Evaluation of the practice of dose rounding in Paediatrics

ABSTRACT

Objectives

To investigate the rounding of prescribed drug doses for paediatric administration.

Methods

A cross-sectional medication chart review was conducted at a UK paediatric hospital. Proposed administration dose volumes were calculated for prescribed doses using available manufactured liquids measured with oral and intravenous syringes. Resulting percentage deviations in doses administered were calculated.

Results

Of 2031 doses observed 524 (25.8%) required rounding. The majority of which were for children aged 1-12 months. Twenty-seven rounded doses deviated from the prescribed dose by more than 10%.

Conclusion

This study highlights the impact of dose-rounding in paediatrics and the need for standardisation.

Keywords:

Paediatric practice, dose-rounding, children, paediatric dosing

Introduction

The most common patient safety incidents reported in children are medication errors, including wrong dose errors. Causes include calculation errors and dose-rounding errors.[1-3]

Measuring calculated doses precisely from liquid formulations can be difficult. Recommended devices, e.g. oral syringes, may not measure sufficiently accurately, especially when small volumes of liquids are needed.[4-6]

There are no established UK standards or guidelines on dose-rounding. A US study proposed dose-rounding tolerances for use in electronic prescribing systems.[7] Unfortunately, these do not include drugs commonly prescribed in the UK. Greater understanding of dose-rounding and its potential impact on patient safety is required. This study aimed to investigate dose-rounding of prescribed oral liquid and intravenous (IV) medicines in a UK children's hospital.

Methods

A cross-sectional medication record review was conducted for all paediatric inpatients (0-18 years) over two 5-day study periods 7 days apart.

Data were collected prospectively. Details of prescribed oral liquid and IV medicines prepared for administration were recorded. Patients' age and weight were noted. Drug concentrations available for administration were identified. Corresponding dose volumes (DVs) were calculated and compared to graduations on available oral and IV syringes. Where doses were rounded % deviations from prescribed doses were calculated.

The need for dose-rounding depends on the administration device used, drug concentration and dose prescribed. Different syringes have different graduation markings. DV accuracy depends on the graduation markings and measurement volume.[6] Parameters were calculated (box-1). Nurses at this hospital are taught that the midpoints are rounded up (i.e. 1.5 rounded to 2.0).

Box-1 Calculated parameters

Calculated DV (mL):	Exact volume equalling the prescribed dose
Proposed administration volume (mL):	Prescribed DV rounded to the nearest graduation of an appropriate syringe
Proposed administered dose (mg):	Calculated dose corresponding to proposed administration volume
Deviations (%):	$\frac{\text{Proposed administered dose} - \text{Prescribed dose}}{\text{Prescribed dose}} \times 100$

The percentage deviation of proposed administered doses was compared with a published dose-rounding tolerance.[7]

Data analysis was conducted using Stata11. Data are presented as number, percentage and median (interquartile range, IQR), unless otherwise specified.

The paired t-test and One-way ANOVA test were used where appropriate. Statistical significance was considered at $p \leq 0.05$.

This study was registered as a service evaluation therefore no ethical approval was required.

Results

Dose-rounding was required for 524 of 2031 (25.8%) doses prescribed for 171 patients [median age 0.5 years IQR 0.1-3.0 years; median weight 5.3 kg IQR 2.8-16.5]. Of 524 rounded doses, 35.1% (184) were for patients aged between 1-12 months and 64.1% (336) were for those weighing 1-10 kg. [Supplementary table 1]

Overall, there was a significant difference in percentage deviation of proposed administered volume from calculated DV between age groups ($p<0.002$). A similar significant difference was identified between weight groups ($p<0.004$), and between oral and intravenous routes of administration ($p<0.01$). [Supplementary table 1]

Of 524 rounded doses, 27 (5.2%) deviated from prescribed doses by more than 10%. 65.6% (344/524) of rounded doses were higher than the prescribed dose. For 11 patients, doses were rounded up by 11.1 - 20%. Doses were rounded down by 12% - 30.6% for 10 patients.

Morphine doses were commonly rounded including deviations of more than 20% for 6 patients. [Supplementary table 2]

Figure 1 shows the percentage deviation of proposed administered DV from the prescribed DV. Small prescribed DVs resulted in greater percentage deviations in rounded volumes. Maximum DV deviation was a 30.6% deviation below the prescribed dose for a child (weight 1.6 kg) prescribed a morphine injection.

Only 25 drugs that were included in the US study were observed.[7] Rounding tolerances of 10-15% were defined for 13 of these drugs.[7] However, for the same 13 drugs, rounded dose deviations of -12% to 8% were observed in this study.

For 12 drugs rounding tolerances of 0 - 5% were defined. However, deviations of -30.6 to 20% were observed in this study, (Table 1).

Among the drugs with a 0% rounding tolerance was morphine.[7] In this study, the greatest deviations observed was for morphine rounded doses; 20.0% above prescribed dose (rounded up) and -30.6% below prescribed dose (rounded down).

Discussion

This study highlights significant variations between prescribed and administered doses, especially in infants with low body weight where greatest deviations occur.

Limitations include the assumption that the most appropriate drug concentration and syringe size was always used. Other deviations are possible. The impact of reported deviations on patients was not studied. The study was conducted in a single hospital. Findings may differ in

other healthcare facilities. Differences in the methodologies between US and UK studies, mean comparison of findings should be interpreted with caution. Despite limitations affecting the generalisability of this study, it provides an insight into the relationship between prescribing practices and accuracy of medicines administration to children.

It is recommended that dose-rounding should only be undertaken once, ideally at the prescribing stage where a standardised approach could be implemented, and the potential impact on patient safety considered, particularly for drugs with a narrow therapeutic index. The US study suggested a rounding tolerance of 0% for morphine, clonidine and atropine.[7] Our study identified doses of morphine rounded by more than 20% for six patients. Opiates are high risk drugs and potentially fatal in overdose.[8] Guidance for dose-rounding for drugs with greater deviations between administered and prescribed doses should be prioritised.

Although actual doses administered were not observed, our findings are consistent with other studies where final morphine infusion concentrations deviated by more than 20% from prescribed dose.[9-11]

Most patients receiving rounded doses were under 1 year old or weighed between 1-10kg. Dose deviations were also highest in these patients where changes in dose may have a large clinical impact.[12]

Due to changes in body weight and physiology during the first year of life greater care should be taken when rounding prescribed doses for administration to this patient group. Deviations should be kept to a minimum with consideration to pharmacokinetic and pharmacodynamic parameters, and clinical condition (e.g. critical care).

Deviations between prescribed and rounded doses depend on design of measuring devices. In this study deviations were predicted based on the most suitable device according to size

and graduations. In practice where no dose-rounding guidelines exist practitioners may round doses differently or use different devices.

Further work is needed to produce standard dose-rounding limits for drugs commonly prescribed for paediatric patients in UK.

Conclusion

This study identified that many children are prescribed doses of commonly used medicines that cannot be accurately measured in a syringe without dose-rounding. DV rounding may result in administration of higher doses, particularly in children aged less than 12 months and weighing 1-10 kg.

This study highlights the need for standard rounding limits for safe prescribing in children, particularly for high risk drugs. Risks associated with dose-rounding may be managed through availability of appropriate manufactured medicine formulations and administration devices.

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References

1. National Patient Safety Agency. Review of patient safety for children and young people. National Reporting and Learning Service, London, 2009. http://webarchive.nationalarchives.gov.uk/20171030124315/http://www.nrls.npsa.nhs.uk/resources/?entryid45=59864&p=11 (accessed 13 Aug 2018).

2. National Patient Safety Agency. Safety in doses: improving the use of medicines in the NHS. National Reporting and Learning Service, London, 2009. http://webarchive.nationalarchives.gov.uk/20171030124426/http://www.nrls.npsa.nhs.uk/resources/?entryid45=61625&p=10 (accessed 13 Aug 2018).

3. Booth KA, Whaley JE. Fractions and decimals. In: math and dosage calculations for medical careers. 2nd ed. New York: McGraw-Hill, 2007.

4. Grießmann K et al. Dosing accuracy of measuring devices provided with antibiotic oral suspensions. *Paediatr Perinat Drug Ther* 2007; 8:61–70.

5. Paediatric Formulary Committee. British National Formulary for children (BNF- C) 2017-2018. London: BMJ Group, Pharmaceutical Press and RCPCH Publication Ltd.

6. Arenas-López S et al. Accuracy of enteral syringes with commonly prescribed paediatric liquid medicines. *Arch Dis Child* 2017; 102:659-63.

7. Johnson KB et al. Automated dose-rounding recommendations for pediatric medications. *Pediatrics* 2011; 128:e422-8.

8. Rashed AN et al. Adverse drug reactions in children--international surveillance and evaluation (ADVISE): a multicentre cohort study. *Drug Saf* 2012; 35:481-94.

9. Rashed AN et al. Sources and magnitude of error in preparing morphine infusions for nurse/patient controlled analgesia in a UK paediatric hospital. *Int J Clin Pharm* 2016; 38:1069-74.

10. Aguado-Lorenzo V et al. Accuracy of the concentration of morphine infusions prepared for patients in a neonatal intensive care unit. *Arch Dis Child* 2013; 98:975-9.

11. Campino A et al. Strategies implementation to reduce medicine preparation error rate in neonatal intensive care units. *Eur J Pediatr* 2016; 175:755-65.

12. Taylor BL et al. Prescription writing errors in the pediatric emergency department. *Pediatric Emergency Care* 2005; 21:822-7.

Table 1 Rounding tolerance reported in the US study [7] and percentage deviation in the UK study

Drug Name	US study	UK study	
	Suggested rounding tolerance (%)	Proposed administered dose deviation (%)	Number of doses deviated
Carbamazepine	2	2.7	1
Clonidine	0	2.2 to 3.2	8
Dexamethasone	5	-1 to 5.3	15
Diazepam	2	0.8 to 4.0	4
Digoxin	0	-0.94 to 4.0	2
Furosemide	5	-3.2 to 11.11	3
Levothyroxine	0	1.56	1
Lorazepam	2	1.33	1
Metronidazole	5	-1.04 to 4.35	8
Morphine	0	- 30.6 to 20.0	39
Phenobarbital	2	-2.5 to 2.0	4
Topiramate	2	2.22	1