inserted. (These letters are send by post not emailed. A brief trial of electronic discharge was established but did not survive.)

Back up procedures are in place. In case of a system crash or to cover planned downtime periods all records can be printed out from a dedicated PC which stores back up information. These records can then be used, for example, by nurses to administer drugs. Printing these “downtime sheets” takes at least 30 minutes and is done in order of ward number. This can occasionally cause problems for the off-site wards, who always come last. All new medication orders and administrations made during downtime, must be entered back into the system when the system is live again. Pharmacy can print labels for outpatients on a different system.

This back up system is most appropriate for short term breakdowns. New procedures for “worst case scenarios” are currently being developed so the hospital can cope with a crash lasting up to seven days.

*“We always said, up to 2000 or 2001, that if it went down for more than 24 hours that would be the end of the story, we’d just shut it down and go back to paper but ... we can’t do that now. It is too entrenched in the whole setup. We have to look at seven day downtime – accommodate up to seven days – which I think is the absolute worst scenario you could think of.” [Pharmacist ]*

### **Outcome**

The HIS technical system (including EP) is a product of a decade’s on-going effort by QHB and Meditech staff and the system continuously evolves; there are minor, continuous changes, and every two years – bigger changes/upgrades. Many are reported as the results of incidents; if there is an error, for example, it is then investigated and a procedure/system function might be changed.

One primary outcome we therefore should note is the establishment of a working relationship between the hospital and the supplier, based on longstanding and generally positive regular contact. As a result, and through years of working on analysis of emerging requirements and their prioritisation, negotiating of interests, and on-going development, as well as careful implementation plans, the system in the large as well as in the specific case of electronic prescribing, has been maintained in use on the

majority of wards and across many departments of the hospital. Overall, the technical system is judged by its users to be reliable, to perform well, and to substantially meet the hospital needs.

### **B 3.2 Human Perspectives**

As a hospital- wide system, and with the fluid boundary between the overall system and the specific element of electronic prescribing, there are inevitably many human stakeholders drawn in to the system, including nurses, pharmacy staff, doctors (from house officers to consultants), other health care professionals, hospital IT staff, management, and of course patients. The following sections presents views of the representatives of the three main stakeholder groups (pharmacists, doctors and nurses), as well as some comments from other health care professionals including dieticians and speech therapist. The views of patients are reported separately.

#### ***Structure***

##### Training

An important element of this system's ability to operate is the induction of new staff and the confidence staff in general have in their ability to learn to work with the system, seek information, report problems and receive peer support. The quality of training is thus one significant factor influencing attitudes to the system.

At QHB an on-going training programme for doctors and nurses is provided by dedicated nurse trainers. An initial formal training lasts for about 2.5 hours, but much training happens "on the job" and it is common that new staff are "shadowed" by more experienced ones. Because of low staff turnover there is usually someone experienced to assist new employees. Some new junior doctors may have seen the EP system as medical students, or during a previous house job at QHB.

Generally, the people we interviewed were very satisfied with the training and support received, with both the formal and informal aspects "on the job". Nevertheless, we were told that the system is enormous and it is difficult to know all its parts. Even members of the core implementation team were still learning

## Doctors

Some senior doctors have played a major role in the whole process of acquiring and developing the HIS and were a significant element of the organisational driving force. They had been at QHB for a number of years and their attitudes to IT systems in general, and EP in particular, have been formed and modified over a long period.

Members of the core team reported a range of opinions at the time of the HIS introduction, from worry and apprehension to enthusiasm in being involved in something new and adventurous. More recently, the main areas of resistance have been in anaesthesia, intensive care, and the neonatal unit, where some doctors felt the system was not flexible enough to meet their specialist dosing requirements.

*“ From the neonatal point of view we has issues as well as critical care whether it was safe practice to actually implement that because of very tiny doses and making that sort of work. But we actually worked through that didn't we and we implemented that..”. [Nurse]*

*“It is the emergency drugs basically they were worried about because they are nanogram and microgram and somebody has to calculate and check it before we give”. [Doctor]*

*“It was the format as well wasn't it, the way the screen was formatted. We felt it should be clearly specific to either critical care areas or neonatal with it being such tiny doses”. [Nurse]*

Except for the comments above, it seems from interviews that those who are frustrated with EP tend to be frustrated with the hardware (e.g. limitations of laptops), rather than the software itself. It seems too that it is the junior staff who more clearly see EP ( rather than other HIS functions) as a benefit, despite the initial effort to learn it and their short term appointments (see Figure 24). Younger doctors are more likely to see the computers as a future, as a part of a natural progress. As one young house officer said:

*“The way forward is definitely computers. Change what you can but it’s quite difficult not to use computers”*

*“It takes four weeks to get used to the system and once you’ve got the system working, you cannot imagine how you ran 45 patients with drug charts all over the hospital. Because...jobs which will perhaps take you two hours in a... hospital with paper charts, you can do all that in half an hour easily....I think it’s fantastic, electronic prescribing. It is like using a GP system. All your drugs are on there, a lot of them have got your doses, so you don’t get spelling mistakes. What you prescribe is what you get given and there is none of this confusion.”*  
*[Junior doctor]*

*“They [computers] are everywhere in the hospital! Everywhere. Every single place in the hospital. I won’t do it without. No computer, I won’t do a clinic. Because all the letters are there, the last letters, the new letters, the results, the trends, other peoples letters, they’re all organised. My notes come that thick, I can’t go through that in a clinic.”* *[Senior Doctor]*

**Figure 24: Some positive opinions expressed by doctors**

### Nurses

Like doctors, nurses use the HIS extensively in their work, and EP is just one aspect. Nurses’ attitudes, as reported to us, have changed over time – from mixed feelings, anti-new system, apprehension and fear, to acceptance and a generally “taken for granted” feeling.

The sequence in which the modules were introduced may be significant here, and this was deliberate. The Admissions module was done first but then soon after Order Entry and Results Reporting were implemented, so that staff could see real benefits in terms of not having to chase up test results. It appears that senior nursing staff quickly saw the advantages. However, the nursing module (introduced in 1992/3) was a problem, because nurses had to input their notes (including physiological measurements such as blood pressure, fluid balance etc) on to the system but they felt they got little out of it. One system trainer, herself a nurse, told us:

*“On the whole the nurses are very positive towards the system, they are vigilant as well if they think something is not quite working right, they are good at reporting it, more so*

*towards the help desk.....[ ]They [nurses] were probably more sceptical over electronic prescribing than anything because they are safety conscious and it has got to be safe”.*

### Pharmacists

Any EP system would be expected to have significant consequences for the structure of pharmacy work, offering opportunities to change the way it is organised. One good example illustrated here is the way that, contrary to the usual arrangements in UK hospitals, pharmacists at QHB are attached to consultants not wards (except for care of the elderly where one person does those three wards, for geographical reasons). It may also be significant that, at QHB, pharmacists do not tend to rotate but retain their specialism. A number of pharmacists at QHB have been there for many years and have seen the system from its inception to the present state.

In general, the pharmacists had a positive attitude towards HIS and EP, and none wanted the system to be taken away. As one said: *“I just think this is so much better than the paper system”* .

The impression given in interviews was that the structure of the system fitted well with the way pharmacists work; methodically and carefully and in collaboration with other health care professionals. Although the system might be seen as extending control over the way they work, it also offers them opportunities for more control over their workloads ( the flow of information and the times they do their work), allowing prioritisation and flexibility.

### **Process**

#### Doctors

As is usual in hospitals, most prescribing is done by junior doctors, usually house officers (HOs), and the vast majority of prescribing in QHB is done electronically (sliding scale insulin and neonatal gentamicin being two exceptions). For doctors this is the most immediate process change brought by EP. Prescribing is also a more distributed activity, with many reporting making prescribing decisions remote from the patient, for example at a screen in the doctors' mess.

Senior doctors choose to use (or not) HIS in different ways and to different extents. Some have embraced the system enthusiastically and considerably altered the way



they work (what, how and where). For example, one senior doctor reported regularly accessing patients' notes and ordering tests remotely, often from home.

Junior doctors reported that, by accessing computer records, they can more easily deal with out of hours calls, sometimes avoiding going to the ward. Because of this some things, for example about a patient's condition, might be missed. This risk had existed before EP with telephoned orders but in that situation there was an additional risk of confusing exactly what had been said. It could be argued that because doctors have access to computer records they are less likely to go to see the patient in such a situation. However, as one junior doctor suggested: *"I think the people who would have got out of bed then, still get out of bed now."*

One doctor also noted that an on-call doctor looking after a very ill patient could deal with other problems via a computer and continue looking after the vulnerable patient instead of having to go to another ward. This was more effective use of time and might lead to better patient care. However, she also thought the EP system had changed aspects of the way she worked :

*"Sometimes you have to remember, as well, to tell your patients if you are starting on a new medicine. If you are going down to the end of somebody's bed and scribbling on their chart it does kind of jog your memory....But [with EP] you can say 'I have seen this patient' when what you have actually done is prescribe".*

As a result of changing practices (facilitated by the system) many doctors noted that they have less personal contact with pharmacists. Some did not even know who is the pharmacist working with them.

*"I hardly ever see a pharmacist now. Just get random bleeps".* [Junior Doctor]

Opinions differed regarding the potential effects the use of the system might have on doctors' prescribing practices. In the words of another junior doctor: *"It just makes you think a little bit more. Because it saves time, it saves errors elsewhere"*.

Another junior doctor did acknowledge that there was a potential risk of relying too much on the computer:

*“Maybe the consultants are worried we’ve lost our thought process, we don’t think any more. We don’t realise we’ve accidentally added a zero, or just copied what the patient had written down, which was wrong.[...] Computers are there to help us but we still need to use our brains. As long as we check up on each other ... “*

But contrary to a prediction that doctors might lose prescribing skills by using EP, one SHO noted that she learns things about drugs while using HISS. She told us:

*“I do find it interesting. I have sort of learned things occasionally- oh, I didn’t know that drug did that to that one”*

### Nurses

The introduction of EP meant a major change of medicine administration practice for nurses. The primary benefits cited for EP were that medication orders were legible, standardised and complete, and that a patient’s medication record was always available. Nurses felt the system was safer but not necessarily faster than with paper charts. There were benefits in terms of time which had previously been spent on checking and ordering drugs for inpatients, and on visits to the pharmacy to chase up discharge medication (TTOs). The EP system automatically flagged up prescribed items which were not carried as check the progress ward stock, so nurses no longer had to do “out of stock” lists. TTOs were printed out automatically in the dispensary, and nurses could check on the system to confirm when they had been dispensed.

At times nurses might need to discuss drugs with patients so they learn how to take them. This was easier with a paper record. One nurse caring for elderly patients explained:

*“Before, you would sit with your patient and have their medication printout sheet with you . Obviously you would have your own printout sheet with you, but the list you would work down together.... You would be more like the patient sitting in the bed and you right by them. [Now] I am having to turn and look down at my screen”*

Another nurse, prompted by the interviewer on whether using computers meant that nurses were getting further away from the patients, said:

*“Well, it isn’t the way it should be, but I can’t see an alternative....It is so American now, with people suing for everything and you have to cover yourself.... You have got to be accurate, you have got to cover yourself if it ever came to court.”*

While some nurses cite improved communication between professionals because everyone has access to the system, one nurse pondered: *“I think sometimes we do communicate too much with the computer but I suppose at least it is useful that we can always look back and see what professionals said about a particular case...”*

It was suggested that it might be easier for junior nurses to call doctors to check something, knowing they do not have to come all the way to the ward. This can also mean that certain orders are done faster. When the need arises, nurses can also search the system to check how drugs should be administered and thus might be more likely to challenge doctors. They also appreciated the facility to write notes on the system as to why drugs were not given.

However, like doctors, some nurses noted that the computer system is less flexible than the paper system. For example, notes regarding administering a drug in the future cannot be made on the computer record.

### Pharmacists

As noted earlier, the system allows pharmacists to a degree to choose how they go about their daily tasks. They can either use EP on the ward or somewhere else (for example, at their desk in pharmacy). The system allows them to refine their process, for example when reviewing to focus directly on new items, and items marked as needing monitoring. These items are checked daily, while other orders might be looked at once or twice a week (for example, to check that an antibiotic course doesn’t go on for too long). While doing such clinical checks pharmacists can check varied information within HIS. For instance, pharmacists reported often reading nursing notes, for example to see why a patient has been admitted, and also accessing relevant test results.

Checking can be done any time, even when doctors are doing rounds, as computer records can be accessed by many, with no need to have a set time or set amount of time, so pharmacists are no longer tied to the ward timetable.

Some reported a preference to do their work in the pharmacy which gave them the opportunity to do clinical checks in a relatively quiet environment. One pharmacist chooses to print out a “to do” list in pharmacy and then does clinical checks on the ward when doctors are doing ward rounds. Others reported *not* going during rounds.

Easy access to information may mean that pharmacists are more likely to be more thorough in checking different results and more pro-active in finding problems. One described it thus:

*“... because we are linked in with biochemistry with the pathology reports, with the X-ray reports, we have got access within pharmacy to just about everything now. So we can actually do our monitoring of things like the electrolytes, checking on the bacterial growth that they have got the right antibiotic. We can do it here and be far more efficient and again far more pro-active whereas if you are having to go up to a ward, rifle through the notes ... it does not get done as much, the result may have been telephoned through but you are not aware of it.”*

However, they were more likely to do this from desks in the pharmacy, and less likely to have direct contact with patients and other health care professionals on the wards.

*“I think the thing that hit me most was the fact that we had been used to going around the wards and often the cards were by patient and suddenly that contact had gone so we were here sitting at our desks in pharmacy and unless there was a definite reason for us to go and see the patient then we didn't see them”*

As one pharmacist admitted: *“So you possibly lose some of the contact that you will have had – not with the patient – but more with the professional staff. Whereas you may have been going and having a word with the doctor and you would be doing it on a face to face basis so you could build up a relationship, that is I think harder to do because everything is done with the computer and then it is perhaps done with a telephone call and they do not know who they are talking to. [...] We see them [nurses] less. I would hope that when we do contact them that we are being more pro-active and more positive, so perhaps what we say is more relevant.”*

Some argued that the system allows pharmacists to focus on cases which need investigating. The contra argument is that patients should be seen as patients, not as a set of notes, and talking to patients and seeing them in the flesh is important. One

pharmacist described being told by a patient, who had been in hospital several weeks, about a medication which had been missed off on admission.

However, as one pharmacist pointed out, rather than just asking patients general questions, pharmacists can now go to wards prepared, after checking different results, and then ask patients specific, targeted questions. Furthermore, some argued that even when pharmacists used to go to the wards all the time the quality of care wasn't necessary better – did they really talk to patients or just look at the drug chart at the end of the bed?

In terms of quality of working life there was a difference of opinions. Some pharmacists enjoyed working at the pharmacy, having an opportunity to do clinical checks in a quiet environment without many disruptions. Others would have preferred to be on wards more.

For pharmacy work itself the system does seem to facilitate significant efficiency gains. It speeds the supply side and order turnaround time (i.e. from prescribing to dispensing of a prescribed item) is reported as much faster than in other hospitals. The system also allows the supply and clinical sides of pharmacy work to be separated and done by different professionals.

The system also facilitates an enforcement of the hospital formulary, described by one senior pharmacist as: *“wonderful with the EP, because there is a flag on it saying it is prescribed, yes or no, and if you put no then it doesn't come up and they can't prescribe it.”*

#### Other health care professionals

EP had a significant impact on the practice of dieticians at QHB. One told us that, at her previous hospital, nutritional supplements had to be ordered by doctors because only they were allowed to write prescriptions. At QHB dieticians did their own prescribing using the EP system. The benefits (better access to patient information; better organisation of time; more visible errors) and drawbacks (lack of flexibility in administration times; system crashes) were similar to those cited by other professional groups.

Interviews with other health care professionals revealed little direct involvement in the EP aspects of the system, but emphasised that easy access to information seems to encourage inter-professional communication. A speech therapist described how, before the HIS, no-one outside her profession saw her notes: now “ *if a nurse or a physiotherapist wants to look what I’ve done then they can actually access my notes directly through the system.*”

### **Outcome**

The majority of people interviewed were satisfied with EP and more generally HIS and did not want to go back to a paper-based system. However, one doctor we interviewed was not sure if she wanted the system to be abandoned but did express a preference for it not to have been implemented in the first place. However, because it has been consistently the Trust policy to have EP, such problems have been worked through and generally EP is in use, even if, as reported to us, they still have “ *niggling problems*”.

Most doctors, nurses and pharmacists interviewed considered the system as safer because all information is available at hand and certain procedures are made easier. Because of the easy access to test results and nurses’ notes, as well as prescribing data, doctors and other health care professionals are more likely to check such items.

Specific issues of safety mentioned in interview by doctors as outcomes included:

- More attention to drug-drug interactions in prescribing and dosing options.
- Prescribing warfarin: ability to check INR (international normalised ratio – measures clotting time of blood).
- Legibility and completeness of data.

*“I think if you trained well and if you know your drugs well, this system supports you rather than makes you more dangerous”* [ junior doctor].

Nurses too perceive the system as safer. “ *Yes it is a safer system and it makes us feel better.*” [senior nurse].

A related issue to safety is visibility of data and the audit trail produced:

*“That’s another big bonus of the system as it stands is that you have, if a drug has been given you can see that it has been given and if it’s not been given, you can see why it’s not been given. And it is verifiable and you can tell who did the ward round giving drugs out”*[senior doctor]

Pharmacists were aware of different errors that might result from (others) using EP. For example, they mentioned doctors making picking errors (picking a wrong drug or even a wrong patient from a list), risks of making errors when patients are transferred from wards not using EP, and risks resulting from systems crashes. They also acknowledge that the way their practices have changed might lead to some risks. For example, some prescriptions are only reviewed once (usually only new items are checked unless some items are marked for continuous monitoring). So, if something was missed it may not be picked up till much later (for example, during discharge).

However, pharmacists interviewed generally perceive the system as safer, citing the usual aspects, including legible and complete prescriptions, greater accessibility of records and access to test results, as well as such features as automatic production of labels.

The general hypothesis is that a safer system in specific areas should lead to a better care overall. However, as our discussion above suggests, EP facilitates some more qualitative changes in the way care is performed and in the nature of relationship between different professionals, changes which might have significant implications for patients safety and quality of healthcare.

A significant outcome for both doctors and nurses is the different ways that the computerised records afford for visualising information. Some suggested that, compared to a paper-based chart, the system does not provide an equivalent overview of drugs. A small minority of doctors interviewed do not like EP because of this; one said he would like to “*dynamite*” this particular module. This seems to be a particularly acute problem in neonatal, as one paediatrician described:

*“When it’s on computer you have to just go into it and people may sometime just continue the medication even when it should have been discontinued or something and you can’t really see what the child is on. So some people just didn’t like it.”*

To the degree that the system makes practice more visible, this should result in increased safety. It also leads to a better awareness of variations in practice. For example, timings of administered drugs is now recorded. This was reported to have made nurses realise how often drugs are not given at times when they supposed to have been given (for example, because a drug round takes a long time), and also how practice differs in each area (for example, what is acceptable practice - such as waking patients to give them drugs early in the morning or not).

Because of the potential for audit, mistakes are more visible and more accountable. As one of nurses said: *“you are aware that it is your number in there.”* But this also means that potentially mistakes may be rectified quicker and that people can learn from them.

*“ A lot of the time these things would have happened on paper anyway – you just wouldn’t have been aware of them. [...] So I can’t say that the system causes errors. There is [no] perception out there that it does cause errors. I think most people appreciate that this system shows up the errors but doesn’t actually cause them”* [core team member]

We cannot say whether the system actually saves time for nurses or doctors and this was not directly the focus of this research. Junior doctors interviewed certainly *felt* it saved time on routine tasks such as ordering tests and rewriting drug charts (described as “mind-numbing” and “secretarial”), and both doctors and pharmacists said it cut non-productive travel time to and from wards. The nurses interviewed felt more ambivalent about it. According to some, drug rounds take less time, while others believe the opposite, because instead of looking at paper records nurses have to take a laptop to the patient. Time-saving examples they raised included: not having to query doctors about illegible or incomplete prescriptions; TTOs done much faster; no need to manually do out of stock drug lists.

From a dispensary service viewpoint (and also for pathology services), the more efficient use of time just produced more work to do. One senior pharmacist told us:

*“I think the workload has gone up a lot. We have managed to absorb it whereas perhaps we wouldn’t have done if we hadn’t got the system....We are lucky in a way that we don’t have a lot of vacancies which you do in the big city hospitals. At the moment we haven’t got a vacancy...but it [staffing level] hasn’t increased over the last*



*two years so there is actually more pressure really.... You don't actually get any reward for being efficient sometimes, do you?"*

Finally, we must acknowledge that you cannot improve everything with a computer system, there are other bottlenecks and constraints. Thus a nurse on COE reflected:

*"Social services is a big problem with the elderly and there is always a lot of delay on it. So it has not really improved it on the computer, because social services are so delayed as it is. They are improving."*

### **B 3.3 Organisational context**

#### **Structure**

A number of the essential organisational elements have been introduced already in this Chapter. These include the long term commitment of the hospital to computerisation including by many of its medical leadership, the stable labour force within the hospital, the commitment to training and the established relationships with the software supplier.

It is significant that the HIS is well embedded in the hospital and expresses, and is expressed through, the general working culture. In this sense the HIS has become an accepted and almost taken for granted resource, developed, used, maintained and upgraded over the years and in use almost uniformly across the hospital. The required resources, skills and managerial competences are in place and seem to be working well to maintain the technical components and their integration within the working practices across the Hospital.

Through our interviews we have seen expressed a general agreement that computers are "the way of the future" and an acceptance based on experience of the "unstoppable progress" towards computerisation of hospitals. In this way, at QHB, EP has long been seen as natural and inevitable. Because of the largely successful implementation of different HIS modules, there is an atmosphere of quiet belief that they can get things right (have proved it), even if there is a greater distrust of national initiatives. It is significant that this is different to the prevailing NHS-wide image of IT as expressed in failures.

## **Process**

The section on Human Perspectives has outlined many areas in which the HIS has altered delivery and practice of health care within the Hospital. EP at QHB has to be understood as a part of a hospital-wide commitment to computerised systems and many of the benefits of EP come from its connectivity to HIS, allowing access to different data, for example patients' records, test results, etc. More generally, as a part of HIS, and therefore as a part of a wider hospital commitment, EP is not generally understood as a "pharmacy" project imposed on others. This aspect may be quite significant when comparing the experience at QHB with other systems in use in other hospitals – in particular the CHX ServeRx system described in this report. Our general sense from the two studies is that it becomes quickly important that doctors and nurses perceive EP as their system, rather than a system designed for and controlled by pharmacists. As suggested by one of the interviewees at QHB, doctors are the only group who has real power to refuse to use the system, but the support of nurses is pretty vital too.

The distinctive character of EP at QHB is manifested in many ways, but taken all together these can be described in terms of three key features – presented here in essentially positive terms.

*Establishment of a data driven practice* that assumes availability (and quality) of data and seeks to maximise the benefits that can be derived from the facilitation of a fluid interaction between health care professionals. Building on this, as we were told by one senior doctor, the system will become "protocol heavy" as a way to help doctors to keep up-to-date and as a primary means to achieving better quality of care for the patient.

*A process orientation* that lifts the individual health care worker (in particular doctor and pharmacist) out of specific times and places and offers them (at best) an opportunity to restructure their work and refocus their professional commitments. However, that such a system allows this does not mean that it will happen. Our research has shown that different professionals have chosen to do things differently – been allowed to choose – and in this trust policy, management practices and a positive organisational culture have been vital in ensuring that, for the most part, relationships between different professionals have been preserved.

*An organisational and professional alignment with technology and its suppliers, taken forward by responsible actors, enthusiasts and champions, and that balances resources committed to perceived benefits achieved, and future benefits to be strived for. The organisation has, from its earliest involvement with this technology, had a strong focus on workable (indeed working) solutions*

*“... it is only enthusiasts that take things forward in the hospital...” [Senior Doctor]*

*“We never buy anything in Burton that we haven’t seen in use.” [Senior Doctor]*

### **Outcome**

*“I think they [patients] think we are very advanced because we are using computers.”  
[Nurse]*

As has been mentioned a number of times, staff turnover at QHB is lower than in many hospitals. In part this is a feature of their location, but there seems to be some evidence that the HIS helps QHB to attract and keep doctors, pharmacists and nurses. House Officers reported that they are often keen to stay after their initial period, in part because of the computerised environment in which they work. (There were of course other factors mentioned: nice, calm environment; less “macho” culture, mature and very helpful nursing staff.)

It is then perhaps surprising that one outcome that has been often mentioned is that, despite the undoubted achievements of QHB in making EP and an integrated HIS work within the NHS structures, that they have received relatively little attention through a period in which computerisation of the NHS has been a major political policy. For now the system is going to stay, is sustainable, though the wider national programme (NPfIT/ Connecting for Health) is acknowledged as presenting some question marks for the future.

## B 4 Patients' Views

### B 4.1 Methods

The semi-structured interview (see Annexe Biii) was adapted from one already been used with inpatients at Charing Cross Hospital, the prospective arm of our study. Piloting took place on one acute medical ward in February 2005. Data collection began the following day, and was completed on a subsequent two-day site visit in March 2005.

To provide some consistency with the quantitative study, patients were recruited from general surgical (including orthopaedic), general medical, and acute care of the elderly wards. Recruiting patients or relatives from paediatric and off-site COE wards was not attempted.

Sampling was purposive, based on use of “*as required*” (PRN) medication and admission history. On each ward, the aim was to recruit at least one first admission, at least one previous admission to QHB, and at least one previous admission to another hospital.

A paper listing of eligible patients was generated for each ward by a senior pharmacist and then checked with the ward sister before patients were approached. Patients expressing an interest had the study explained to them, and were given a leaflet. Verbal consent was obtained and documented by the interviewer for all respondents. Where feasible, written consent was also obtained.

		General surgery	Acute medicine
Interviews were done on the ward, and took around 15-20 minutes.	<i>Gender</i>		
	Female	4	3
Written records were anonymised before analysis. Interviews were not taped, but the patient's comments were noted verbatim as far as possible. Text “ <i>in italics</i> ” indicates the respondents own words (For further comments on the methodology see Annex Bv.)	Male	8	4
	<i>Age (years)</i>		
	26-30	1	0
	31-40	2	1
	41-50	2	0
	51-60	2	1
	61-70	1	1
	>70	4	4
	<i>Hospital admission history</i>		
	First ever admission	1	1
	Previous at QHB	5	2
	Previous at QHB and elsewhere	6	4

**Table 46: Patient demographics**

## **B 4.2 Results**

### ***The patients and their medicines***

Twelve male and seven female patients aged from mid-20s to over 80 were interviewed on acute medical and surgical wards at QHB (see Table 46). Just over half (10) were over 60 years old. Seven had been in hospital for less than a week; the remainder from two to eight weeks. Only two patients were first-ever hospital admissions. The majority had been in QHB as inpatients before; 10 of them had also had previous admissions to other hospitals.

A listing of the current medication orders for each patient was produced by Pharmacy department staff immediately before the interview. One patient had been recently admitted and his records were not available.

All but two patients had current medication orders on a PRN basis. The drugs involved were for pain (9), sickness (9), constipation (2), night sedation (2) and bronchodilators (1). All patients also had at least one regular medication order (range 2-10 drugs).

In general, the patients were vague about their current medication, recognising painkillers and antibiotics but underestimating the total number of drugs they were on. Changes made to regimens on admission ( *“threw them all away and start again- I don't know what's happened”*.) and products from different manufacturers were mentioned as sources of confusion by older patients.

Only five said they had discussed their medicines with a health care professional since admission. One said *“ Not anything specific, but it's always good to question things. You shouldn't be passive”*

Of those that had not, only two said they definitely had things they would like to ask about their medicines. As one patient put it: *“Why am I taking them? What's it doing for me?”* But the majority had no specific questions, saying they had got used to the way things were in hospital. One patient was surprised at the idea: *“They say they've got the knowledge. You're going in to be made better. Why would I challenge my consultant who clearly knows best?”*

### ***Patient view of the hospital medicines system***

We asked patients for their general impression of the system for prescribing and administering medicines on the ward, and how satisfied they were with it.

We also asked specific questions about missed or refused doses, access to medicines outside normal drug round times, and discharge medication.

### ***General satisfaction***

Patients considered “the system” as the ward environment, with all its equipment and staff. *“Just pleasant polite staff. Brilliant technology, the future. Beats a load of paperwork, notes getting lost.”*

The computer on the drug trolley was only a small part of this system and not particularly important.

*“When you are really ill you don’t give much thought to the drugs trolley. ... They check your number to make sure. I’ve never known any different. It seems to work”*

The majority rated themselves as very satisfied with the system which they saw as modern and efficient. Cited benefits related to time-saving for nurses, legibility, rapid access to notes and other information, and a visible checking process which one patient said made him “*feel safe*”. Another patient explained:

*“I can see them doing it. It’s one of the most efficient ways they can work, and less complicated. If you start making things complicated it’s bound to confuse. That’s how mix-ups and mistakes happen”*

Another thought EP was:

*“Probably a lot safer than writing it down. No human brain is infallible, you could forget. It’s on the system so you know. Time due-you need to know you haven’t given it too soon or too late.”*

However, one patient felt unable to give a satisfaction rating because it was humans who put the information into the system, and they could make mistakes. If a member of staff was called away in the middle of a round they could get “*side-tracked and forget*”

*what they were doing*". It was also possible to make mistakes if the screen was not user-friendly, or if the sun was glaring on the screen.

Two patients said they were not satisfied with the system. Both related to delays in prescribing and administration of medicines. One patient who had been prescribed a midday dose of an IV antibiotic said she was still waiting for this at 2pm. She felt that wards varied; the one she was on was "*too laid back*".

### **Questions and concerns**

We asked patients if they had any questions they would like to ask the hospital about the computer system. Only one specifically said yes (about test results) However, a range of concerns were mentioned in responses to other questions.

Several related to the accuracy and completeness of clinical information obtained on admission. One patient who had been admitted to QHB before wondered why she had been asked again about drug allergies. "*I think it's very good but does it hold all your medical records? I was admitted 3 years ago- that information should be there already*"

Others wondered why their medicines had been changed. One patient said that he was not receiving all his medicines in hospital. At home he had eye-drops, but had not brought them in with him.

Two patients mentioned the system going down. One was also a member of staff, and described it as a "*nightmare*". The second was concerned about what happened if the computer was not working.

### **Better than paper?**

We asked patients how satisfied they would be if the hospital switched back to using paper drug charts. Eight said they would not be happy about this, eight were neutral and three gave no rating. Although many of the patients had had a previous admission at a time when paper drug charts would have been used, only two had specific recollections. Their views therefore have to be interpreted with caution as they may have been influenced by the way the interviewer described how a paper chart system worked.

In general, patients felt safer with EP (*"Humans make mistakes"*) and that things were "easier". They felt that less paperwork meant more time for nursing and that EP enabled accurate transfer of information between nursing shifts. One patient explained why s/he would be *"a bit worried"* if the hospital changed back to paper charts :

*"There's more backup [with computer]. Paper leaves a lot more room for things to go wrong. Staff are so overworked they don't need the extra hassle, especially if they are really tired. There are so many things that could go wrong. I wouldn't feel so confident"*

Confidentiality and security of personal information was an important issue for some interviewees. A paper chart was *"open to tamper with. It's not personal"*. With EP, *"no-one else can get at it"*. However, it would be quicker for doctors to see all the patient's medicines with a paper chart at the end of the bed.

One patient compared the two systems:

*"With paper, someone you wouldn't want to see your information could see it at the end of the bed. With computer, it's different. Someone you want to see your information may have difficulty accessing the computer for some reason"*

Patients saw nurses entering PIN numbers, and liked the fact that "Joe Public" could not view or change their personal details. One patient felt strongly that access to the system had to be strictly controlled, and that ensuring staff competency was an ongoing process because *"familiarity breeds contempt"*.

Losing the "personal touch" or the "human element" was mentioned repeatedly by one patient who was dissatisfied with the medicines system at QHB. She felt the doctor looked at the computer and not at her, and that they did not actually ask patients directly.

### ***Saying no to medicines***

Most patients appeared compliant and unquestioning, taking whatever they were given *"I say no to medicines full stop. [But] you are in hospital to get better. You must take the drugs"*. While they retained some autonomy over analgesia (*"Painkillers, you can please yourself when you have them"*), most rejected the idea that they might refuse a dose of another type of medicine if they felt it was not helping them. *"You cant just say when you want it. I take what the doctor tells you to take"*



The majority (12) were not aware that nurses could record on the EP system the reason why a dose was not given. Most thought this was a good idea because people who didn't take their medicines were "*not helping themselves*". The EP record indicated that there was "a problem", and helped transfer that information when nurses changed shift. (*"There's no error, if someone forgets to tell, it's on computer"*)

### ***As required (PRN) medicines***

All but two patients said they were aware that they could ask for medicines outside the normal drug round times. One of those patients had not been prescribed any prn medicines; the response in the second case was unclear.

Seventeen patients had been prescribed at least one prn medicine. However five of them were unaware of this. Two had been prescribed as required anti-emetics but no doses had been given; the remaining three patients had a variety of prns, including analgesics, laxatives and bronchodilators.

For the majority of patients, as required medicines meant painkillers (although bronchodilators and laxatives were also mentioned) and the system for getting them when they needed them worked pretty well. Nurses asked patients during normal round times; outside these patients press a call button or asked a nurse. The post-op analgesia and anti-emetic order sets allowed the nurse flexibility in choice of painkiller, but no patient mentioned being given a choice. Some types of prn medicine (inhaler, skin creams) were left with the patient.

As with the Serve-Rx system at CXH, nurses did not have to bring the drug trolley to the patient bedside. "*If you say you want something you get it. You just shout to them. They don't bring the computer –just bring two tablets*"

Patients were aware that checks were made on the frequency of prn dosing. One described asking a nurse: "*if I get a twinge I'll ask "am I due"?*" Another said: "*the computer checks to make sure you are in timescale*"

However, if prn medicines which the patient normally took at home had been missed on admission, the outcome could be less satisfactory:

One elderly patient who had suffered from migraines since a child developed symptoms when in hospital. She said she had tried to explain to two doctors the drug

she usually took at home, "... *but they didn't understand and didn't prescribe it*". Instead she was first given tramadol, despite saying that she usually took something else.

Her migraine had continued to worsen and she had started to vomit. Later she received co-codamol ; there was a delay in getting this prescribed, and it had not been as effective as her usual treatment. She told the interviewer she had experienced "*a day and a half of pain which could have been relieved much earlier*"

### ***Getting medicines to take home***

We asked patients who had been in hospital before what they remembered about getting medicines when they left hospital.

Eight people said they had been prescribed medicines to take out (TTOs), and gave positive accounts of the time the dispensing process took. One patient described waiting "*about 3 hours*", but most waits were shorter than this, and several described their TTOs being "*ready on the ward*" when they wanted to leave.

Another compared the supply process with and without EP:

*"It was very quick and correct. The previous hospital was terrible. I waited half a day"*

### ***General views on computers/IT***

The interviewees expressed a very positive view of computers, seeing them as "*the future*" and "*a good thing*".

*"Computers are more efficient, better on confidentiality. Paper is not lying around for people to see. Access is more secure. Computers make things better for the future"*

There was a sense that having computers in hospital was the inevitable next step because "*everybody uses them now*". They were fast, efficient, prevented duplication of effort in communication and saved getting "*bogged down with paperwork*". Patients noticed them on the front desk of the hospital, in outpatients, in A&E as well as on the ward desk and the drug trolley. One patient said computers generated a background noise which told him that they were "*always here*". Another thought there was one under his bed.

In a minority, there was also an awareness that computers were not foolproof, and that backup systems were needed in case they went wrong. The system could not be considered in isolation from the users: *“Computers have got to be good. But nurses are key-the people who use them”*.

### **B 4.3 Conclusions**

These data provide a complementary perspective on issues raised in staff interviews, particularly with regard to accessing and sharing information, professional accountability, and personal communication. As with staff, “the system” for medicines was seen as more than EP itself. In general, patients perceived EP as safer and more efficient than paper charts. They also saw it as more secure and confidential.

## **B 5 Summary of evaluation: key findings**

### **B 5.1 System Functions**

#### ***Structure:***

- EP implemented as a custom-built front end for Meditech pharmacy system.
- Developed as part of a whole-hospital HIS, interfacing with other HIS modules.
- Accessed via wireless laptops, static PCs and dumb terminals.
- A number of technology problems including competition for laptops, short battery life and sometimes unreliable wireless connection, but technical capacity of the system is not seen as significant hindrance to clinical activities.
- DOS interface perceived as initially difficult to learn and requires complex combinations of keystrokes. However, this system is perceived as more stable and safer than Windows systems.

**Process:**

- Few problems reported with data processing and reliability.
- System enables co-ordination of work within the hospital to support the patient care process and allows different health professional groups to share data, communicate and justify decisions.
- Facilitates rapid availability of test results, accurate medication history on transfer to another ward, and legible, timely discharge letters containing a complete list of current medication.

**Outcome:**

- A stable, usable, continuously evolving system which supports the complex workflows surrounding medicines use
- Generally meets local user needs, though lack of reporting facility noted.
- Most data collected is judged as of good quality (more complete, legible, accessible) and is sharable among multiple users.

**B 5.2 Human perspectives**

**Structure:**

- Formal on-going training programme with dedicated system trainers supported by informal staff mentoring by more experienced colleagues.
- Individual professional groups are willing to work through initial problems and adopt a new way of working that may not always provide their own group with obvious benefits.
- View of computers as part of natural progress.

**Process:**

- Legible, standardised, complete patient medication records which are always available have made prescribing a more distributed activity with some decisions made remote from the patient.
- Effective multitasking when on call is easier.
- Fits well with the way that pharmacists work, and offers new opportunities to change the way that work is organised.
- EP both improves and diminishes inter-professional communication and may reduce direct communication with patients.
- Potential risk of “deskilling” prescribers is balanced by opportunity to learn new drug information.
- Availability of information may empower nurses to check and challenge doctors. EP facilitates enforcement of Trust prescribing policies.

**Outcome:**

- Perceived by staff and patients as more efficient and probably safer, with a better audit trail than with paper records.
- Patients perceived EP records as more secure and confidential. However, the system is also perceived as introducing new types of “picking” error when prescribing.
- Changes in working practice for all health professionals, helping them manage and use time more efficiently and effectively.
- Significant change to the working practices of pharmacists, with less pharmacy work done on the wards but also more freedom for individuals to define their own way of working.

- Practice of all health professionals more visible, highlights variation in practice, and makes mistakes more visible and accountable.

### **B 5.3 Organisational context**

#### ***Structure:***

- Hospital has a long-term commitment to computerisation and an established, generally good, relationship with software supplier.
- From its earliest involvement with HIS, the hospital developed a strong focus on workable solutions that do indeed work.
- A stable workforce and the required resources, skills and managerial competencies to maintain the technical components of the system.
- A belief that they can “get things right”.

#### ***Process:***

- Doctors and nurses perceive EP as “their” system, not as a system designed for and controlled by pharmacists.
- EP (as a part of HIS) has facilitated an establishment of a data driven practice that seeks to maximise the benefits of inter-professional working.
- Offers health care worker (in particular doctors and pharmacists) an opportunity to restructure their work and to choose to do things differently.
- Organisation policy and practices have helped to foster the preservation of relationships between different professional groups.
- An organisational and professional alignment with technology and its suppliers, taken forward by responsible actors, enthusiasts and champions, balances resources committed to perceived benefits achieved, and future benefits to be striven for.

**Outcome:**

- A sustainable EP system that operates as just one part of a HIS.
- A system that attracts staff and may contribute to low staff turnover.
- Staff and patients perceive QHB as a modern, advanced organisation that embodies state of the art technology
- Staff often reflect on why, despite their success, they have received relatively little attention by policy makers.

## Annex Bi Analysis of initial scoping interviews

Themes from initial interviews could broadly be classified under two main headings.

1) *Getting there (surviving implementation)* Staff on the core team had all been at QHB for over 15 years and been intimately involved with the development of the Hospital Information System (HIS) from its first beginnings in the early 1990s. For them, “getting there” encompassed both their experiences of implementing and adapting the software, and how the system had changed the way they worked. The users had been at QHB for less time ( 1-5 years ) and had experienced at most only one upgrade (v4.8 in 2002) For them, “getting there” was described in terms of the initial training they got, and having support while they gained confidence.

All spoke of learning to trust the system (it did not increase errors; it made mistakes more visible). One core team member mentioned that the audit trail had not initially been popular with users “because it records who does what”. They also gave examples of things they would like to change (mainly around decision support and reporting facilities), but the mechanisms for registering suggestions and getting them actioned were unclear.

2) *Promise vs reality* All three prescribers had had some experience of traditional (ie paper-based) medicine systems and made positive comparisons on the availability, clarity and completeness of medication records, and on warfarin prescribing. These initial interviews made it clear that EP could not be considered in isolation; it was an integral part of the wider HIS system. For users not involved in its development, it was impossible to speak of EP without talking about test ordering and reporting, and reviewing clinic letters and nursing care notes.

Other, slightly more negative, issues to do with lack of flexibility in prescribing of specific drugs (insulin, IV fluids) and the scheduling of doses, were also raised.

All interviewees described a significant time saving with the system. However, they were ambivalent on the impact on face-to-face contact with other health professionals or patients



## Annex Bii Staff Interview guide for Queen's Hospital Burton

(Check current job title and where they work)

- How long have you been working at QHB?  
*(interviewer to clarify this in terms of timeline of the HIS project)*
- What was it like, learning to use the system? Did you have any problems when you first started? How were these resolved?
- Have you ever experienced the system crashing/going down when you've been using it or needed to access it? *(Lead on to ask about other critical events, risky situations – do they remember any specific events, what have they learnt from incidents like that?)*
- What would you miss most about the system if it went?
- What would you like to change about the system? *(prompts: reporting facility, allergies pop-ups, insulin etc)*
- What do you do if there's something you think could be improved? Are there procedures in place to deal with system improvement? E.g. User groups?  
*(probe: how easy is it to get things changed- feeling of involvement in the system development over the years)*
- Has your behaviour/practice been changed by the system? If so, in what way?
- How is the audit trail used? What do you think of the fact that there is an audit trail of everything that every system user does? Do you think it makes mistakes more visible? *(explore issues of accountability)*
- Have you had experience with paper-based systems? *If yes, do you think the system makes you think more or less about what you do compared to the paper-based system? (prompts: are things sometimes too easy? Or does it encourage people to think, to “engage the brain”?)*
- Have you ever felt constrained in what you want to do by the system? *(explore dosing flexibility; timing of doses etc)*
- Has the system ever pushed you to make a certain decision? *(prompt: ever had to do something that was against your professional judgement?)*
- Has the system affected the amount of time you spend with patients? *(if no experience of other system, ask if system helps or hinders time for direct patient contact)*

- Has the system affected the amount of time you spend with other health care professionals? (*prompts: better or worse relationships compared to using a paper-based system. If no knowledge of other system, ask if system helps or hinders time for direct patient contact*)
  
- Who is more in control – you or the computer?
  
- Does the system make you feel safer?







**Q. 5** In most other hospitals medicines are listed on a paper “drug chart”. This is often kept at the end of the bed. Nurses use the paper chart to record when medicines have been given.

**A.** Do you have any experience of this paper-based system (as a patient or otherwise)?

Yes  **GO TO Q5B**

No  **Go to Q6**

Don't know  **Go to Q6**

**B. *If yes, probe:*** Can you tell me more about that? How well did that system work for you?

**Q. 6** The system works as follows. Details of all medication are written on a paper drug chart which is usually kept at the end of the bed, so anyone can look at it. This paper chart shows everyone involved in your care which medicines you are on now, and what you have had since coming into hospital.

When the nurse reaches your bedside, he or she would read the drug chart and select your medication from the drug trolley. They would then give you your medicine, and initial a box on your drug chart to show that it has been taken.

**A.** What do you think of such a system?

**B.** Do you have any reservations about that system?

**C.** Do you think that such a system would have had any advantages over the current computerised system?

*If yes, probe*

**D.** With a paper chart, the nurses are still able to give ‘when required’ medication outside the scheduled ‘drug round’. What effect, if any, do you think the computerised system has had on the way nurses administer ‘when required’ medication?



**Q. 10** Some people say this is a “paperless” hospital because it uses computers for so many things. As a patient, how do you feel about that?

*Probe: Are computers a good or a bad thing?*

**Q11.** Are there any questions you’d like to ask the hospital about how the computer system works?

**Q12.** Apart from the system for medicines, have you noticed any other uses of computers in this hospital?

*Probe: What have they noticed? How did it affect them?*

I am now going to ask you a few standard questions:

**Q. 13** How long have you been in hospital ?

**Q. 14** Is this your first time as an inpatient in a hospital?

Yes       **Go to Q16**  
No       **Go To Q15**  
Don't know

**Q 15.** The LAST time you were in hospital, were you prescribed medicines to take home with you?

Yes   
No       **Go To Q16**  
Don't know



**A. IF YES:** What can you remember about that?

*Probe: How long did it take for you to get your medicines? Were they ready when you wanted to leave hospital?*

**B.** What did you do when you needed a further supply?

**Q. 16** Finally, may I check your age?

- |       |                          |
|-------|--------------------------|
| 21-25 | <input type="checkbox"/> |
| 26-30 | <input type="checkbox"/> |
| 31-40 | <input type="checkbox"/> |
| 41-50 | <input type="checkbox"/> |
| 51-60 | <input type="checkbox"/> |
| 61-70 | <input type="checkbox"/> |
| >70   | <input type="checkbox"/> |

***Thank you very much for talking to me  
Reassure on confidentiality***

## **Annex Biv Medication errors with EP: Two views of the same picture**

Qualitative data on staff perception of errors has been claimed to provide weaker evidence than quantitative counts of actual errors<sup>97</sup>. The QHB study allowed us to compare the “error picture” provided by these two different approaches: interviews and structured clinical review of patient notes.

**Qualitative data** The primary aim of the staff interviews was to explore the impact of a whole-hospital EP system on working practices not to document examples of specific medication errors. However, it became apparent during the charting and analysis of interview transcripts that talking about the perceived benefits and drawbacks of EP had generated many accounts of specific errors which “could” or “might” happen, and also descriptions of near misses which had been made by other people. Nobody described an error they had made themselves, and there were no clear reports of actual harm.

The accounts covered the full drugs use process: including patient movement in and out of the EP system, and the types of incident described reflect the respondent’s role. Junior doctors (who do most of the prescribing) and pharmacy staff (who supply the drugs and review most of the orders) reported the widest range of incidents. Nurses focused on drug administration and were generally cautious in their responses.

**Quantitative data** The retrospective review of patient notes has already been described. (Chapter 5) In this, prescribing errors were classified on where they occurred in the drug use process, and also on the prescribing stage (admission, inpatient, discharge). A small subset of records was also reviewed for administration errors. All error records had a short text description containing information on the drug, dose, and clinical situation.

**Data comparison** Interview transcripts were searched systematically for accounts of medication incidents, both actual and hypothetical. A classification scheme was developed through iterative review of individual reports and applied to the text descriptions contained in the post-EP quantitative data sets (see Table 47)

### ***Comparative analysis***

Both methods covered the full drug use process but the range of drugs involved was wider in incidents identified from records. Interviewees often described incidents without mentioning the specific drugs involved. Warfarin was frequently mentioned in interviews, but anticoagulant errors detected in the review involved low molecular weight heparin, not warfarin. Insulin and intravenous fluids were two other frequently mentioned drugs.

Both methods identified decision support issues (drug allergy warnings; use of contraindicated drugs) although records review unsurprisingly contained much more detail on clinical need and drug knowledge (cautions and interactions with other medication).

Interview data provided more detail on the process of drug and dose selection by the prescriber, and identified two possible EP-specific errors: prescribing contraindicated drugs which were “hidden” in multiple drug order sets. and menu picking or scrolling errors for selecting patients, drugs and doses. It was not possible to tell if picking wrong drug or strength from menu was purely a scrolling error, or whether the prescriber did not know what the correct choice should be. Interviews with junior doctors suggested that some “cry for help” prescribing might occur. With paper systems they just “*scribbled at the end*” when they didn’t know a drug name and hoped the nurses or pharmacy would query it; with EP they knew the new order would be checked by pharmacy.

Interviews were also a rich source of information on reasons for delays or non-administration of medicines linked to the system for scheduling administration times. They also identified that urgent “stat” orders and some as required (*prn*) medicines were missed because they “*fell off the screen*”. In patient interviews we found some patients who didn’t know they had been prescribed *prn* drugs, and had never received them. Review of administration records produced a less detailed picture, but identified supply failure (dose omission because the drug not available on ward) which was not mentioned in interviews.

The majority of incidents described by staff (and detected in records review) were close analogies of things that also happen with paper charts (see following page for details). In interviews, screen views, notably the inability to “*see the whole picture*” appeared to

be mainly a problem for those relatively new to the system, (and much less of a problem than in the recent USA study <sup>14</sup> by Koppel *et al*)

The overall picture provided by the two approaches is similar in scope, but has logical differences in focus. Qualitative data identified all types of error identified in the retrospective notes review. The method also identified two “EP-specific” errors which were not detected (and probably could not be) by record review, and provided

Data source	PRESCRIBING								ADMINISTRATION				Non-EP interface		
	Clin need	Select Record	Select Drug		Select Dose			Select Form	Dose omission		EP record		Monitor	Adm	Disch
			Choice	Pick from menu	Dose Or strength	Freq	Dose duplicn		Stats/prns	Reg	Rx	Admin			
Junior doctors		✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Senior doctors	✓		✓								✓	✓	✓		✓
Nurses					✓				✓	✓		✓	✓		
Pharmacy staff		✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	
Record review	✓		✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓

**Table 47: Comparing medication incidents identified in interviews and by records review**

more detail on the process of prescribing and administering drugs on the wards. The data took considerably less time to collect, so associated staff costs were much lower. However this needs to be offset against transcribing and analysis costs.

So is one method really better than the other? If we are looking for evidence to help decide what to do next (as opposed to proving that X is better than Y) then interviews tailored to address policy-makers questions could offer better research value than the more labour-intensive records review, particularly if the study site is remote from the research contractors usual workplace.

### ***Comparison of medication incidents in interviews and record review***

**Clinical need** As might be expected, record review provided a wider range of examples where the need for treatment, review or investigation had not been met. Cases included antibiotic therapy for MRSA, potassium supplementation in a hypokalaemic asthmatic, hyponatraemia with fluoxetine, statins, salbutamol, insulin and oxygen. Interviews provided one example: neglecting to prescribe antibiotic cover for a patient with heart valve disease.

**Patient selection** A case where medicines had been prescribed for the wrong patient because the cursor was still scrolling down the list of inpatients when the enter key was pressed was described in a pharmacy interview. Junior doctors also described near misses, and said that this error could happen “*because you are not going to the bedside*”. Calling up the wrong outpatient record by entering the patient name rather than their hospital number was also mentioned. No cases of prescribing to the wrong patient were detected in the record review

**Drug selection** *a) drug choice* Knowledge-based errors identified in record review included a potentially clinically significant interaction between phenytoin and an antibiotic; use of acitretin in renal impairment and prescribing of a penicillin to a patient recorded as query allergic. Interviews with doctors mentioned lack of penicillin allergy warnings. The prescribing to an asthmatic of a non-steroidal analgesic drug as part of a post-operative “order set” was also described. Both record review and interviews identified unintentional drug duplication by prescribing paracetamol, and a paracetamol-containing combination product. *b) menu picking* Pharmacy staff described cases where doctors had ordered the next drug on the lookup menu. Drugs included methotrexate instead of methotrimoprazine (“*I don’t think she would have [hand]written the wrong one*”) and ethamsylate instead of ethambutol. This type of error was not identified by record review

**Dose selection** *Wrong doses, product strengths and dosing frequencies* were identified in both interviews and notes review. However the drugs involved were different. Interviews primarily cited warfarin and specialist paediatric drugs while errors identified in reviews involved sodium valproate, low molecular weight heparin and different paediatric drugs. Dose frequency errors frequently involved the lack of a daily limit on “as required” analgesics and anti-emetics, reflecting the inflexibility of EP for this type of drug order. Interviews generated two examples of possible dosing frequency errors: a one a week drug prescribed once a day, and drugs for Parkinson’s disease. The risk of *dose duplication*, where a drug was prescribed orally and by other routes to allow nurses flexibility depending on the patient condition was cited both in interviews and records review. *Formulation selection* errors involved enteric coated products (prednisolone in interviews; diclofenac in review).

**Dose omission** *Give now (stats) and as required (prns)* In interviews, junior doctors and nurses mentioned that stats and prns could be missed because they came at the end of the patient's drugs list. Frusemide was a specific example of a stat drug which had not been given. Record review did not identify errors concerned with non-administration of this type of drug order.

*Regular medicines* Interviews described how EP dose scheduling could delay the start of a new drug because of the default timings in the system. Some doctors explained how they had learned to get round this problem. Difficulties with flexible dose drugs warfarin and insulin were also cited. Review of administration records identified several regular drugs (including antibiotics and anti-epileptics) which had not been given because no stock was available on the ward.

**EP recording** The risk of dose duplication when EP records were incomplete or not available was identified in both interviews and record review. Nurse and doctor interviews described being unsure if a patient had received an analgesic dose or not when the system was down and there were no records to check. Record review found cases where analgesics and propranolol had been prescribed as regular drugs, but no administration records had been made so it was not clear if they had been given. Two interviews described cases where drugs (IV fluids and skin products) had been given but not prescribed on the system, or prescribed but administration not recorded. There was also a report that analgesic doses given in theatre (which does not use EP) might be repeated on the ward. Record review identified several cases where oxygen had been given but not prescribed on EP.

**Monitoring** Record review identified errors involving digoxin in renal impairment and aminophylline plasma levels Interviews generated a wider range of situations: warfarin, gentamicin, sliding scale insulin ( which is prescribed on paper charts) and electrolyte monitoring for patients on IVs.

**EP interface** One interview described a case where medicines had been missed off on admission. The patient had been in hospital for 2 months before she told the pharmacist that she normally used eyedrops at home. In another interview, a junior doctor spoke of a diabetic patient who had been discharged to a care home with no insulin because the prescriber had not put a note on the EP system. Record review found three cases where medication (salbutamol, amitriptyline, insulin) was not continued as expected when the patient moved.

## **Annex Bv Reflections on qualitative methodology**

### ***Identifying and recruiting staff respondents***

In this retrospective evaluation, the research team had little prior knowledge of the hospital, and did not have access to the names or job titles of key staff. The majority of potential staff interviewees were identified and arranged with the help of a key local contact, a senior hospital staff member who was a member of the core HIS implementation team. At Queen's hospital, this method worked very well and allowed data collection to be completed in 12 person-days. There was no evidence of bias in the selection of interviewees; the people we interviewed had a range of views on EP, and the wider issues raised by computerisation.

However this way of recruiting subjects relies heavily on the person selected as the key contact. He or she must not only be relatively impartial but also sympathetic to the aims of the research, and able and willing to help. We were fortunate; but there is no guarantee that this would be the case in every hospital

There are two ways of recruiting staff for an evaluation without the help of a suitable on-site key contact. The first would be to identify potential subjects from hospital ward or department staff lists or telephone directories, then write or telephone. This would require access to internal information which is not usually available to the public. The second method would be to advertise the evaluation and call for interviewees via posters or internal email systems within the hospital. This method was totally unsuccessful at Queen's Hospital but it could well work in another setting. Recruiting staff, and scheduling interview times would take longer, and this method would probably be less efficient in the use of research time.

### ***Qualitative data on medication errors***

The primary aim of the staff interviews was to explore the impact of a whole-hospital EP system on working practices not to document examples of specific medication errors. However, it became apparent during the charting and analysis of interview transcripts that talking about the perceived benefits and drawbacks of EP had generated many accounts of specific errors which "could" or "might" happen, and also descriptions of near misses which had been made by other people. Nobody described an error they had made themselves, and there were no clear reports of actual harm.

The accounts covered the full drugs use process: including patient movement in and out of the EP system, and the types of incident described reflect the respondent's role. Junior doctors (who do most of the prescribing) and pharmacy staff (who supply the drugs and review most of the orders) reported the widest range of incidents. Nurses focused on drug administration and were generally cautious in their responses.

Qualitative data on staff perception of errors is widely perceived as providing weaker evidence than quantitative counts of actual errors<sup>97</sup>. The QHB study allowed us to compare the "error picture" provided by these two different approaches: interviews and structured clinical review of patient notes (see Annex Biv for details)

The overall picture provided by the two approaches was similar in scope, although with logical differences in focus. Qualitative data identified all types of error identified in the retrospective notes review. The method also identified two "EP-specific" errors which were not detected (and probably could not be) by record review, and provided more detail on the process of prescribing and administering drugs on the wards. The data took considerably less time to collect, so associated staff costs were much lower. However this needs to be offset against transcribing and analysis costs.

### ***Conducting interviews with inpatients***

The short interviews we conducted produced a good deal of information on patient views of the benefits and concerns of EP. However the interview conditions were unsatisfactory, with patients in adjacent beds and nursing staff being able to hear, interrupt, and comment on what was being said. Patients were unwell, and some were clearly concerned not to appear critical of the people who were caring for them. They also had limited experience of any other medicines system. Some negative views were elicited, but in general it is likely that patients told us what they thought the hospital wanted to hear.

The HIS enabled inpatients to be screened against our selection criteria before visiting the wards. However, this initial list had to be checked by a nurse before we could know who was well enough to be approached. This had to be done on the ward, and took staff away from other more pressing duties. Ward sisters were notified that we were coming, but the level of co-operation was markedly better when we were introduced personally to senior staff by a pharmacist who normally looked after the ward.



<b>Ward type</b>	<b>On prn medication</b>	<b>Potentially suitable</b>	<b>Interviewed</b>
Female surgical	27	15	5
Acute elderly	22	?	4
Acute medical	11	6	3
Male surgical	8	6	6
Trauma	27	8	1
<b>Total</b>	<b>95</b>	<b>&gt; 40</b>	<b>19</b>

**Table 48: Patient sample frame**

Many patients were not actually available, because of examinations, personal care, off-ward investigations or visits from friends. Much of this non-availability could not be predicted in advance.

Having interviews done by hospital staff (as was the case in the prospective arm of the study) would probably make the recruitment process easier. However the concerns over bias would be greater.

An alternative method could be to use a self-completion questionnaire, given to a larger sample of patients on discharge and returned anonymously by post. Issues identified could be followed up in focus groups with a sample of respondents.

## **Appendix C. Issues for the economic evaluation of measures to reduce/avoid errors in the prescribing/administration of medicines on hospital wards**

*Professor Martin Buxton, Director: Health Economics Research Group,  
Brunel University*

### **C 1. Introduction**

The push for increased patient safety and the very proper desire to avoid, or at least reduce, errors in the prescription and administration of drugs within hospitals has led to the considerable interest in electronic prescription systems. This study has demonstrated, and no doubt others in future will also demonstrate, that such systems can reduce errors and increase patient safety but at a cost in terms of capital investment and staff time. It is essential that, prior to major system-wide investments in such systems, the cost-effectiveness of these interventions is carefully assessed, and thus their opportunity cost, in terms of other health care benefits foregone, is determined.

However, the standard approaches to economic evaluation of health-care interventions do not necessarily lend themselves to the evaluation of such systems. Standard methods of economic evaluation, as, for example, have been well developed and tested in the context of NICE, deal relatively well with well-defined, static technologies such as drug interventions provided on an individual basis to selected patients to directly achieve demonstrable improvements in individual health. Electronic prescribing systems have a number of characteristics that raise rather different issues. They typically involve high initial investments and need to be applied across large parts, or for maximum efficiency perhaps all, of a hospital. At early stages in their development the capital cost may be uncertain and an inaccurate reflection of future costs, either because of initial subsidy by developers or because future, larger-scale production would lead to lower costs. The systems may have small but widespread effects on resource use, such as the time of a large number of staff. Most importantly it is difficult to appropriately value the benefits: how should we value the avoidance of a “prescribing error”. Is that not dependent on the consequences of that error?

Moreover, these prescribing systems are embedded in complex and dynamic systems – hospitals – which exhibit a wide range of existing behaviours, patterns of working including current handling of prescriptions and resulting error rates. Even when we have established reasonable estimates of the cost-effectiveness of a particular implementation, the results may not be transferable or generalisable from that context to others.

This Chapter does not provide a formal evaluation of the cost-effectiveness of the ServeRx system at Charing Cross Hospital. Rather, in the light of the analysis of the “clinical” evaluation of that implementation, it reviews the main issues that will arise in future economic evaluations and indicates some of the problems that will have to be addressed and the approaches that may be useful in doing so.

The Chapter focuses on the following issues:

- Identifying, measuring and valuing the net costs of the intervention;
- Identifying, measuring and valuing the main benefits of the intervention;
- Implications for sample size and study design;
- Generalisability of results and the need for modelling alternative future scenarios;
- Conclusions and recommendations for future research.

## **C 2. Identifying, measuring and valuing the net costs of the intervention**

In estimating the costs of implementing a system we need naturally to consider both the one-off “capital costs” (associated with purchase and installation), the continuing direct running costs (including system management and maintenance) and the cost-impacts in terms of time of the staff who use the system or whose work is affected by it.

At early stages in the development of a new technology such as this, there may be difficulty in establishing the real cost of the investment. Systems may be provided on a non-commercial basis as test beds or as part of the producer’s development process. Whilst there should be information on the contract price for the investment, the development process may well be collaborative and this initial contract price may

reflect expectations by the supplying company of the value of the specialist or managerial expertise that will be provided by staff at the development site. Even if there is no expectation of input to the commercial development process, such expert time will still be required in implementing a major development of this sort. This implies that, as well as information on the capital cost of the system and its installation, data will need to be collected to estimate the main time inputs from those involved in the planning and implementation of the project.

Capital costs will need to be amortised over an appropriate period: that is the estimated useful life-time of the capital. There may be little direct experience on which to base this estimate. With new systems, in a rapidly developing market, obsolescence may well occur well before the equipment would otherwise need replacement. Or developmental systems may fail without producer capability to maintain them. Given that uncertainty, sensitivity of the cost-effectiveness to assumed length of useful life will need to be established.

As regards running costs of the system, this study has demonstrated how the difference in time taken by medical, pharmacy and nursing staff can be estimated. However, the valuation of small differences in time taken by staff may be more problematic. Whilst these could simply be costed at a marginal hourly rate for the staff concerned, it may be more meaningful to use diaries, or qualitative techniques, to try to establish what activities are displaced or curtailed as a result, particularly on wards where the staff time-complement is relatively fixed. Such an approach would indicate what are the direct opportunity costs of any extra time involved. The opportunity costs might be viewed as highly valuable, for example if the amount of time spent on direct patient care were negatively affected, or they might be rather lowly valued, if it were seen as drawing on otherwise unproductive time.

All these costs need to be expressed in terms of some unit of "activity" or "outcome". The next section considers the best ways to value the benefits of error reduction. However, if these benefits are not valued then it may make sense to estimate a cost-effectiveness ratio of *the additional cost per extra error avoided*. However, if the benefits of error reduction are valued then it would be better to estimate costs and the valued "benefits" per some standardised unit of activity – probably per (thousand) patient day(s). Data on patient days in the relevant wards should be readily available.

### **C 3. Identifying, measuring and valuing the main benefits of the intervention**

Whilst it is clear that all stakeholders value a reduction in errors, it is not clear how these errors avoided should most appropriately be valued. But, if we are to assess the cost-effectiveness of investing in error reduction, then the value we place on reducing the errors is fundamental. Two rather different approaches might be adopted. The first is to attempt to estimate an “intrinsic value” of avoiding an error. The second is to estimate the value based on the present value of the undesired course of events avoided. Each of these is considered in more detail below.

However before considering the underlying concept behind the value placed on an error, it is important to consider precisely how errors are defined.

#### ***What constitutes an error?***

Errors were defined in this study as:

*‘a prescribing decision or prescription-writing process that results in an unintentional, significant: (i) reduction in the probability of treatment being timely and effective or (ii) increase in the risk of harm, when compared to generally accepted practice. Prescribing without taking into account the patient’s clinical status, failure to communicate essential information and transcribing errors (from one prescription to another) were all considered prescribing errors. However, failures to adhere to standards such as prescribing guidelines or the drug’s product licence, were not considered errors if this reflected accepted practice.’<sup>31</sup>*

This definition is used by the Department of Health <sup>30</sup>. It is important to note that the definition refers to a “significant”, but significant is undefined, “reduction in the *probability*” of timely/effective treatment or “increase in the *risk* of harm”. In other words, actual “disbenefit” may not have occurred. Whilst this may be an appropriate overall definition of errors, it is a definition that includes a range of circumstances that would have very different clinical implications.

This issue is partially dealt with by attributing a “*clinical significance score*” to errors identified. This is based on a reproducible, validated scoring system for the clinical significance of medication administration errors. Errors were assessed on a scale of 0 (no harm) to 10 (death) by 5 independent judges, the mean of their ratings being used<sup>36,37</sup>. However, such definitions are not intended to accurately represent a classification of what is economically important, where economic importance may stem from one or both of two factors: a significant cost impact, for example, by leading to an extension of length of stay, or a significant health impact on the patient, for example by prolonging the period of recovery or producing serious side effects.

### ***Intrinsic value of error reduction***

Some stakeholders may well value error “reduction” per se. However, it would be irrational to be prepared to spend unlimited amounts simply to reduce errors. Using resources in this way has an opportunity cost to the NHS, which can easily be exemplified in terms of what might be achieved by spending the same sums on new expensive drugs or on the provision of additional capacity to reduce patient waiting times. But whilst this value is clearly finite, stakeholders might adopt a view that this value in avoiding prescribing errors is independent of the particular implications, or consequences, of the errors. This approach would imply that the value of avoiding any error is the same and independent of the severity of that error. Certainly, some of the rhetoric around error reduction appears to be consistent with this view. If this is the case, then it should be possible to elicit from groups of stakeholders (patients, nurses, pharmacists, hospital managers, politicians) the value they place on error reduction. This elicitation might be undertaken using contingent valuation methods or stated preference techniques.

However, it is unlikely that these values would be independent of an assumption about the consequences of an error, and in undertaking the elicitation the danger is that respondents incorporate an implicit assumption or view as to what are the implications of the errors they are valuing. And these assumptions will vary between respondents. However, this issue could be studied experimentally.

### ***Consequential value of error reduction***

It seems more probable that for most stakeholders the value they place on errors would vary with their perceptions of the severity or clinical significance. The avoidance of a minor error, say in dosage within the normal prescribing range which

was not likely to impact on the patient, would be less highly valued than the avoidance of a error in the actual drug prescribed which might be potentially fatal.

If the values placed on errors do vary with the significance of the error, then it may be more appropriate to estimate directly the consequential value of errors avoided rather than to seek stakeholders' perceptions of that value. Logically such consequential values might be expressed as the net present value (NPV) of the additional health resource usage plus the health loss (QALY reduction) resulting from the error. Whilst this may be conceptually clear, the process of estimation of such values is highly speculative.

In most cases, what is observed in a study of error reduction are instances where a defined error occurred but was quickly noted and rectified shortly afterwards. The very process of identifying errors in a study is likely to lead to the avoidance of their major consequences, for the severity of the consequences depends on how speedily an error is noticed and corrective action taken. Thus, we rarely have, in a study such as the prospective evaluation of ServeRx, observations of uncorrected errors. There is a substantial literature on the use of clinical judgement to assess both the consequences of identified and corrected errors and of assessing the avoidability (through error reduction) of severe adverse events, particularly deaths.

Fundamentally, the problem is that we cannot observe the counterfactual, that is to say: *“What would have happened in a particular patient circumstance if an error that was avoided had not been avoided, or an error that did occur had not occurred.”* Any attempt to estimate this is hindered by the problem of the huge between patient/case variability in the outcomes and circumstances, and the difficulty of predicting events “down-stream” of the error.

Nevertheless, these values remain fundamental to any serious attempts to assess the cost-effectiveness of error reduction systems and a substantial research effort to begin to attempt to estimate the NPV of such errors is urgently required, but will probably need to be undertaken as a separate exercise. The development in this study of a method of detecting prescribing errors from the patients' notes gives an indication of how this could be done, and provides some information from which a sample size can be calculated.

#### **C 4. Implications for sample size and study design**

The principal implication of there being very different valuations for different types of error is that for an economic evaluation we need robust assessment of the rates of reduction of errors of different potential magnitude. But generally studies are powered (as in this case) to provide accurate estimates of overall rates of error reduction. The problem is akin to that which arises in many cardiac studies, where, to achieve an adequate event rate a number of different cardiac events (ranging perhaps from angina to fatal acute myocardial infarction) are aggregated in a combined endpoint. But as they are clearly not “valued” equally they need to be disaggregated for purposes of economic evaluation. However, cardiac studies often do not provide sufficiently robust estimates of the rarer, but economically most significant, events.

This issue is illustrated in the data from prospective evaluation of ServeRx. Whilst the rates of prescribing error fell overall (from 3.8% of all medication orders written to 2.0%:  $p=0.0004$ ), and the mean severity of the errors hardly changed (4.2 pre, 4.6 post:  $p=0.24$ ) the percentage of these errors adjudged to be of “major” potential clinical significance rose from 3% (3) to 12% (6). Whilst this difference in rates was not statistically significant, the study was not powered to show differences in sub-groups of errors. Were such a difference to persist in a larger sample, it might well be of economic significance, and could conceivably mean that the estimated NPV of errors increased after the introduction of the ServeRx system. The problem here is that relatively rare events, the frequency of which are not well characterised by small studies, may be much more important economically than the common (more minor) errors that from the bulk of the events observed.

This suggests that for robust economic evaluation much larger sample sizes may be necessary. The alternative possibility is that it might be possible, from careful review of data from a range of such studies to establish, generalisable proportional frequencies for different types of error, so that it might be possible to estimate long-term/large-sample rates for major errors from the frequency of minor errors. Whilst such a possibility is highly attractive, the recent report on the use of Heinrich ratios<sup>80</sup> in this way suggests it would be unsuccessful. It also seems rather unlikely that generalisable patterns will emerge from studies in different settings. The issue of generalisability is discussed below.



## **C 5. Generalisability of results and the need for modelling alternative future scenarios**

Any single study such as the prospective evaluation of ServeRx, although important as an assessment of a particular application of computerised prescribing technology, may not be readily generalisable. What is observed is the product of a complex interaction between a particular early implementation of a specific proprietary version of the technology, interacting with, and compared to, particular patterns of working, prescribing and administration arrangements, and explicit (and implicit) operational protocols by a range of staff of varying skill/ability trialled on one ward within a particular hospital in the context of a particular non-random subset of the hospital's patients. The results are the product of these very specific circumstances and may or may not reflect what might be achieved, if any one or more of the circumstances were different. Therefore extreme caution should be exercised in assuming that the results from this study (clinical or economic) can be applied to different circumstances, even one as close as a different ward at the same institution.

This would be true of any single setting study, and, but for the unlikely possibility of a huge multi-centre study of various variants of the technology applied in a variety of settings, the evidence-base is likely to accumulate from a small but growing number of one-off studies. It therefore becomes essential that such studies provide all the key information (using consistent definitions and methods) to enable comparisons to be made and major differences and similarities established and potentially explained.

This also means that, for the purposes of using evidence from this and other studies to estimate the cost-effectiveness of future potential applications, a decision analytical framework is required that can draw on and synthesise data from the full range of observed experience, where necessary incorporating appropriate judgements as to the effect of different circumstances on the likely results.

## **C 6. Conclusions and recommendations for future research**

This study provides some important indications of the possibilities and challenges for undertaking a formal economic evaluation of an electronic prescribing system. As regards cost estimation, it emphasises the need to realistically estimate the initial costs which need to include not just the capital costs of the system and its

installation, but also the costs of the time of key staff involved in the development of the system/implementation of the project. Measurements undertaken in this study show that it is feasible to estimate the time implications for staff involved in tasks associated with prescribing/administration of medication, but this report emphasises that it may be more appropriate to establish the actual opportunity cost of marginal changes in staff time, rather than simply cost at a standard cost per hour. Nevertheless, costing of the system itself is not particularly problematic.

Much more difficult is the appropriate valuation of the errors avoided. Two approaches have been identified, and both merit further exploration. It needs to be established whether key stakeholders have a concept of an “intrinsic” value for error reduction, or whether a “consequential” valuation is more appropriate. If the latter, then a substantial programme of work is needed to establish a robust method of valuation and provide mean estimates of the value of avoiding different types of error.

The implication of the value of error avoidance varying with the significance of the errors implies that we need robust estimates of the reduction in error rates for different types of errors, particularly for significant errors which, because of their relative rarity, are not well characterised in relatively small studies. It needs to be explored whether it is possible to use aggregated experience or alternative data-bases to establish robust and generalisable ratios of different types of error that occur in different settings.

The problem of lack of generalisability of individual studies needs to be recognised and for the purposes of estimation of the cost-effectiveness of future implementations a decision-analytic framework will need to be used that can incorporate parameter values from studies of particular past implementations such as this as well as estimates of the value of avoiding different types of error. For this to be achieved requires that all such studies collect a set of consistently-defined key parameters that can be used in modelling. This study provides a starting point to define such a standard data-set.

## **Appendix D. Statistical issues in the evaluation of electronic prescribing**

*Dr. James Carpenter, Medical Statistics Unit, London School of Hygiene & Tropical Medicine*

### **D 1. Introduction**

With the increased interest in various forms of electronic prescription systems in hospitals, in the near future there are likely to be a number of studies, similar to those reported in this research project, to compare these systems with each other and with existing procedures. Such studies raise a number of statistical issues, both in the study design and the analysis. Informed by the practical experience with this project, and further reflections, we discuss some of these issues below and consider how they can be addressed. The aim is to give practical guidance for the effective design and analysis of such studies.

The aim of these studies is to understand the effect of introducing new prescription systems. The “gold standard” tool for establishing cause and effect in medicine is the randomised trial. By randomising the intervention to the units (i.e. wards in hospitals) randomisation seeks to ensure that the units receiving the intervention differ, on average, only in the intervention given, not in any other way. This ensures that effects can be confidently attributed to the intervention, rather than to any other systematic differences between units which happen to occur concurrently with the intervention and thus confound the intervention effect.

While a randomised study should be carried out to conclusively demonstrate the benefit of any system before its widespread adoption in the health service, we recognise that in the early stages it is not possible to perform randomised studies, usually because the interventions are being piloted in individual wards in a hospital.

Nevertheless, it is important to keep the “gold-standard” of randomisation in mind when planning these smaller studies. Specifically, we should always be on the lookout for possible systematic changes which occur concurrently with the intervention and whose effects may falsely be attributed to the intervention. While non-randomised studies can never rule out such biases, steps can be taken to minimise them.

Data arising from such studies also present particular issues for analysis. In particular, data are often discrete (being counts of errors of one form or another) and are also correlated. The correlation arises because each patient typically receives a number of prescriptions, and prescriptions are more likely to be similar within a patient than between a patient. This gives rise to so called *multilevel* data, where observations (prescriptions) are nested within patients. In turn, patients can be viewed as nested within surgical teams, within wards, and within hospitals. Failure to allow for this correlation can lead to bias in the estimation of an effect, and also over confidence in the precision or variability of any estimated effect. Both these errors can lead to misleading conclusions being drawn.

The plan for the remainder of this article is as follows. Section D.2 describes issues in the design of these studies, looking both at possible biases and how to avoid them, and how to choose sample sizes likely to give meaningful conclusions. Section D.3 elaborates on the analysis of the resulting data. We discuss some of the implications in Section D.4.

## **D 2. Design issues**

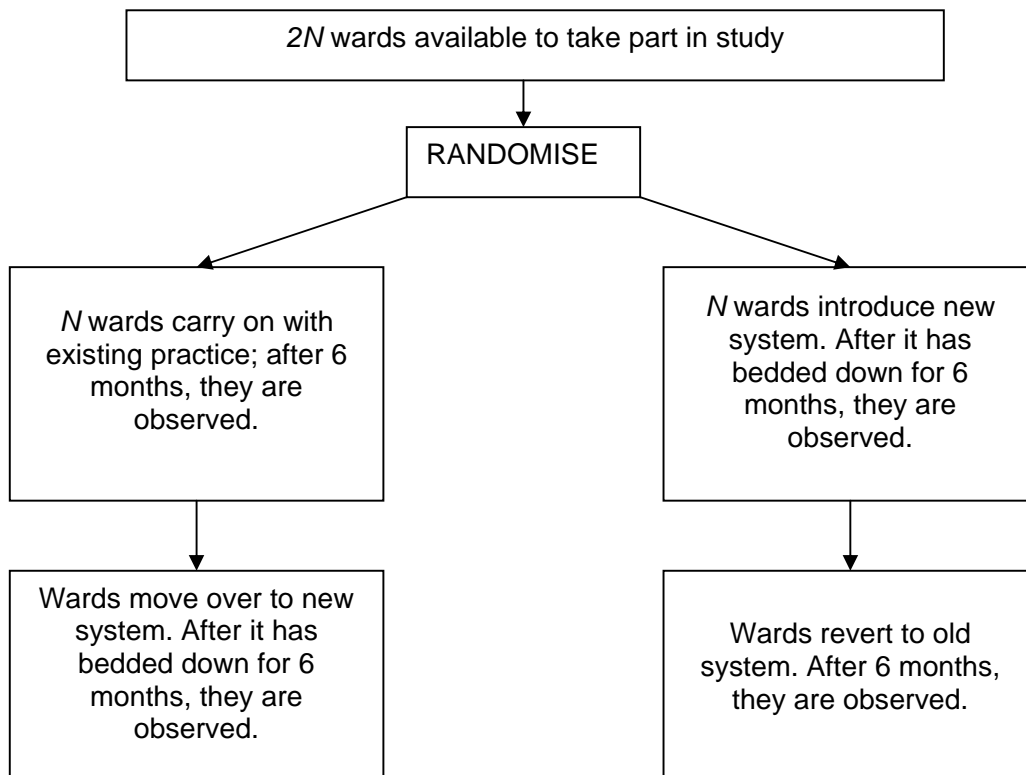
We have already touched on the importance of any study so the effects can be confidently attributed to the intervention. In order to do this, it is worth noticing how possible biases may occur. First, it is necessary to have a “control” group who do not receive the intervention. It is not sufficient to compare the results of applying the new procedure to a ward with documented levels of prescription errors from other studies at other times. The differences between patients and staff, and their resultant effect on the chance of prescription errors, make the results meaningless.

Having agreed that a control group is required, we need to think how best to choose it. The two factors most likely to change over time, and affect error rates, are the staff and the patient case mix. Further, the fact that staff are aware they are under observation is likely to result in atypical behaviour, which may reduce or increase the number of errors. Again, the introduction of a new system will involve training staff, and the possible presence of additional support staff (for example an extra pharmacist on the ward to help with the system). Both these have the potential to affect error rates.

### ***Ideal study design***

To address these concerns, we propose that the ideal study design for the investigation of a new treatment is a randomised cross over design carried out at the ward level. Suppose we

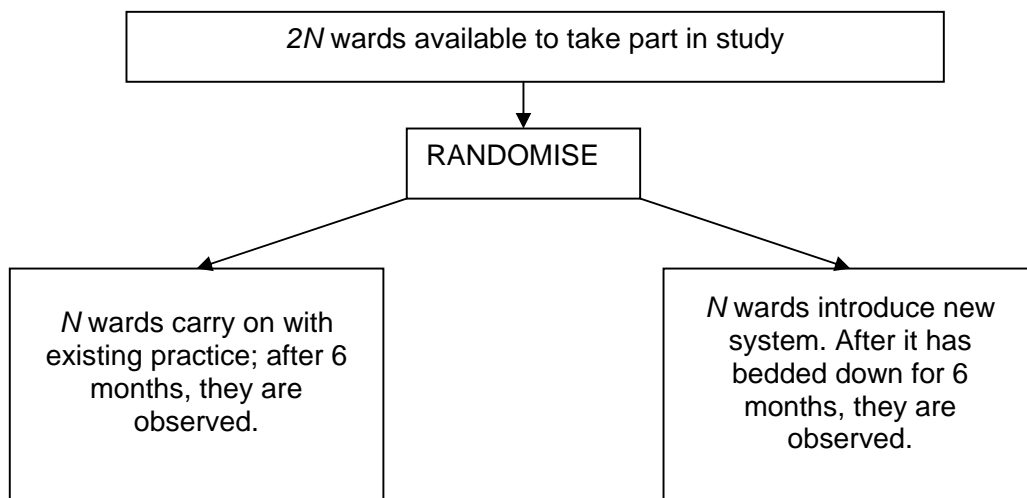
have  $2N$  wards where the electronic prescribing could be used. A possible design is detailed in Figure 25 below. Half the wards are randomly selected to receive the new system, and half to carry on as usual. Then, after say six months, when the new system has bedded in, both are observed. Then, the prescription procedures are swapped. Again, a period of time, say six months, elapses before further observations are made.



**Figure 25: Possible design for cross over study of electronic prescribing**

Although this design is more costly, and awkward for staff who have to revert to their original practice after using the intervention, it goes a long way to reducing potential biases. Wards are randomised to receive the intervention, not selected on the basis of past performance or willingness to try a new system. The same staff, on the same mix of patients, are observed operating both systems. Wards are observed over the same periods, so any variation over the year (e.g. due to seasonal change in patient case mix) is likely to be similar. This design has an additional advantage because there is likely to be marked variation in error rates, and the types of error, between wards. Thus, as each ward uses both systems, the effect of the system can be estimated in each ward, and fewer wards will be required in the study.

If, however, it is not thought practical to use this design, an alternative is a simpler two group randomised study, as shown in Figure 26. This does not have the advantage of the “cross-over” design where each ward gets both systems; therefore more (possibly considerably more) wards will be needed. However, it preserves the key aspect of randomisation and also matches the observation period for the new intervention and control group.



**Figure26:Design for randomised two group study of electronic prescribing**

### ***Non-randomised designs***

Here we discuss alternative designs where, for one reason or another, a randomised design is not possible. However, if experience from clinical trials is a guide (and there is no reason to suppose it will not be) even the best non-randomised studies can be seriously misleading, as biases occur in many, often unexpected, ways<sup>98</sup>

The aim in a non-randomised study is to try and re-capture what randomisation guarantees: that the intervention and control group differ only in which prescription method they use, so any effect can be attributed to the intervention.

This motivates the following guidelines

1. A ward should act as its own control

Differences between wards, in terms of case mix, staffing, staff procedures are likely to be substantial, and difficult to quantify, so comparisons with retrospective data from other wards and other hospitals will render the conclusions very unreliable.

2. Staffing

Similar staffing levels and, if possible, staff should be used for the control and intervention phase. In particular, if the intervention requires, e.g., an extra pharmacist on the ward, they should also be available for the control period.

3. Systems should be observed after they have bedded down, to enable a reliable estimate of the error rate.

4. Observation of the control and intervention should be at a similar time of year.

This helps reduce the effect of biases resulting from the time of year.

5. Subject to these two points, observation times should be as close together as possible.

6. Analyses should take account of patient data and type of prescription, staff loads, expertise and process, and sufficient information should be collected to make this possible.

It may be that certain kinds of prescription are more common to error and more likely to be used with certain kinds of patient.

In summary, these point to a design based around the observation of wards, before and after the intervention, set up to address the points raised above. Using control data from different hospitals or wards, especially from some time in the past, is best avoided.

### ***Sample size***

Having established the design, the next question concerns the sample size. The choice of sample size is determined by frequency of the outcome (prescribing error of one sort or another), its variability, and the size of a practically relevant reduction we want to be confident of picking up. In addition, as patients have repeat prescriptions, we need to take account of the relative size of between and within patient variability in prescribing errors.

Thus, in order to get a reasonable idea of a suitable sample size, a fair amount of information is required; however reliable estimates of the frequency and variability of prescribing errors is hard to come by. It therefore makes sense to look at how the sample size required varies with these quantities. Taken together with budgetary constraints, an appropriate sample size can then be arrived at.

Here, we first give formulae for calculating the sample size, and then illustrate its use. The idea is to provide a starting point for future calculations.

To use the formula, besides specifying the proportion of prescription errors in the control and intervention group, and the average number of prescriptions per patient, some statistical quantities need to be specified. For a fuller, non-technical, description of these, the reader is referred to the Encyclopaedic Companion to Biostatistics<sup>99</sup>. The first is *size*. In our context, this is the chance that our study detects a difference between the prescription error rates between the control and intervention groups when, in truth, none exists. Typically this is chosen in the region of 1/20 or 5%. The second is the *power*. This is the probability that our study detects a difference in the prescription error rates between the control and intervention groups when, in truth, there is a difference<sup>1</sup>. Typically, this is chosen in the region of 9/10 or 90%.

Lastly, we need to specify the proportion of the total variability in prescription errors that is due to variation between patients (between 0 and 100%). We call this proportion  $\rho$ ; it is usually referred to as the intra-class correlation coefficient (ICC). A value of 100% means that if someone has a single prescription error, all their prescriptions are errors. Conversely, a value of 0 means that prescription errors do not “cluster” within patients at all. While it is to be hoped that  $\rho$  is small, in practice, whether because of the complexity of a patient’s illness, or some other combination of reasons, errors will cluster. While in health care settings  $\rho$  is typically less than 10%, in small clusters (here, the number of prescriptions on an individual) it may rise considerably, though it is still typically  $< 30\%$ <sup>100</sup>.

Now suppose we are carrying out a within ward comparison, such as described at the end of the previous section. Let  $p_c$  be the proportion of prescription errors in the control group (expressed as percentage) and  $p_i$  the proportion of prescription errors in the intervention group. Further, let  $a$  be the average number of prescriptions per patient,  $\alpha$  be the size,  $\beta$  the power and  $\rho$  the ICC (see previous paragraph). Then the number of patients needed *in each group* is given by:

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<sup>1</sup> We assume that the detected difference is in the same direction as the true difference.



$$\frac{\{p_c(100 - p_c) + p_I(100 - p_I)\}}{(p_I - p_c)^2} \times \frac{\{100 + (a - 1)\rho\}}{100a} \times f(\alpha, \beta),$$

where  $f(\alpha, \beta)$  is found from Table 49.

		$\beta$ , probability we detect a difference when, in truth, there is a difference			
		95%	90%	80%	50%
$\alpha$ , probability we detect a difference when, in truth, none exists	10%	10.8	8.6	6.2	2.7
	5%	13.0	10.5	7.9	3.8
	2%	15.8	13.0	10.0	5.4
	1%	17.8	14.9	11.7	6.6

**Table 49: Values of  $f(\alpha, \beta)$**

Note that, following Pocock (p. 127)<sup>101</sup> our formula is based on a normal approximation (adjusting for clustering<sup>102</sup>), and alternative approaches might give slightly larger sample sizes. Our formula is for two sided tests.

To illustrate our approach, if we hypothesise that the prescription errors in the control group run at 8%, electronic prescribing will reduce this by 50% (to 4%),  $\rho = 5\%$ ,  $\alpha = 5\%$ ,  $\beta = 10\%$  and  $a = 10$ , then the number of patients in each group is

$$\frac{(8 \times 92 + 4 \times 96)}{4^2} \times \frac{(100 + (10 - 1) \times 5)}{100 \times 10} \times 10.5 = 107.$$

Thus we would need 107 patients in our control group and 107 in our intervention group.

Using this formula repeatedly, we can obtain tables showing how the sample size varies with the ICC, the size and power, the reduction in prescription error rate and the typical number of prescriptions per patient. For example, Table 50 below shows how the number of patients required in each group varies with  $\rho$  equal to 5%, 15% and 25%. We see how critical the value of  $\rho$  is to the sample size.

Lastly, if we are able to use several wards, then, in the absence of any further information, it makes sense to choose an equal number of patients from each ward. Note, though, that there are likely to be quite large differences between wards, because of their different case mix. As a rough guide, if the between ward ICC is  $\eta\%$ , and there are  $w$  wards, the number of patients  $n$  calculated using the formula above should be replaced by

$\frac{1}{100} \left( 100 + \left\{ \frac{n}{w} - 1 \right\} \eta \right)$ . Consideration would have to be given to further increasing the number of patients if wards from different hospitals were used, and the between hospital ICC was thought to be non-negligible.

Percentage error rate in control and intervention groups	Intra class correlation, $\rho$		
	5%	15%	25%
5%; 2%	114	184	254
5%, 3%	292	473	653
5%, 4%	1308	2120	2931
$\alpha = 5\%, \beta = 90\%, a = 10.$			

**Table 50: Sample sizes for various ICC values, calculated using the formula above.**

### D 3. Analysis issues

#### ***Hierarchical nature of the data***

As discussed in the introduction, data arising from studying prescribing errors are hierarchical, or multilevel. This results from each patient having typically 10 prescriptions over the course of their stay in hospital, and each ward containing a number of patients. Prescriptions on individual patients are more similar than those on different patients. Likewise, patients in an individual ward are more similar, in terms of their prescriptions, than patients on different wards. Thus we can view prescriptions (level 1) as nested within patients (level 2) in turn nested within wards (level 3), thus building up a multilevel hierarchy.

It is now widely known that the analysis of such multilevel data cannot proceed under the traditional assumption that each observation (here prescription) is independent. Failure to acknowledge the within patient and within ward similarities results in the estimated effect of interventions being too precise (so that p-values are too small) and can result in biases in the estimated effects<sup>103</sup>.

Biases result, for example, if a particular patient, who is fairly rare, is prone to both a long stay and a particularly high chance of prescribing error. In this case, an analysis that

ignores the multilevel structure will have an upwardly biased estimate of the prescribing error rate. Conversely, a multilevel analysis will adjust for the fact we have a single patient with a lot of repeat prescriptions. One can similarly think of other scenarios which will bias traditional analyses in either direction.

In the light of this, traditional summaries using contingency tables and means should only be used for descriptive purposes. Definite conclusions should not be based on chi-square tests/t-tests based on such summaries. Instead, a multilevel model or generalised estimating equation (GEE) approach should be used to account for the multilevel structure.

The difference between multilevel and generalised estimating equations is discussed by Carpenter<sup>103</sup>. In this context, we capture the effect of the intervention by estimating the ratio of the odds of a prescribing error when using the intervention system versus when using the control system (odds ratio, henceforth OR). An OR obtained using a GEE directly estimates the OR that would be expected over the whole population of patients if the intervention was adopted. This is known as a population averaged estimate. Conversely, a multilevel model estimates the OR of an *individual*. The effect of averaging is to shrink ORs; thus population averaged ORs are generally less than those from multilevel models. The significance (p-values) of population averaged ORs may also be slightly reduced. Note, though, that this distinction between GEEs and multilevel models only holds for discrete data. For continuous data, the ORs have the same (population averaged) meaning.

It is worth noting that population averaged ORs can be recovered from multilevel ORs, although this is not automatic in standard software<sup>104</sup>. An advantage of multilevel modelling is that it enables the sources of variability to be modelled. Further, while most software for GEEs allows only a two-level hierarchy, data from prescription errors may well have at least three levels. This is not a problem for multilevel models, though.

### ***Form of model***

When modelling prescription errors, we can choose between a logistic model and a Poisson model. The logistic approach models each prescription as a binary variable, which is 0 if the prescription is correct and 1 for an error, say. Then, if  $i$  indexes people and  $j$  prescriptions we model  $\text{logit Pr}(Y_{ij} = 1)$  as a function of covariates. The estimated

coefficients are then (log) odds ratios, for example the (log) odds ratio of a prescription error under the new system versus the old system.

An alternative is to adopt a Poisson model. Here, for each individual, we count the total number of prescription errors, say  $P_i$  over the total observation time (either the physical time for that person, or some measure of the time “at risk” from prescription error). If we denote this  $t_i$ , then a Poisson approach models  $\log(P_i) = \log(t_i) + \text{covariates}$ . Here  $\log(t_i)$  is an offset (with fixed coefficient of 1) and the estimated coefficients are now (log) risk ratios, for example the (log) risk ratio of a prescription error under the new system versus the old system.

Of the two approaches, the first may be preferable, as there is no natural “observation time” in the hospital setting, especially if we are only studying each patient during ward rounds. However, in other settings, such as monitoring prescription errors in care homes, the Poisson approach may prove useful. In any case, providing prescription errors are relatively rare, the risk ratios and odds ratios will be similar.

### ***Adjusting for covariates***

We have already noted that, without the protection of randomisation, it is important to measure patient and ward/process specific variables that might vary between occasions and adjust for these in the analysis. Important patient level variables should reflect the severity of their illness; ward and process level variables reflect the staffing levels, training and experience of the staff. Additional variables could include time of year, or other surrogates for variation in case mix and process.

A useful precursor to adjusting for these variables in an analysis is to use them to examine how closely the control and intervention group agree. We define a variable, say  $I_i$ , to be 1 if person  $i$  is in the new intervention group and 0 if not. We then perform a logistic regression of  $I$  on the variables listed above. If all is well, there should be relatively weak association between the above variables and  $I$ , reflecting the fact that there is little to distinguish the control and intervention group (besides the intervention). In other words, the propensity of a patient to be in the intervention group does not depend on these variables. A useful check is to obtain the fitted probabilities from the logistic model for  $I$ , and plot a histogram, using different colours/symbols to differentiate the fitted probabilities from the intervention and control groups. If the two distributions overlap, this confirms the propensity of a patient to

be in the intervention group is similar to their propensity to be in the control group. However, if they are very different, the propensity to be in the control group depends on the case mix/process variables, and the control group is quite different from the intervention group. In this case, the analysis of the effect of the intervention must be interpreted very cautiously.

In effect, this “propensity score”<sup>105</sup> for being in the intervention group is a way of formally checking that the groups are compatible. Strictly, since the only thing different between individuals with the same propensity score is whether or not they were actually in the intervention group, we should compare the effect of the intervention on individuals with the same propensity score. Usually, an approximation to this is done. We divide individuals into 5 groups, based on quintiles of propensity score, and calculate the effect of the intervention in each, then combine. In practice this is most easily done by including propensity score (split into quintiles) as a covariate in the logistic or Poisson analysis, described above.

There are two potential advantages of propensity<sup>105</sup> score analysis. First, if it were possible to measure and include in the propensity model all the relevant variables, then the propensity score analysis would give the “correct” answer — i.e. the same answer as a randomised study. However, we can never be sure of this in practice. The second advantage is that the propensity score model (i.e. the logistic model for  $I$ ) can include far more terms than we would want to adjust for in the model that estimates the effect of the intervention. This is because there is less need to worry about over fitting propensity models.

In summary, a propensity score analysis has two models. First we fit the logistic model to the variable  $I$ , and calculate the resulting fitted probabilities, termed propensity, to be in the intervention group. Then we fit the “model of interest” (which estimates the effect of the intervention) adjusting for propensity score. The adjustment for propensity score usually involves categorising the fitted probabilities into quintiles, and fitting a factor with a different level for each quintile.

### ***Propensity scores versus traditional covariate adjustment approach***

Propensity score analyses do not give estimates of the effect of the covariates on the outcome (apart from intervention) as they are all subsumed into the propensity score. For this reason, and as a check on the propensity analysis, having established the compatibility of the control and intervention patients using a propensity score, one can then adopt the

usual strategy of adjusting for important patient/process/environment covariates directly in the intervention model. Such a covariate adjusted analysis may be more informative. Statistically (in terms of bias and precision of estimated intervention effects) the relative merits of the two approaches are not yet properly understood.

#### **D 4. Discussion**

We set out to explore statistical aspects of studying the effects of electronic prescribing on prescription errors. The two aspects where statistical issues will impact on the quality of the research are study design and analysis.

Regarding study design, if possible randomisation should be used to ensure “cause” (electronic prescribing) can be definitively linked to any “effect” (hopefully reduced prescription error). A randomised study should certainly be used before the widespread adoption of any single electronic prescription package. In practice, we realise that for many smaller studies, randomisation may not be practical (although it remains highly desirable). For such cases, informed by the ideal randomised study, we highlighted factors that should be taken account of in the design. We further went on to describe methods for choosing an appropriate sample size, deriving an appropriate formula and illustrating its implementation.

The analysis of data from such studies needs to take into account the hierarchical structure of the data, using multilevel modelling or generalised estimating equations. This is because patients have typically 10 prescriptions during their stay, yet the length of stay, severity of illness and hence number of prescriptions can vary widely. Failure to take into account this patient level information (eg by analysing the data using contingency tables) could be misleading, as the conclusions are vulnerable to bias from atypical patients. Secondly, we discussed the relative merits of a logistic versus a Poisson model for data (the latter giving rise to risk ratios, rather than odds ratios). In practice, we prefer a logistic approach. Thirdly, we described how “propensity score” methods can be used, in the absence of randomisation, to provide a check on the similarity between the control and intervention groups. If the intervention and control groups are found to differ substantially, estimated effects of intervention will be unreliable. Lastly, we outlined how the propensity score can be used in the model for estimating the effect of intervention.

In conclusion, we note that considerably more could be said regarding all the aspects described above. In particular we have not addressed the practical/budgetary constraints that often feature largely in study design, nor the technical details of the analysis. Nevertheless, we hope the issues discussed, based on experience to date, will prove a useful starting point for future research in this area.

## **Appendix E. Clinical decision support features of the two systems studied**

### **E.1 Introduction**

This Chapter discusses the clinical decision support capabilities of the two electronic prescribing systems studied, highlighting the elements of decision support that are possible with each system, and those that are actually in use.

The relevant objective for this part of the study was:

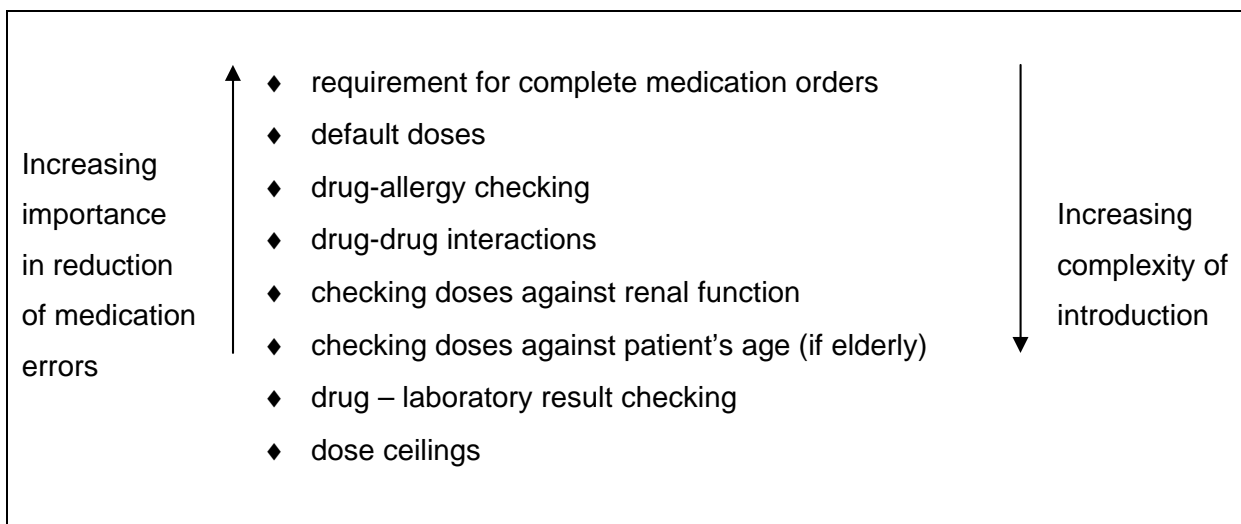
- To describe the decision support software in each system, and assess aspects of it.

### **E.2 Defining decision support**

While a commonly used phrase, there are few definitions of decision support that are specific to electronic prescribing in secondary care. We therefore adopted Teich *et al's*<sup>106</sup> definition and list of examples, as applied to electronic prescribing in US primary care. Decision support was broadly defined as providing clinicians or patients with clinical knowledge to enhance patient care<sup>107</sup>. This was taken to include reactive alerts and reminders (such as for drug allergies and interactions), structured order forms, pick lists and patient-specific dose checking, proactive guideline support to prevent errors of omission, medication reference information, and any other knowledge-driven interventions that can promote safety, education, communication, or improved quality of care<sup>106</sup>.

We also considered a hierarchy of decision support in relation to secondary care electronic prescribing, as proposed by Bates (reported by Franklin)<sup>108</sup> (Figure 27).





**Figure 27: Hierarchy of types of decision support, as proposed by Bates (as reported by Franklin, 2003)**

Finally, there are also other elements commonly understood to comprise decision support in the context of electronic prescribing for UK hospital inpatients. These include:

- Use of a drug dictionary to avoid the need for free text entries;
- Provision of dosing advice, such as a link to drug monographs or the electronic British National Formulary;
- Links to the hospital's patient administration system so that patient details are automatically entered;
- Formulary control;
- Creation of discharge prescriptions without further transcription of inpatient medication orders.

For the purposes of this chapter, we considered all of these elements. We did not include recording the reasons for non-administration of doses, or other aspects of information transfer that are standard practice with paper-based systems.

### **E 3 Methods**

Following our observations and interviews with key stakeholders, we summarised the decision support capabilities of each system according to the elements presented above. We considered whether or not each aspect was possible within the system, as well as whether or not it was in use at the time of the study.

## E 4 Results

Results are summarised in Table 51.

Type of decision support	ServeRx, Charing Cross Hospital		Meditech, Queen's Hospital	
	Possible?	In use?	Possible?	In use?
Link to hospital patient administration system	Yes	Yes	Yes	Yes
Drug dictionary	Yes	Yes	Yes	Yes
Requirement for complete medication orders	Yes	Yes	Yes	Yes
Formulary guidance or control	Yes	Yes	Yes	Yes
Direct creation of discharge prescriptions	No*	-	Yes	Yes
Default doses	Yes	Yes	Yes	Some
Drug-allergy checking	Yes	No	Yes	No
Drug-drug interactions	Yes	No	Yes	Some
Dose ceilings	No	-	Yes	For selected drugs
Checking doses against renal function	No	-	Yes	No
Checking doses against patient's age (for elderly or paediatric patients)	No	-	Yes	For selected neonatal drugs
Drug – laboratory result checking	No	-	Yes	No
Drug monographs	No	-	Yes	Yes
Guideline support	No	-	No	-

**Table 51: Summary of the decision support available and actually in use for each system.**

\* Creation of discharge prescriptions was not possible with the ServeRx version in place at the time of the study, but was possible and used in practice following installation of a subsequent version.

### ***Links to patient administration system***

Both systems were linked to the patient administration system, allowing patient names, hospital numbers and basic demographic information to be downloaded to the electronic prescribing system. The Meditech system at Queen's Hospital also allowed links between the prescribing system and laboratory data; this was not possible with the ServeRx system.

### ***Provision of a drug dictionary and requirement for complete medication orders***

Both systems provided a drug dictionary to ensure that drug names were specified correctly, and required all medication order fields to be entered. At both sites, the drug database supplied by First Data Bank Europe was used. The Meditech system also had a "look up" index which allows prescribers to enter any brand or generic

name and then be presented with a list of available preparations. With the ServeRx system, it was possible to prescribe dosage forms that could not be given by the route specified (for example, vancomycin capsules to be administered intravenously). At Queen's Hospital the pharmacy department had linked drugs with possible routes of administration, so that the system would not allow prescribing by an inappropriate route.

### ***Formulary guidance***

At Charing Cross Hospital, prescribers were guided towards selection of products that were in the Trust's formulary, and preferably, those in stock on the study ward. When searching for a drug product, prescribers were first presented with a list of products that were stocked on the ward. If required, a prescriber can then choose to look at the list of all drugs in the Trust's formulary, and then if needed, the list of all products in the drug dictionary.

Formulary control at Queen's Hospital was more stringent. Non-formulary drugs did not appear on the default drop-down pick lists; junior doctors had to ask pharmacy staff how they could be prescribed.

### ***Creation of discharge prescriptions***

Creation of discharge prescriptions was not possible with the version of ServeRx in use at the time of the study. A subsequent version of the software did allow this feature, which was then routinely used. This feature allowed selection of those drugs which were to be prescribed on discharge, which then appeared on a printout resembling the Trust's standard discharge prescription / discharge summary. The printed discharge prescription was then signed by the prescriber, checked by a pharmacist and dispensed in the pharmacy department as for paper-based prescriptions.

The procedure for creating discharge prescriptions in the Meditech system has been described in Chapter 2. Drugs required at discharge were marked (\*) by the prescriber and at pre-determined times during the day, all of the marked prescriptions were printed in the pharmacy for dispensing. As for inpatient medication orders, these discharge prescriptions were considered to have been electronically "signed". Details of discharge medication were exported into the discharge summary that is sent to a patient's general practitioner.

### ***Default doses and dose ceilings***

At Charing Cross Hospital, default doses were set up by the pharmacy computer services team for the majority of products that were prescribed to be given regularly. However, it was not possible to set default doses for drugs prescribed less often than once daily, and it was therefore not possible to set the default frequency for oral methotrexate to be once weekly, for example. There was also a problem with drugs prescribed to be given “when required”, as the system’s default dosing frequency was one-hourly. This could not be amended locally and is not appropriate for the majority of drugs; medical staff training therefore had to include the importance of amending this field. There were no dose ceilings.

At Queen’s Hospital, default doses and dosing frequencies were set by the pharmacy team for specific drugs when the general consensus was that they would be useful. The number of drugs controlled in this way was relatively small; one example was the proton pump inhibitor lansoprazole. Maximum dose warnings were set for some neonatal and paediatric drugs. All defaults could be over-ridden; the system allowed full audit of all such decisions. It was also possible for doses to be individualised on a weight or surface area basis. However this facility was not in general use, partly because the necessary physiological data was not often entered into the patient record.

### ***Drug - allergy checking***

While the ServeRx system at Charing Cross Hospital was theoretically capable of allergy checking, this feature was not activated and was not in use at the time of the study. The main reason for this was that the system did not carry out drug-allergy checking until prescribed drugs were deployed (usually by nursing staff) to specific drug round times. Since this often occurred some time after the prescribing act, particularly if hand-held computers were used, any warnings would have had to be dealt with by nursing staff, which was not considered appropriate. Additional problems were also encountered, but these could probably have been resolved. First, the proposed use of allergy checking software opened up a debate about the level of cross-sensitivity at which an allergy warning should operate. For example, if a patient with a documented penicillin allergy was prescribed a cephalosporin, stake-holders were of divided opinions as to whether a warning should appear. Second, there were concerns about the deskilling of prescribers, who would also be required to prescribe on wards that did not operate electronic prescribing. Third, there was a problem with allergies that were entered in error and then removed, as these still appeared on the system. Finally, allergies had to be entered in relation to a specific product (for

example, penicillin V tablets 250mg) and it was not possible to enter an allergy to a group of drugs (for example, penicillins). The system did crosscheck across the group of drugs, but the format of allergy entry did not make this clear.

At Queen's Hospital, drug and other allergy information was required to be entered into the Meditech system on admission, and staff could check the allergy record for an individual patient. The system could automatically check orders for drugs and foodstuffs (including those which are ingredients in pharmaceutical products) against this allergy record. However again, this facility was not switched on, and doctors spoke of their lack of confidence in the accuracy of allergy reports obtained from patients on admission. As for Charing Cross, there were also concerns about being unnecessarily constrained in the choice of antibiotics.

### ***Drug-drug interactions***

This facility was possible within the ServeRx system, but was not activated at Charing Cross Hospital. This was for the same reason as for drug-allergy checking, as any warnings only appeared on deployment of medication by nursing staff. There were also concerns over duplication warnings as the same drug is often intentionally prescribed twice. Examples included analgesics prescribed in a low dose regularly with extra doses prescribed 'when required', and prescriptions for drugs such as levothyroxine 150 micrograms which had to be prescribed as two separate orders for 100 microgram and 50 microgram tablets. Finally, the warning messages were not in plain English and felt to be unhelpful. Rewording the warnings was possible but would have required a great deal of work.

The Meditech system automatically screened for drug interactions using a third-party database from First Data Bank. This was customised by pharmacy staff so that only clinically significant interactions, as defined by the British National Formulary, were presented to prescribers. Prescribing a drug that interacted with one on the patient's current list produced a red box warning. If the prescriber still wished to prescribe, then s/he could override the warning. This decision, and the identity of the prescriber, was recorded by the system. Pharmacists screening prescription orders could check all possible interactions, no matter how trivial.

### ***Checking against patient's age, renal function and laboratory data***

These facilities were not possible with ServeRx as there was no link to test results.

Although electronic prescribing at Queen's Hospital was part of the Hospital Information System, the system did not carry out automatic checks, for example for renal function; this was instead part of the clinical check which pharmacist made for all new orders. There was a "magic key" which took users straight from a prescribing screen into pathology tests and other investigations. It was also possible for doses to be individualised on a weight basis, which was used to check the doses of certain neonatal drugs.

### ***Drug monographs and guideline support***

The ServeRx system did not incorporate drug monographs or guideline support, although such information is available separately via the trust's intranet. In contrast, the Meditech electronic prescribing system incorporated a full set of drug monographs, as part of the package provided by First Data Bank Europe. Local guidelines and policies written by Trust staff were also included.

## **E 5 Discussion**

While the common perception of clinical decision support relates to specific features such as drug-allergy and drug-drug interactions, we took a wider view and included a range of other features.

We found that both systems studied offered various elements of decision support, but at both sites, many potential features were not enabled. This was for a variety of reasons, including a deliberate policy to ensure that staff (particularly junior doctors) did not become deskilled in prescribing. Queen's Hospital has taken a cautious approach to implementing decision support features, concerned not to automate aspects of clinical decision-making, but also not to overload staff with warnings, for example, on interacting drugs<sup>91</sup>. The view of key stakeholders was that the Meditech system best supported clinical staff by providing rapid access to all information about a patient.

However, a common theme in our qualitative work at Charing Cross (but not at Queen's Hospital) was that staff assumed that an electronic prescribing system would have features such as allergy checking enabled. They may have been less vigilant in their prescribing behaviour as a result; this is an example of how new errors could be created following the introduction of EP. At Queen's Hospital, allergy checking was a thorny issue with both doctors and pharmacists. New prescribers

were explicitly informed in writing during training that the system would not check doses and allergies, and that it was their responsibility to do this.

At both sites, one company (First Data Bank) was used to provide the data files for drugs and their properties. First Data Bank is currently the only possible supplier; there is no British National Formulary-compatible product.

Decision support seems to be derived from what is possible rather than what is needed. Queen's Hospital stakeholders told us that they had the basics of what they needed, but could do much more if they had the resources. The pharmacy department has managed to do some developmental work, (for example, neonatal dose checking) in-house but did not have the resources to do more.

There are specific potential advantages if electronic prescribing can be linked to laboratory data; for example, linking an order for an antibiotic with a check on the patient's microbiology test results. This is possible with the Meditech system, but would require significant software changes, which would cost money and take staff time. However, of the eight cases of harm found in the retrospective studies across the two sites, arguably all of them would have been either avoided or detected more quickly if there had been drug-drug interaction checking, automated dose checking in renal impairment, or alerts when drugs caused a measurement, such as INR, to go outside normal range.

Most features considered decision support in the EP community are really decision removal or reduction. These features ensure that drugs chosen are on the formulary and are prescribed in strengths and dose forms that exist in the hospital. These are important functions, and contribute to safety and economy, however they are not really helping prescribers in a reasoned decision making process. There is an important debate to be entered into as to the extent to which EP should force the correct action, and the extent to which it should enhance decision making by an individual or care team.

## **E 6 Conclusion**

We found that both systems offered a range of decision support features, but notably, many of the features were deliberately not activated. Most features were actually decision removal or reduction. Concerns about automating aspects of clinical

decision-making and producing “warning fatigue” in prescribers contributed to this situation. The whole area of decision support for prescribing requires a substantial amount of work to get it to meet expectations.



**Appendix F. Retrospective Review Form (Chapter 3)**

**CONFIDENTIAL**

**MEDICATION ERROR REVIEW FORM**

**for**

**Retrospective Case Record Review**

Data sources available.

Please identify if the following are present for the study period: 1 = Yes 2 = No 3 = N/A or not required

1. Initial medical assessment

2. Medical progress notes

3. Nursing/midwifery progress notes

4. Laboratory/Pathology reports

5. Prescription records: Present? Page no.s missing

Prescription Report

Administrations Report – Medications, Vital signs, Physician instructions

Transfer Prescription Record (Summary)

ServeRx computer record of stopped medication

Current medication chart

Medication chart (from previous ward)

6. Discharge summary

7. Other (give details)

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**Stage A: PATIENT INFORMATION AND BACKGROUND TO ERROR.**

**A1 REVIEWER INFORMATION.**

Date of Review:   
                          d d m m y y

Time Commenced Review:

Hospital number:

Time Review Finished:

(use 24 hour clock)

**A2 PATIENT INFORMATION.**

**Pre ServeRx**

**Post ServeRx**

Date of Admission:

Admission to 8North:

Date of Discharge:  
or Date of Death   
                          d d m m y y

Discharge/transfer:  
from 8N   
                          d d m m y y

**Reason for admission and relevant background**

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Date of Birth   
                          d d m m y y      Age (on admission to 8N,yrs)       Sex **M/F**

Weight (Kg)       Est?       Height  ft  inches      Obese? **Yes**  **No**

IBW (Complete if pt obese)

Creatinine ( $\mu\text{mol/L}$ )       Date that serum creatinine was measured

Creatinine clearance (ml/min)       Dialysis? \_\_\_\_\_      d d m m y y

Does the patient have hepatic impairment?      **Yes**       **No**       ?

If yes, please give details of relevant liver function tests:

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Is the patient pregnant?  **Yes**  **No**  
Is the patient breastfeeding?  **Yes**  **No**  
Does the patient have any allergies?  **Yes**  **No**

If yes, please give details:

---

---

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### A3 CO-MORBIDITIES.

Please tick all of the following co-morbidities that apply to this patient or

<input type="checkbox"/>	No co-morbidities
<input type="checkbox"/>	Not known

#### Cardio-vascular

- Coronary artery disease
- Peripheral vascular disease
- Cardiac insufficiency or dysrhythmia
- Hypertension
- Other (specify) \_\_\_\_\_

#### Respiratory

- Asthma
- COPD (chronic obstructive pulmonary disease)
- Other serious lung problem (e.g. *severe tuberculosis scarring, pneumonectomy*) (specify) \_\_\_\_\_

#### Gastro-intestinal

- Chronic or recurrent dyspepsia
- Inflammatory bowel disease Crohn's / colitis
- Chronic liver disorder
- Other (specify) \_\_\_\_\_

#### Endocrine

- Diabetes - type \_\_\_\_\_
- Endocrine disorder (e.g. *thyroid, adrenal*) (specify) \_\_\_\_\_

#### Neurological

- Epilepsy
- Stroke
- Parkinson's
- Dementia
- Other serious neurological disorders (e.g. *MS, MND*) (specify) \_\_\_\_\_

#### Renal

- Chronic renal disease
- Other (specify) \_\_\_\_\_

#### Haematological

- Anaemia
- Leukaemia
- Lymphoma
- Other (specify) \_\_\_\_\_

#### Existing cancer

- Specify \_\_\_\_\_

#### Psychiatric

- Schizophrenia
- Affective disorder
- Other (specify) \_\_\_\_\_

#### Psychosocial

- Alcoholism
- Drug abuse
- Smoker
- Homeless
- Other (specify) \_\_\_\_\_

#### Infection

- AIDS
- Chronic infection (e.g. *Hep C, MRSA*) (specify) \_\_\_\_\_

#### Bone/joint disorders

- Osteoporosis
- Severe rheumatoid arthritis
- Severe osteoarthritis
- Other (specify) \_\_\_\_\_

**Disability**

- Wheel chair bound
- Blind
- Deaf
- Learning difficulty
- Other (specify) \_\_\_\_\_

**Trauma**

- Multiple Traumas (*e.g. RTA*)

**Nutritional status**

- Obese
- Cachetic
- Other (specify) \_\_\_\_\_

**Other co-morbidity**

- Specify \_\_\_\_\_

#### A4 SPECIALTY CARING FOR PATIENT.

**GENERAL**  0 uncertain  1 Accident & Emergency (A&E)  2 General Intensive Care

- |  |   |   |   |
|--|---|---|---|
| <b>S<br/>U<br/>R<br/>G<br/>E<br/>R<br/>Y</b> | <input type="checkbox"/> 3 Anaesthesiology        | <input type="checkbox"/> 10 Obstetrics          | <input type="checkbox"/> 17 Urological Surgery    |
|  | <input type="checkbox"/> 4 Cardiac Surgery        | <input type="checkbox"/> 11 Orthopaedic Surgery | <input type="checkbox"/> 18 ENT Surgery           |
|  | <input type="checkbox"/> 5 Colon/Rectal Surgery   | <input type="checkbox"/> 12 Paediatric Surgery  | <input type="checkbox"/> 19 Eye Surgery           |
|  | <input type="checkbox"/> 6 General Surgery        | <input type="checkbox"/> 13 Plastic Surgery     | <input type="checkbox"/> 20 Other (specify) _____ |
|  | <input type="checkbox"/> 7 Gynaecology            | <input type="checkbox"/> 14 Thoracic Surgery    | _____   |
|  | <input type="checkbox"/> 8 Hepato-biliary Surgery | <input type="checkbox"/> 15 Vascular Surgery    | _____   |
|  | <input type="checkbox"/> 9 Neurosurgery           | <input type="checkbox"/> 16 Upper GI Surgery    |   |

- |  |  |   |   |
|--|--|---|---|
| <b>M<br/>E<br/>D<br/>I<br/>C<br/>I<br/>N<br/>E</b> | <input type="checkbox"/> 21 Cardiology (incl. CCU)           | <input type="checkbox"/> 30 Internal Medicine<br>(not otherwise classified) | <input type="checkbox"/> 38 Physical Medicine     |
|  | <input type="checkbox"/> 22 Dermatology                      | <input type="checkbox"/> 31 Medical Oncology                                | <input type="checkbox"/> 39 Psychiatry            |
|  | <input type="checkbox"/> 23 Endocrinology                    | <input type="checkbox"/> 32 Medical Ophthalmology                           | <input type="checkbox"/> 40 Pulmonary Disease     |
|  | <input type="checkbox"/> 24 Family Practice                  | <input type="checkbox"/> 33 Neonatology                                     | <input type="checkbox"/> 41 Radiation Therapy     |
|  | <input type="checkbox"/> 25 Gastroenterology                 | <input type="checkbox"/> 34 Nephrology                                      | <input type="checkbox"/> 42 Radiology             |
|  | <input type="checkbox"/> 26 Geriatrics (care of the elderly) | <input type="checkbox"/> 35 Neurology                                       | <input type="checkbox"/> 43 Rehabilitation Unit   |
|  | <input type="checkbox"/> 27 Haematology                      | <input type="checkbox"/> 36 Pathology                                       | <input type="checkbox"/> 44 Rheumatology          |
|  | <input type="checkbox"/> 28 Immunology and Allergy           | <input type="checkbox"/> 37 Paediatrics                                     | <input type="checkbox"/> 45 Other (specify) _____ |
|  | <input type="checkbox"/> 29 Infectious Disease               |   | _____   |

**A5. CURRENT MEDICATION**

Please list all the medication that the patient is currently prescribed

<b>Prescribing stage</b> <b>Medication name</b>	<b>Strength</b>	<b>Route</b>	<b>Dosage regimen</b>	<b>No. of medication orders</b>
<u>Prescribing on admission</u> STAT  REG  PRN  IVI				
<u>Prescribing during stay</u> STAT  REG  PRN  IVI				



**A5. CURRENT MEDICATION (cont.)**

Please list all the medication that the patient is currently prescribed

<b>Prescribing stage</b>	<b>Strength</b>	<b>Route</b>	<b>Dosage regimen</b>	<b>No. of medication orders</b>
<u>Transcribing onto ServeRx</u> STAT  REG       PRN    IVI				
<u>Writing TTA</u> STAT          REG          PRN          IVI				

## **CHECKLIST FOR REVIEWING NOTES FOR POTENTIAL ERRORS.**

### **1. Medical clerking.**

Read initial medical clerking and medical progress notes. Check entries from pharmacist or nurse.

### **2. Drug history.**

Check drug history on admission and identify any omissions from the drug charts. Also check for any GP's prescribing errors continued on admission.

### **3. Check drug chart.**

- A. Any administration omissions?
- B. Any prescription errors? Check the following:
  - Appropriate doses, watch for...
    - Drugs with a narrow therapeutic index
    - Drugs requiring dose adjustment in renal or hepatic impairment.
  - Contra-indications
    - Check allergies
  - Completeness of prescription (signed, dated, dose, drug name, delivery route, no abbreviations or Latin names)
  - Drug interactions
    - Including diluents for IV infusions
  - Correct formulation
- C. Any drugs stopped? Why were they stopped?
- D. Are each of the drugs required?
- E. Check the lab results for signs of toxicity.
- F. Any co-prescribing required?
- G. Any drugs that patient should be on but not prescribed?
- H. Are all drugs transcribed correctly?
  - when rewriting a patient's drug chart
  - when writing a patient's discharge medication

**Stage B: ERROR DETAILS**

**B1 a. Error no:.....**

**1. Demographic details of the error**

Date that error occurred

d	d	m	m	y	y

Type of error:

Prescribing

Dispensing

Administration

**Type of prescribing error**

Prescribing error

Prescribing error - by a pharmacist

**Prescribing stage**

Prescribing on admission

Prescribing during stay

Transcribing onto ServeRx

Re-writing drug chart

Writing TTA

**Stage of drug use process**

Need for drug

Selection of drug

Selection of dose

Selection of formulation

Supply

Monitoring

Counsel/educate

**Type of dispensing error**

Content error

Labelling error

**Type of administration error**

Omission - unavailability

Omission - other

Extra dose

Selection of drug

Wrong dose

Wrong formulation

Unordered drug

Other

**Did the patient receive any doses of the drug before the error was corrected?**

No

Yes: \_\_\_\_\_doses

Don't know

N/A

**2. Description of the error – including drug name, formulation, dose, frequency and route**

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**B1 b. Additional treatment as a result of the error**

Did harm occur as a result of the error?

Yes  No  Not known

If yes, please provide details below:

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What additional *procedures* (medical or surgical procedures, including any unnecessary investigations) were performed as a result of the error?

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What additional *medications* (including intravenous fluids and blood transfusion) were administered as a result of the error?

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What additional *treatment* (e.g. physiotherapy, counselling) was given as a result of the error?

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Was there an increase in length of stay as a result of the error? If so, please give details.

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Did the patient have to be transferred to a different ward as a result of the error? If so, please give details.

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## Appendix G Trigger tool review (Chapter 3)

Reviewer

Date of review

Time started

Time finished

Patient's hospital number

Date of birth

Drug chart data							Chart not present
Code	UK trigger	Potential problem identified	Present?		Error?		Notes
			Y	N	Y	N	
T1	Chlorphenamine / loratadine / hydrocortisone	Hypersensitivity reaction of drug effect					
T2	Vitamin K (phytomenadione)	Over-anticoagulation with warfarin					
T3	Flumazenil	Over-sedation with benzodiazepines					
T4	Droperidol, ondansetron, promethazine, hydroxyzine, prochlorperazine, metoclopramide, cyclizine, granisetron or domperidone	Nausea/emesis related to drug use					
T5	Naloxone	Over-sedation with narcotic					
T6	Anti-diarrhoeals: loperamide, diphenoxylate, codeine or co-phenotrope	Adverse drug event					
T7	calcium resonium	Hyperkalaemia related to renal impairment or drug effect					
T22	Unexpected medication stop	Adverse drug event					

Patient notes data							Notes not present
Code	UK trigger	Process identified	Present?		Error?		Notes
			Y	N	Y	N	
T20	Over-sedation, lethargy, falls, hypotension	Related to overuse of medication					
T21	Rash	Drug related/adverse drug event					
T23	Transfer to higher level of care, such as ITU or CCU	Adverse event					



Kara O'Grady and Bryony Dean Franklin, 7 May 2004  
Updated 4 June 2004, Bryony Dean Franklin  
Updated 16 July 2004, Sylvia Birch

**Appendix H. Types of medication orders written during the pre- and post-ServeRx prescribing error data collection periods (Chapter 4)**

Prescribing stage	Number of medication items written for each type of medication order						
	Once only	Regular	PRN	IV	TTA	Total	% total
On admission	56	267	76	90	-	489	<b>20.0</b>
During stay	148	319	216	501	-	1184	<b>48.3</b>
Re-writing chart	24	276	99	-	-	399	<b>16.3</b>
TTA	-	-	-	-	378	378	<b>15.4</b>
Total	228	862	391	591	378	<b>2450</b>	-
<b>% of total</b>	<b>9.3</b>	<b>35.2</b>	<b>16.0</b>	<b>24.1</b>	<b>15.4</b>	-	<b>100.0</b>

Extrapolated number of medication orders written during the pre-ServeRx study period.

PRN = “When required” medication; IV = intravenous; TTA = discharge medication

Prescribing stage	Number of medication items written for each type of medication order						
	Once only	Regular	PRN	IV	TTA	Total	% total
On admission	58	198	61	94	-	411	<b>17.4</b>
During stay	201	493	137	488	-	1319	<b>56.1</b>
Transcribing onto ServeRx	0	318	143	-	-	461	<b>19.6</b>
TTA	-	-	-	-	162	162	<b>6.9</b>
Total	259	1009	341	582	162	<b>2353</b>	-
<b>% of total</b>	<b>11.0</b>	<b>42.9</b>	<b>14.5</b>	<b>24.7</b>	<b>6.9</b>	-	<b>100.0</b>

Extrapolated number of medication orders written during the post-ServeRx study period. PRN

= “When required” medication; IV = intravenous; TTA = discharge medication



## Appendix I. Detailed work sampling results (Chapter 4)

Task	Doctor			Nurse			Other			Patient			Self			Total		
	No.	%	Hr	No.	%	Hr	No.	%	Hr	No.	%	Hr	No.	%	Hr	No.	%	Hr
Change in therapy/monitoring	1	0.38	0:02:02	3	1.14	0:06:06	-	n/a	n/a	-	n/a	n/a	6	2.27	0:12:13	10	3.79	0:20:21
Giving advice/information	3	1.14	0:06:06	3	1.14	0:06:06	-	n/a	n/a	9	3.41	0:18:19	10	3.79	0:20:21	25	9.47	0:50:53
Information gathering	9	3.41	0:18:19	4	1.52	0:08:09	-	n/a	n/a	7	2.65	0:14:15	19	7.20	0:38:41	39	14.77	1:19:23
Looking for Charts	-	n/a	n/a	1	0.38	0:02:02	-	n/a	n/a	1	0.38	0:02:02	6	2.27	0:12:13	8	3.03	0:16:17
Non-Productive	1	0.38	0:02:02	7	2.65	0:14:15	5	1.89	0:10:11	-	n/a	n/a	3	1.14	0:06:06	16	6.06	0:32:34
Other	1	0.38	0:02:02	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	7	2.65	0:14:15	8	3.03	0:16:17
Patients' Own Drugs	2	0.76	0:04:04	-	n/a	n/a	1	0.38	0:02:02	9	3.41	0:18:19	2	0.76	0:04:04	14	5.30	0:28:30
Prescription annotation	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	24	9.09	0:48:51	24	9.09	0:48:51
Prescription monitoring	-	n/a	n/a	1	0.38	0:02:02	1	0.38	0:02:02	-	n/a	n/a	39	14.77	1:19:23	41	15.53	1:23:27
Supply	-	n/a	n/a	19	7.20	0:38:41	-	n/a	n/a	-	n/a	n/a	41	15.53	1:23:27	60	22.73	2:02:08
Travel	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	19	7.20	0:38:41	19	7.20	0:38:41
<b>Total</b>	<b>17</b>	<b>6.44</b>	<b>0:34:36</b>	<b>38</b>	<b>14.39</b>	<b>1:17:21</b>	<b>7</b>	<b>2.65</b>	<b>0:14:15</b>	<b>26</b>	<b>9.85</b>	<b>0:52:55</b>	<b>176</b>	<b>66.67</b>	<b>5:58:15</b>	<b>264</b>	<b>100</b>	<b>8:57:23</b>

Detailed work sampling results pre-ServeRx.

No observations were made during which the ward pharmacist was in contact with the pharmacy department; this column is therefore omitted for clarity.

Task	Doctor			Nurse			Other			Patient			Pharmacy			Self			Total		
	No.	%	Hr	No.	%	Hr	No.	%	Hr	No.	%	Hr	No.	%	Hr	No.	%	Hr	No.	%	Hr
Change in therapy/monitoring	16	3.86	0:31:18	-	n/a	n/a	-	n/a	n/a	2	0.48	0:03:55	-	n/a	n/a	10	2.42	0:19:34	28	6.76	0:54:47
Giving advice/information	26	6.28	0:50:52	9	2.17	0:17:37	8	1.93	0:15:39	35	8.45	1:08:29	1	0.24	0:01:57	-	n/a	n/a	79	19.08	2:34:34
Information gathering	5	1.21	0:09:47	7	1.69	0:13:42	2	0.48	0:03:55	8	1.93	0:15:39	2	0.48	0:03:55	38	9.18	1:14:21	62	14.98	2:01:18
Looking for Charts	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a
Non-Productive	5	1.21	0:09:47	7	1.69	0:13:42	8	1.93	0:15:39	1	0.24	0:01:57	2	0.48	0:03:55	21	5.07	0:41:05	44	10.63	1:26:05
Other	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	3	0.72	0:05:52	-	n/a	n/a
Patients' Own Drugs	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a
Prescription annotation	3	0.72	0:05:52	1	0.24	0:01:57	-	n/a	n/a	2	0.48	0:03:55	-	n/a	n/a	26	6.28	0:50:52	32	7.73	1:02:37
Prescription monitoring	1	0.24	0:01:57	1	0.24	0:01:57	-	n/a	n/a	-	n/a	n/a	4	0.97	0:07:50	87	21.01	2:50:13	93	22.46	3:01:57
Supply	-	n/a	n/a	1	.24	0:01:57	-	n/a	n/a	-	n/a	n/a	2	0.48	0:03:55	53	12.80	1:43:42	56	13.53	1:49:34
Travel	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-	n/a	n/a	17	4.11	0:33:16	17	4.11	0:33:16
<b>Total</b>	<b>56</b>	<b>13.53</b>	<b>1:49:34</b>	<b>26</b>	<b>6.28</b>	<b>0:50:52</b>	<b>18</b>	<b>4.35</b>	<b>0:35:13</b>	<b>48</b>	<b>11.59</b>	<b>1:33:55</b>	<b>11</b>	<b>2.66</b>	<b>0:21:31</b>	<b>255</b>	<b>61.59</b>	<b>8:18:55</b>	<b>414</b>	<b>100</b>	<b>13:30:00</b>

Detailed work sampling results post-ServeRx

## Appendix J. Analysis of types of prescribing error (Chapter 6)

Type of error	Methods used to identify errors				
	Pharmacist alone	RRF alone	Pharmacist and RRF	Spont. report alone	Total errors detected
<b><i>Need for drug</i></b>					
Omission from drug history	6	23	0	0	29
Omission from TTA	0	11	0	0	11
Other omission	1	5	0	0	6
Duplication of drug	2	0	0	0	2
No indication for drug	0	0	0	0	0
<b><i>Select specific drug</i></b>					
Drug incorrect	1	3	0	0	4
<b><i>Select drug dose</i></b>					
Dose incorrect	17	28	6	0	51
<b><i>Select formulation</i></b>					
Formulation incorrect	1	2	0	0	3
<b><i>Give instructions for product supply</i></b>					
Sign and date prescription	0	2	0	1	3
Specify correct strength and form	6	6	1	0	13
<b><i>Give administration instructions</i></b>					
Route incorrect	0	4	0	0	4
Other administration	7	2	0	0	9
<b>TOTAL (% of all errors)</b>	<b>41 (30.4%)</b>	<b>86 (63.7%)</b>	<b>7 (5.2%)</b>	<b>1 (0.7%)</b>	<b>135 (100%)</b>

**Comparison of prescribing errors identified using each method or combination of methods, presented according to type of error, for the pre-ServeRx cohort.**

RRF = Retrospective Review Form. TTA = discharge prescription.

No errors were detected using the trigger tool

Type of error	Methods used to identify errors				
	Pharmacist alone	RRF alone	Pharmacist and RRF	Spont. report alone	Total errors detected
<b><i>Need for drug</i></b>					
Omission from drug history	2	19	0	0	21
Omission from TTA	1	11	0	0	12
Other omission	1	11	0	0	12
Duplication of drug	2	2	1	0	5
No indication for drug	4	1	0	0	5
<b><i>Select specific drug</i></b>					
Drug incorrect	0	6*	0	1	7
<b><i>Select drug dose</i></b>					
Dose incorrect	9	38*	5	0	52
<b><i>Select formulation</i></b>					
Formulation incorrect	1	1	1	0	2
<b><i>Give instructions for product supply</i></b>					
Sign and date prescription	0	0	0	0	0
Specify correct strength	0	1	0	0	1
<b><i>Give administration instructions</i></b>					
Route incorrect	0	4	1	0	5
Other administration	1	2	1	0	5
<b>TOTAL (% of all errors)</b>	<b>21 (16.5%)</b>	<b>96 (75.6%)</b>	<b>9 (7.1%)</b>	<b>1 (0.8%)</b>	<b>127 (100%)</b>

**Comparison of prescribing errors identified using each method or combination of methods, presented according to type of error, for the post-ServeRx cohort.**

RRF = Retrospective Review Form. TTA = discharge prescription

\* In each case, one of these errors was identified by the trigger tool method as well as the RRF.

## Appendix K. UK studies evaluating electronic prescribing systems in hospital inpatients (Chapter 8)

Ref	Setting	System	Outcome measures	Study design	Key results
Cavell et al (1997)	20-bed general medical ward	Not stated - ?decision support - eRx but <u>paper</u> MAR -	1) Medication administration errors (using observation)	Comparison with 31-bed medical ward at different site	1) 5.5% of 1,295 doses had error with eRx; 5.7% of 1,206 doses at control site. No statistically significant difference.
Evans et al (1998)	ICU at John Radcliffe, Oxford	CareVue (ICU package) - flags doses outside ref range - eRx & eMAR	1) Pharmacist audit of adherence to prescribing standards 2) Time taken to prescribe 3) Time taken to document administration	3 week audit pre and post (one month after)	1) IV fluids 64% of 194 correct before; 48% of 255 after. IVIs 48% of 284 correct before; 32% of 247 after. Intermittent drugs 90% of 706 before, 90% of 723 after. No statistical analysis. 2) 20 sec before; 55 sec after (" <i>n</i> " not given – may be one drug?) 3) 2 sec before; 21 sec after (" <i>n</i> " not given – may be one drug?)
Fowle et al (2000) [abstract]	36-bed orthopaedic ward, Scotland	Pharmakon - "on-line Rx support" - eRx & eMAR	1) Prescribing errors ( <i>methods and definitions not given</i> ) 2) Medication administration errors (using observation)	Pre and post (1 month post and 1 year post)	1) 7.4% of 2238 IP orders had errors pre, 7.0% of 2153 at 1 month, 4.7%* of 2030 at one year. 7.5% of 826 TTA had errors pre, 7.7% of 634 at 1 month, 5.9% of 1658 at 1 year. 2) 9.0% of 3364 doses had errors pre, 6.0%* of 3334 doses at 1 month, 5.4%* of 2805 at 1 year. * confidence intervals do not overlap pre
Nightingale et al (2000)	64-bed renal unit, Birmingham	In-house system - Various decision support - eRx & eMAR	1) Attempted medication orders cancelled by system 2) Proportion of warning messages over-written 3) Users comparison of system with previous	Descriptive study post implementation	Descriptive study post implementation

Ref	Setting	System	Outcome measures	Study design	Key results
Almond et al (2002)	33-bed renal / medical ward, Southend	Medichain - Decision support - eRx & eMAR	1) Review of prescriptions for prescribing errors (interventions?) 2) Time taken to do drug rounds 3) Percentage of successful administrations (?MAEs) (observation pre, according to system post?) 4) Timing of ward pharmacist 5) Stock management ( <i>methods not clear in paper</i> )	- 3 month data collection - pre and post (immediately post?) - respiratory ward used as control ward	1) "pattern did not change " ( <i>no results given</i> ) 2) Time doubled( <i>no results given</i> ) 3) 90% of 1169 doses successful pre, 95% of 18,357 post 4) ( <i>no results given</i> ) 5) ( <i>no results given</i> )
Anton et al (2004)	64-bed renal unit, Birmingham	In-house system - Various decision support - eRx & eMAR	1) Number of warning messages generated and proportion overridden; comparison between grades and familiarity with system	Descriptive study post implementation	1) New doctors generated fewer warning messages after 3 weeks, senior doctors more likely to ignore warning messages
Marriot et al (2004) [abstract]	Queens Hospital Burton	Meditech - eRx & eMAR - ?decision support	1) Pharmacists' interventions	3 months data; comparison with hospital using paper system	1) 763 interventions (0.05/FCE) with paper system; 2512 interventions (0.2/FCE) with eRx system. Different types intervention – monitoring of therapy with eRx system / therapy selection and prescribing with paper system
Shulman et al (2005)	22-bed ICU, University College Hospital	QS 5.6 CIS (US system) - no decision support	1) Prescribing errors as recorded by ward pharmacist	6 months before and intermittently during 9 month period after	1) 6.7% pre and 4.8% post ( $p = 0.04$ ; chi square test). Post data varied over time, with higher error rate 10 weeks after introduction; lower error rates by 25 weeks. New types of serious error.

**Comments:**

- no study has used a comprehensive range of outcome measures
- descriptive and not statistically powered
- some of the outcome measures used are “weak”
- one of most promising studies (Fowlie et al) only in abstract form and limited detail