Mapping national surveillance of surgical site infections (SSIs) to national needs and priorities: an assessment of England's surveillance landscape

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Running title:
SSI surveillance vs needs and priorities

SUMMARY

Background: The rise in antimicrobial resistance has highlighted the importance of surgical site infection (SSI) prevention with effective surveillance strategies playing a key role in improving patient safety. This study maps national needs and priorities for SSI surveillance against current national surveillance activity.

Methods: This study analysed SSI surveillance in NHS hospitals in England covering 23 surgical procedures. Data collected were: (i) annual number of procedures, (ii) SSI rates from national reports, (iii) national reporting requirement (mandatory, voluntary, not offered), (iv) priority ranking from a survey of 84 English NHS hospitals, (v) excess length of stay and costs from the literature. The relationships between estimated SSI burden, national surveillance activity, and hospital-reported priorities were explored with descriptive and univariate analyses.

Findings: Among the 23 surgical categories analysed, top priority ranking by hospitals was associated only with current surveillance ($r=0.76$, $p<0.01$) and mandatory reporting (33% vs 8 and 4%, $p=0.04$). Percentage of hospitals undertaking surveillance, mandatory reporting, and the selection of priorities did not match SSI burden. Large bowel surgery (LBS, voluntary) and caesarean section (not offered) were the two highest contributors of total SSIs per annum, with 39,000 (38%) and 17,000 (16%) respectively, while the four orthopaedic categories (all mandatory) contributed 5,000 (5%). LBS also had the highest associated costs (£119m per annum).

Conclusion: Current surveillance and future priorities were not associated with SSI rate, volume, or cost to hospitals. The two highest contributors of SSIs and related costs have no (caesarean section) or limited (LBS) coverage by national surveillance.

Keywords: surgical site infection; surveillance; national surveillance; healthcare associated infections; priorities

Introduction

Despite progress in minimising the risk of surgical site infection (SSI) [1], they still pose a substantial problem globally [2]. In England, SSI remains the third most common healthcare-associated infection (HCAI) in hospitals, accounting for 15.7% of all HCAIs [3]. SSIs result in significant morbidity and mortality and are consequently a public health priority [4]. They are also a considerable financial burden for health systems [5].

Surveillance of SSI is a key component of infection prevention and control (IPC) programmes [6,7] as sustained surveillance has been shown to drive infection rates down [8]. The national public health institute, Public Health England (PHE), coordinates surveillance through the Surgical Site Infection Surveillance Service (SSISS). Prospective data collection and follow-up is performed on an individual basis by a specially-trained healthcare professional. Surveillance is mandatory in NHS hospitals for at least one quarter per financial year in at least one of four orthopaedic procedures, and hospitals can submit data voluntarily for 13 other surgical categories [9].

In 2013, PHE undertook a survey of all acute NHS Trusts in England which included questions on their future priorities for SSI surveillance [10]. The results revealed heterogeneity in priority areas but with strong support for orthopaedic surveillance and caesarean section, the latter not currently included in the programme. However, an objective assessment of the relative burden of SSIs across different surgical categories is needed to inform distribution of surveillance resources.

This study aims to assess the consistency between the current surveillance systems, perception of priorities by Trusts, and the associated SSI burden in England. We mapped the estimated the annual number of SSIs and associated economic burden in each surgical category, against current national surveillance activity, government priority status (mandatory vs voluntary), and the average priority ranking given by Trusts in the survey [10].

Methods

Surgical categories included

The study included 13 clean (minimum wound class I) and 10 clean-contaminated (minimum wound class II) procedure types, including 17 procedures offered by the SSISS (4 mandatory, 13 voluntary). Six additional categories for which national surveillance is not currently undertaken were included as they had an average rank in the top 5 in the survey [10].

Data sources

The numbers of procedures undertaken between 1st April 2014 – 31st March 2015 were obtained from the national hospitals admissions database [11]. Categories already included in the SSISS were identified using four-digit Office of Population Censuses and Surveys (OPCS) codes [12]. Codes which could be used for more than one category were excluded. For surgical categories not included in the SSISS, the procedure types for which SSI rates were available were identified in the literature and corresponding OPCS codes were advised by medical coders (Appendix, Table A1).

Priorities and current surveillance practices were obtained from 84 responses to a survey emailed to 161 IPC teams at all acute Trusts in England by PHE in 2013 [10] and current national surveillance requirements (i.e. mandatory, voluntary, not offered) were obtained from the SSISS protocol [9] .

Data on SSI rates, excess length of stay (LOS) and excess costs were obtained by conducting a literature review searched in order of applicability to the English setting (Appendix, Figure A1), beginning with national SSISS reports, and ending with single-site studies from non-OECD countries. Where research papers were the data source, only observational studies for the purpose of surveillance were included. Interventional studies and studies primarily analysing risk factors were excluded. Unpublished data on SSI rates that included full post-discharge surveillance (PDS, including community and outpatient surveillance) were provided by PHE for the categories included in the SSISS.

Estimations of parameters

Where the rate of SSI including full PDS were unavailable from the SSISS, rates were estimated by scaling up the best available inpatient and readmission SSI rates in line with the proportion of infections identified by PDS reported in the literature. For example, if one study in England reported inpatient and readmission SSI rates of 3% in a category but no rate including PDS, and a French study reported an inpatient and readmission SSI rate of 8%, and 17% including PDS, we calculated ((17-8)/17)*100 = 52.9% of SSIs to be diagnosed through additional PDS, so the equivalent rate in England would be 3*((100+52.9)/100) = 4.59%. The annual number of SSIs per category was estimated by multiplying the annual volume of procedures by the appropriate SSI rate.

Estimation of excess costs

Papers reporting excess costs per SSI were quality assessed using the Newcastle-Ottawa Scale [13]. Costs were inflated to 2014-15 using the Hospital and Community Health Services (HCHS) pay and price inflation indices [14], and converted to GBP where

necessary using the 2014 average exchange rates from UK Forex [15]. The excess cost of SSI to hospitals annually was calculated by multiplying the number of infections among inpatients and readmissions by the inflated and converted mean cost per SSI.

Data analysis

A descriptive analysis was performed by dividing data for each factor into quartiles and assigning a number Q1 to Q4, which are represented by colours in Table I (Q1=green (least compelling reason for surveillance), Q2 & 3=yellow, Q4=red (most compelling reason for surveillance)). Radar charts were constructed to explore relationships between the current surveillance arrangements, number, and cost of SSIs in each category. A narrative description of the patterns based on visual inspection was performed by 2 authors working independently (R.T. and G.B.), and disagreements were resolved by a third person (A.H.). Surgeries were split by minimum wound classification (clean vs. clean-contaminated). To investigate whether the choice of category for surveillance was related to any of the factors (e.g. SSI rate, perceived priority), an analysis was carried out using a Spearman correlation test for continuous variables and a Kruskall-Wallis test for categorical variables. P values ≤0.05 were considered statistically significant.

Results

The 23 surgical categories analysed in the study represented a volume of 2.01 million procedures annually in England. The SSI rate (inpatient and readmission, includes superficial, deep, and organ/space) for all procedures varied from 0.4% [16] (95% confidence interval (CI) not available) in pacemaker surgery to 10.4% [17] (95% CI 9.9-10.8) for large bowel surgery (Table 1). From all evidence sources (see appendix 3), it was estimated that when additional post-discharge infections (community and outpatient detection) were included, surgery in England results in 100,965 SSIs annually.

From the published literature, the excess LOS due to SSI was estimated to range from 1 [18] (95% CI -3-17) day for SSI occurring after cranial surgery and up to 29 days [18] (95% CI not available) for SSI following gastric surgery. Across all surgery types, excess LOS due to SSIs equates to an estimated 501 490 extra bed days annually. Similarly, excess costs ranged from £1 315 [19] (95% CI not available) per SSI in abdominal hysterectomy to £30 171 [20] (95% CI £26 434 - £33 583) in pacemaker surgery (2014/2015 GBP). SSIs across all surgery types were estimated to cost hospitals an extra £232 866 861 annually.

Half of the 84 respondents to the survey (50%) [10] reported hip replacement as a top future priority, followed by CABG (47%) and caesarean section (46%). Cholecystectomy, gastric, reduction of femoral neck fracture, limb amputation and bile duct, liver, pancreatic surgeries were classified as lower future priorities.

Visual analysis of radar charts of the surgical categories and assessment factors revealed mismatches in several surgical categories. Large bowel surgery and cholecystectomy had an annual number of SSIs and estimated costs in the highest quartile (Q4), while surveillance is voluntary (Q3) (Figure 1). Caesarean section had an annual number of SSIs in Q4, costs in Q3, and priority ranking in Q4, but is not included in the national surveillance programme. Conversely, knee replacement has SSI numbers in Q2 and costs in Q3, but the

percentage of hospitals conducting surveillance and future priorities in Q4, and reporting is mandatory.

The survey also asked respondents whether they were currently undertaking surveillance in a given surgical category. The percentage of hospitals undertaking surveillance in a category was not associated with the excess cost to hospitals, or the number of SSIs. Future priorities did not correlate with annual volume of procedures, current estimated no. of SSIs, or the excess cost to hospital, but was associated with surveillance already performed ($r=0.76$, $p=<0.01$).

Discussion

By mapping the current available data on SSI characteristics and surveillance requirements, mismatches have been revealed between surgical categories under surveillance, the economic and disease burden represented by infections, and the identification of future priorities. In general, the risk and number of SSIs, and their excess costs seemed not to influence hospitals in the design of their surveillance strategy or their perception of priorities.

Trusts in England perceived orthopaedic surgery, CABG and caesarean section as top priorities for SSI surveillance strategies [10]. Orthopaedic surgery has historically been included in surveillance systems as a surgical quality indicator, but a recent Australian study [21] concluded that SSI rates are procedure-specific rather than hospital-specific, challenging the rationale behind this indicator. Mandatory surveillance in orthopaedic surgery has contributed to the major decrease of SSI rates nationally to below 1% [17]. However, this may have led to a “tunnel vision” effect, with hospitals focusing on orthopaedic surgery at the expense other specialties [22]. While it is important to continue surveillance in orthopaedic surgery in order to maintain these gains, there is little room for further improvement [17]. More SSIs could now be prevented by extending surveillance to other specialties in order to replicate the reductions seen in orthopaedic surgery.

In 2014/15, hospitals in England submitted data on 130 316 [17] out of a possible 1 205 676 [11] operations to the SSISS based on our calculations. More recently, the Getting It Right First Time (GIRFT) initiative found that only four of the 50 hospitals were able to report SSI rates for general surgery [23]. Consequently, SSIs were targeted by a national audit aiming to tackle unwarranted variation in care quality and procurement [24], which may generate the data and inertia needed for hospitals to strategically expand surveillance into categories not currently included in national surveillance. The fact that many hospitals are already undertaking in-house surveillance in categories not included in the SSISS is an encouraging first step.

The present study suggests there are opportunities to use SSI surveillance to drive improvements in patient outcomes, costs, and efficiency by targeting interventions where they can have the highest impact. A report by Lord Carter focused on savings that could be made by reducing infection rates in orthopaedic surgery [5]. However, the present study shows that SSIs in the four mandatory orthopaedic categories account for only 9% of estimated excess cost to hospitals annually, seven times less than large bowel surgery. Likewise, interventions in categories with a high associated LOS such as gastric surgery (29

days) could create more bed spaces, improve hospital efficiency and avoid patient exposure to other HCAIs [25]. Future studies may examine how these factors should be weighted, and similar studies could be replicated on a local, national, or international scale.

Despite proven clinical value, surveillance methods are labour-intensive, and given financial constraints [5] and staff shortages, surveillance must be prioritised carefully. Automating some aspects of surveillance could help to reduce costs and subjectivity in diagnosis. Several automated or semi-automated surveillance systems have been developed [26–30] and innovative systems of PDS are also being developed [31,32], including an electronic post-discharge questionnaire being developed for the SSISS [33], which are especially important in surgical categories with a short postoperative length of stay. There is growing evidence to support the utility of these systems for SSI surveillance [34], and growing guidance to support their design and implementation [35].

To our knowledge, this is the first paper to assess the fit between current and future priorities of a national SSI surveillance system and the important factors which impact patients and the health system. The strengths of this paper are its scope in including multiple surgical categories and factors, its selection of papers based on their applicability to the setting, and its use of visual and statistical analysis to enable both category-level and overall assessment of agreement.

However, there are some important limitations to this study. However, there are some important limitations to this study. Costs presented were estimated using several different methodologies, some of which focus purely on costing additional LOS, potentially limiting cost comparability and applicability, though, the papers included were all judged to be of a high quality using the Newcastle-Ottawa checklist (data not shown)[13]. Often the costliest facet of SSI treatment for orthopaedics is revision surgery, which is not accounted for if only additional LOS is considered. To assess the extent of this omission, a separate analysis using the cost of revision surgery due to SSIs in hip [36] and knee [37] replacement, the number of joint replacements [11] and proportion of these that were revisions due to infection [17] calculated excess costs due to SSIs of at least £19 844 824 and £23 230 805 respectively. The same may be true in other surgical categories, but unfortunately comparable data on costs for septic revision were not available.

There are other limitations to be considered. Concerns have been raised about reliability of data reported to the SSISS [38,39]. However these concerns are common to all surveillance systems, particularly those that rely on manual data collection [40], and SSISS reports still represent the best data available for estimating SSI rates in England. Not all studies were performed in England; unit costs and patient treatment pathways can vary dramatically between countries, reducing external validity of such estimates [41]. Similarly, some studies such as Jenks et al. [18] were conducted in single centres and so are based on small numbers of patients. Unfortunately, it was not possible to include confidence intervals or ranges in the univariate statistical analysis performed, due to lack of data availability. The lack of data on morbidity and mortality associated with SSI, and the extent to which SSIs are preventable in different categories precluded the inclusion of these factors despite their obvious importance. We recommend further studies on morbidity associated with SSI in different categories using quality-adjusted life years, potentially through data linkage methodologies to reduce the data collection burden on the NHS.

In conclusion, this study suggests that current SSI surveillance and future hospital priorities are not targeting surgical categories with the highest burden in terms of risk, number of SSIs, and cost. Systematic priority setting could provide benefits both to patients and health systems. The methodology used in this study could be used in settings of any size when designing or redesigning surveillance strategies.

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Conflict of interest statement

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Surgery type	% SSIs identified by

Figures

Surgery type	Annual procedure volume[a]	SSIs rate (%) inpatients and readmissions[b]	SSI rate (%) inc. PDS[c]	Estimated no. SSIs	Estimated no. SSIs inc. PDS	Excess LOS (days)[d]	Excess cost per infection (£)[d]	Estimated excess cost to hospitals annually (£)	% already undertaking surveillance [42]	Future priority (1 = top priority) [42]	% ranking as top priority [42]	Current national surveillance [9]
Clean												
Breast	197,397	1 (0.8-1.2)	4.26 (3.9-4.6)	1974 (1579-2369)	8409 (7698-9080)	3 (1-4)	1,524 (1,165-4,210)	3,008,262	25	4	12	Voluntary
CABG	34,859	4.1 (3.9-4.3)	7.26 (7-7.6)	1429 (1360-1499)	2531 (2440-2649)	13 (12–15) [19]	5,340[19]	7,631,563	76	2.9	47	Voluntary
Cardiac (non CABG)	27,539	1.2 (1-1.4)	1.73 (1.5-2)	330 (275-386)	476 (413-551)	23 (19-30)	11,415 (8,836-15,971)	3,772,192	59	3.9	24	Voluntary
Cranial	23,255	1.4 (1.1-1.7)	1.84 (1.5-2.2)	326 (256-395)	428 (349-512)	1 (-3-17)	2,762 (5-21,056)	899,095	33	4.3	7	Voluntary
Hip replacement	88,145	0.7 (0.6-0.7)	1.23 (1.2-1.3)	617 (529-617)	1084 (1058-1146)	12 (10–12) [19]	4,583 [19]	2,827,619	92	2.8	50	Mandatory
Knee replacement	85,255	0.6 (0.6-0.6)	1.72 (1.7-1.8)	512 (512-512)	1466 (1449-1535)	11 (9–13) [19]	4,344 [19]	2,222,159	89	3.1	40	Mandatory
Limb amputation	18,638	3.2 (2.5-4)	4.22 (3.4-5.2)	596 (466-746)	787 (634-969)	21 (13–31) [19]	8,369 [19]	4,991,274	13	4.8	4	Voluntary
Ophthalmic surgery (cataract)	387,991		0.1 (0.1-0.2) [43]		543 (427-660)				10	4.5	0	Not offered
Pacemaker	60,396	0.4[16]	0.4[44]	242	242		30,171 (26,434-33,583) [20]	7,288,903	7	3.1	26	Not offered
Reduction of long bone fracture	105,071	1.1 (1-1.3)	1.52 (1.3-1.7)	1156 (1051-1366)	1597 (1366-1786)	10 (6–14) [19]	3,945 [19]	4,559,678	22	4.8	9	Mandatory
Repair of neck of femur	41,239	1.3 (1.3-1.5)	1.56 (1.5-1.6)	536 (536-619)	643 (619-660)	19	12,557	6,731,839	59	3.7	26	Mandatory
Spinal	66,237	1.2 (1.1-1.3)	1.8 (1.7-2)	795 (729-861)	1192 (1126-1325)	13 (6-27)	7,341 (3,518-18,616)	5,834,761	29	4.1	16	Voluntary
Vascular	37,193	2.7 (2.3-3.1)	4.51 (4-5.1)	1004 (855-1153)	1677 (1488-1897)	12 (10–15) [19]	4,861 [19]	4,881,575	28	3.8	18	Voluntary
Clean-contaminated												
Abdominal hysterectomy	31,968	1.3 (1-1.7)	4.95 (4.3-5.7)	416 (320-543)	1582 (1375-1822)	3 (3–4) [19]	1,315 [19]	546,508	21	4.7	7	Voluntary
Appendicectomy	54,231	2.3 (2.1-2.4) [45]	3.9 (3.6-4.2) [45]	1231 (1136-1326)	2115 (1952-2278)	9 [46]	4,022 [46]	4,952,022	0	3.9	0	Not offered
Bile duct, liver, pancreatic	12,550	5.8 (5-6.8)	7.62 (6.6-8.7)	728 (628-853)	956 (828-1092)	12 (4-24)	2,944 (146-14,750)	2,143,075	17	4.8	9	Voluntary
Caesarean section	166649	1.1 [47]	10 [47]	1833	16665	4 (2-7)	3,855 (927-5,089)	7,066,826	57	2.7	46	Not offered
Cholecystectomy	77,067	4.7 (3.5-6.2)	6.61 (5.1-8.3)	3622 (2697-4778)	5094 (3930-6397)	8	6,469	23,432,884	11	5	2	Voluntary
Gastric	19,607	1.9 (1.2-2.9)	3.31 (2.4-4.5)	373 (235-569)	649 (471-882)	29	22,297	8,306,443	15	4.9	7	Voluntary
Large bowel surgery	304,716	10.4 (9.9-10.8)	12.81 (12.3-13.3)	31690 (30167-32909)	39034 (37480-40527)	9 (8–11) [19]	3,746 [19]	118,721,140	38	3.9	18	Voluntary
Maxillofacial/ENT/oral	133,287		8 [48]		10663				8	4.1	8	Not offered
Prostate	6,599	1.2 [49]	4.3 [50]	77	284				9	4.4	0	Not offered
Small bowel surgery	34,940	7.1 (6.3-7.9)	8.59 (7.8-9.5)	2481 (2201-2760)	3001 (2725-3319)	13 (13–31) [19]	5,260 [19]	13,049,042	22	4.7	5	Voluntary

Clean	
Breast	77
CABG	44
Cardiac (non CABG)	31
Cranial	24
Hip replacement	43
Knee replacement	65
Limb amputation	24
Ophthalmic surgery (cataract)	0 [43]
Pacemaker	0 [44]
Reduction of long bone fracture	28
Repair of neck of femur	17
Spinal	33
Vascular	40
Clean-contaminated	
Abdominal hysterectomy	74
Appendicectomy	72 [45]
Bile duct, liver, pancreatic	24
Caesarean section	89 [47]
Cholecystectomy	29
Gastric	43
Large bowel surgery	19
Maxillofacial/ENT/oral	
Prostate	
Small bowel surgery	17

Table 1 Factors associated with the risk, number and cost of SSIs in England by surgical category along with average Trust-reported priority ranking and current surveillance arrangements. Colours relate to the relative quartile of the figure in its column where red = Q4/top priority/mandatory surveillance, yellow = Q2 or Q3/medium priority/voluntary surveillance and green = Q1/low priority/no national surveillance.
[a] From HES data 2014/15[11]
[b] Incidence from April 2010 – March 2015 from SSISS annual report 2014/15[17] unless otherwise stated
[c] Unpublished data from April 2010 - March 2015 provided by PHE. Data from surgical categories not included in SSISS were scaled up from % SSIs using proportion diagnosed after discharge in source referenced in "SSI rate (%) inc. PDS" column when possible, otherwise quoted directly from the referenced source
[d] From Jenks 2014[18] unless otherwise stated

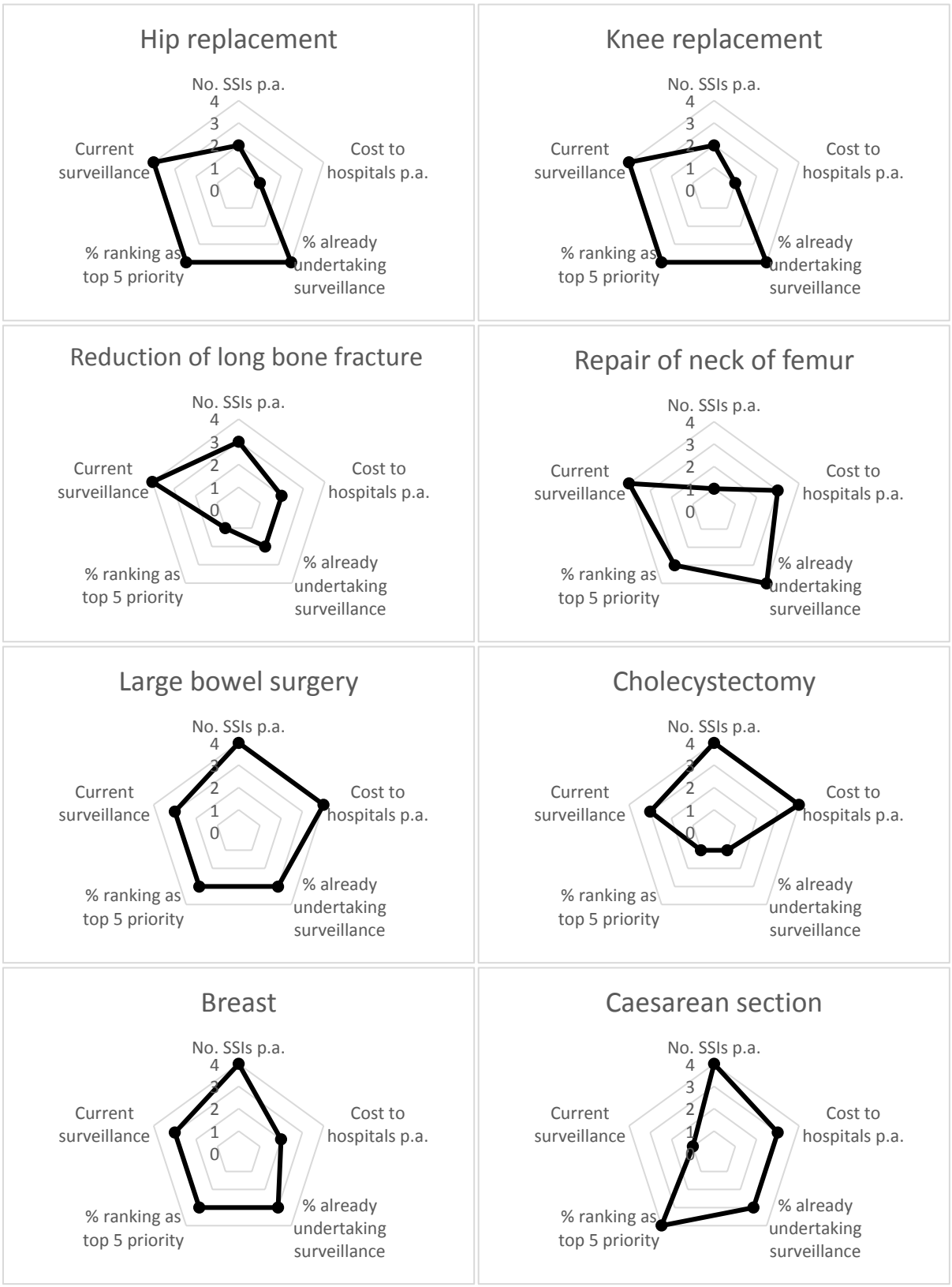

Figure 1 Radar charts comparing surgical categories and quartiles in which the major factors fall relative to other categories. Shown are the four mandatory SSI surveillance categories in England and four categories in which surveillance does not match the relative burden or cost of SSIs. Chosen by independent visual analysis by two researchers (RT and GB). SSIs p.a. is overall estimated no. of surgical site infections per annum; current surveillance where 1= not offered, 3= voluntary surveillance, 4= mandatory surveillance; future priority based on ranking in PHE survey.

Table IIa Contingency table assessing factors explaining the surveillance method and the perception of priorities. An analysis of the data in Table I was carried out using a Spearman correlation test for continuous variables and a Kruskall-Wallis test for categorical variables. P values ≤0.05 were considered statistically significant. Categorical independent variables were described using proportions and continuous variables via medians and 25th-75th centiles.

	Hospitals already undertaking surveillance	p	**Procedures selected as future priority**	p	**Procedures ranked as top priority**	p	**Missing values**
Economic impact, r coefficient							
Excess LOS	0.09	0.69	0.03	0.89	0.15	0.53	4
Estimated excess cost to hospitals annually	-0.22	0.33	0.01	0.95	-0.06	0.81	3
Medical and societal impact, r coefficient							
Estimated no. infections + PDS	0.20	0.34	-0.13	0.54	0.19	0.38	0
Endogenous factors, r coefficient							
Median age in years	0.36	0.09	-0.35	0.09	0.38	0.07	0
Exogenous factors							
Clean, median (Q1-Q3)	29 (22-59)	0.04	3.9 (3.1-4.3)	0.08	18 (9-26)	0.05	0
Clean contaminated, median (Q1-Q3)	16 (9-22)		4.5 (4-4.8)		7 (2-9)		
Factors impacting the surveillance method							
Annual patient volume	0.13	0.54	-0.35	0.09	0.26	0.22	0
% SSIs detected by PDS	0.16	0.47	-0.26	0.23	0.26	0.24	1
National surveillance requirement							
Voluntary, median (Q1-Q3)	25 (17-33)	<0.01	4.3 (3.9-4.8)	0.2	9 (7-18)	0.10	0
Mandatory, median (Q1-Q3)	74 (40.5-90.5)		3.4 (2.9-4.2)		33 (17.5-45)		
Not offered, median (Q1-Q3)	8.5 (7-10)		4 (3.1-4.4)		4 (0-26)		
Hospitals already undertaking surveillance	-	-	-0.57	<0.01	0.76	<0.01	0
Procedure considered as future priority	-0.57	<0.01	-	-	-0.79	<0.01	0
Procedure ranked as a top priority	0.76	<0.01	-0.79	<0.01	-	-	0

*10^3

** 10^6

Abbreviations: PDS, post-discharge; LOS, length of stay; SSI, surgical site infection; Q, quartile

Table IIb Contingency table assessing factors explaining the surveillance method and the perception of priorities. An analysis of the data in Table I was carried out using a Spearman correlation test for continuous variables and a Kruskall-Wallis test for categorical variables. P values ≤0.05 were considered statistically significant. Categorical independent variables were described using proportions and continuous variables via medians and 25th-75th centiles

	Procedures with mandatory surveillance	**Procedures with non-mandatory surveillance**	p	**Missing values**
Economic impact, median (Q1-Q3)				
Excess LOS	11.2 (10.4- 15.25)	12 (4-13.4)	0.76	4
Estimated excess cost to hospitals annually	2.9 (2.1-4.9)**	5.2 (3.2-8.6)**	0.21	3
Medical and societal impact, median (Q1-Q3)				
Estimated no. infections + PDS	1.6 (1.1-1.8)*	1.3 (0.5-10.6)*	0.93	0
Exogenous factors				
Clean, n (%)	4 (100)	9 (47.3)	0.05	0
Clean contaminated, n (%)	0 (0)	10 (52.6)		
Factors impacting the surveillance method				
Annual patient volume	97 (65-105)*	37 (23-133)*	0.20	0
% SSIs detected by PDS	48.7 (34.2-61.7)	47.3 (13.6-72)	0.93	1
Hospital already undertaking surveillance	74 (40.5-90.5)	21 (10-33)	0.02	0
Procedure considered as future priority	3.4 (2.95-4.25)	4.1 (3.9-4.7)	0.21	0
Procedure ranked as a top priority	33 (17.5 – 45)	8 (4 – 18)	0.04	0

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Appendix

Table A1 Description of procedures included in surgical categories which are not included in the SSISS protocol **[12]**. Note that OPCS codes for hip and knee replacement which are used for both were excluded.

Category	**Summary of surgical procedures**	**OPCS codes**
Appendicectomy	Open excisions of appendix	H011, H012, H013, H018, H019, H021, H022, H023, H024, H028, H029
Caesarean section	Elective and emergency caesarean deliveries	R171, R172, R178, R179, R181, R182, R188, R189
Maxillofacial/ENT/oral	Intra-orally performed Le Fort I osteotomies (with a 1-piece or segmented maxilla), mandibular osteotomies, bilateral sagittal split osteotomy (BSSO) and intraoral vertical ramus osteotomy, and functional genioplasty (FG).	V10.4, V16.1, V16.2,
Ophthalmic surgery (cataract)	Insertion of prosthetic replacement lens	C75.1
Pacemaker	Insertion of cardiac pacemaker	K601, K605, K606, K607, K608, K609, K611, K615, K616, K617, K618, K619
Prostate	Open excisions of prostate. Excludes transurethral prostatectomy	M611, M612, M613, M614, M618, M619

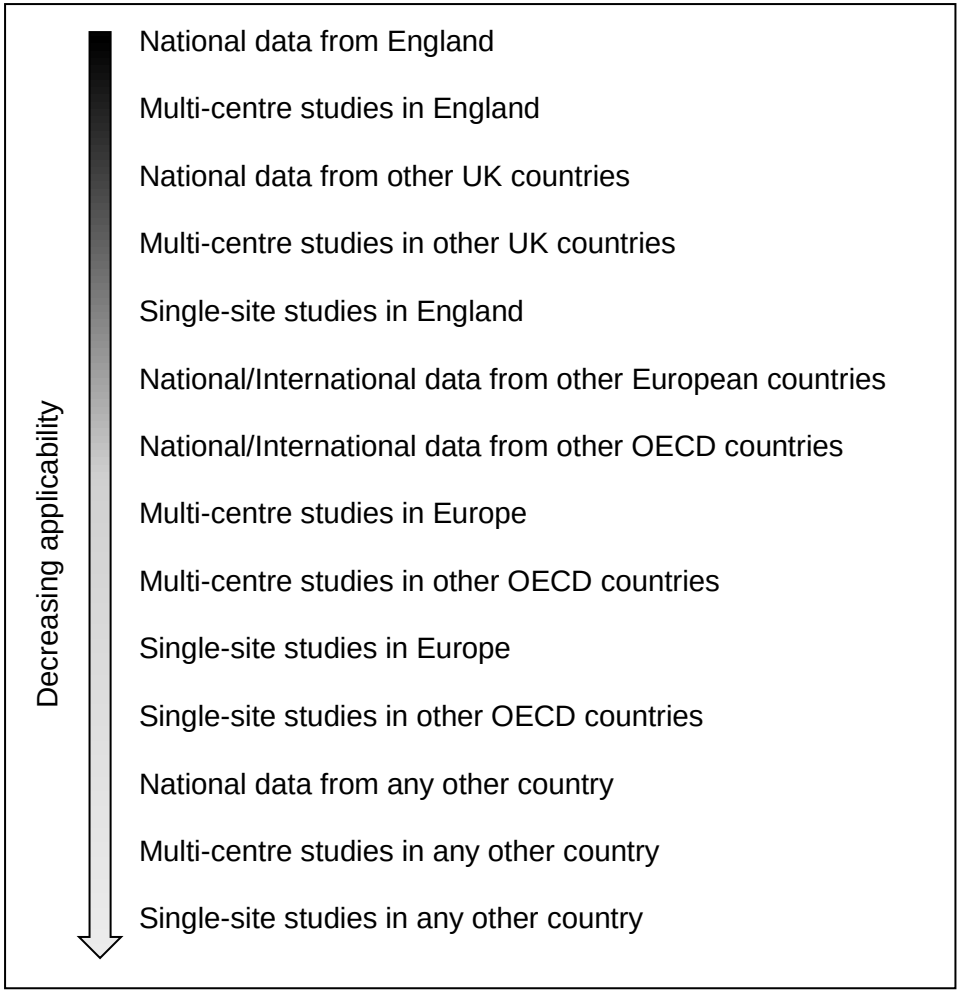

Figure A1 Data sources for surgical site infection rates, costs, and length of stay were selected based on the following hierarchy of applicability to the English setting. OECD, Organisation for Economic Co-operation and Development

Variable	Definition	Data source	Methods used for estimation	Missing values
Annual procedure volume	No. of procedures occurring annually	[11]	No. of procedures per year based on OPCS code in any position in HES database. OPCS codes selected from SSISS supplement or medical coders	-
Infection rate (inpatients and readmissions)	SSIs occurring among inpatients and readmitted patients	[16,18,45,47,49]		Ophthalmic, Maxillofacial/ENT/oral
Infection rate (+PDS)	SSIs occurring among inpatients, readmitted patients, and detected by post-discharge surveillance	Unpublished data provided by the SSISS, [43–45,47,48,50]		-
Estimated no. infections (inpatients and readmissions)			Annual volume x SSI rate (inpatients and readmissions)	Maxillofacial/ENT/oral
Estimated no. infections + PDS			Annual volume x SSI rate (+ PDS)	-
Excess LOS	Median excess length of stay attributable to SSI	[18,19,46]	Matched cohort studies	Ophthalmic, pacemaker, prostate
Excess cost per infection	Mean excess cost attributable to SSI	[18–20,46]	Matched cohort studies – costs inflated to 2014-15 prices[14] and converted to GBP using 2014 average exchange rates [15]	Ophthalmic, maxillofacial/ENT/oral, prostate
Estimated excess cost to hospitals annually			Estimated cost per infection x SSI rate (inpatients and readmissions)	Ophthalmic, maxillofacial/ENT/oral, prostate
% already undertaking surveillance	% of responding trusts indicating they already undertake surveillance either in-house or reporting on this category to the SSISS	[42]		-
Future priority	Mean ranking of category (where 1 is the highest)	[42]		-
% raking as top priority	% of responding trusts ranking the category as the top priority over the next 3 years	[42]		-
Current surveillance		[9]		-
% PDS		Unpublished data provided by the SSISS, [43–45,47]		Maxillofacial/ENT/oral, prostate

Table A2 Definitions, sources, methods and missing values of factors

Legends

Table 2 Factors associated with the risk, number and cost of SSIs in England by surgical category along with average Trust-reported priority ranking and current surveillance arrangements. Colours relate to the relative quartile of the figure in its column where red = Q4/top priority/mandatory surveillance, yellow = Q2 or Q3/medium priority/voluntary surveillance and green = Q1/low priority/no national surveillance. [a] From HES data 2014/15[12] [b] Incidence from April 2010 – March 2015 from SSISS annual report 2014/15[18] unless otherwise stated [c] Unpublished data from April 2010 - March 2015 provided by PHE. Data from surgical categories not included in SSISS were scaled up from % SSIs using proportion diagnosed after discharge in source referenced in "% SSIs inc. PDS" column when possible, otherwise quoted directly from the referenced source [d] From Jenks 2014[19] unless otherwise stated
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