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Computer Calculated Dose in Paediatric Prescribing

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Abstract

Background and objective: Medication errors are an important cause of hospital-based morbidity and mortality. However, only a few medication error studies have been conducted in children. These have mainly quantified errors in the inpatient setting; there is very little data available on paediatric outpatient and emergency department medication errors and none on discharge medication. This deficiency is of concern because medication errors are more common in children and it has been suggested that the risk of an adverse drug event as a consequence of a medication error is higher in children than in adults.
Objective: The aims of this study were to assess the rate of medication errors in predominantly ambulatory paediatric patients and the effect of computer calculated doses on medication error rates of two commonly prescribed drugs.
Methods: This was a prospective cohort study performed in a paediatric unit in a university teaching hospital between March 2003 and August 2003. The hospital's existing computer clinical decision support system was modified so that doctors could choose the traditional prescription method or the enhanced method of computer calculated dose when prescribing paracetamol (acetaminophen) or promethazine. All prescriptions issued to children (<16 years of age) at the outpatient clinic, emergency department and at discharge from the inpatient service were analysed. A medication error was defined as to have occurred if there was an underdose (below the agreed value), an overdose (above the agreed value), no frequency of administration specified, no dose given or excessive total daily dose. The medication error rates and the factors influencing medication error rates were determined using SPSS version 12.
Results: From March to August 2003, 4281 prescriptions were issued. Seven prescriptions (0.16%) were excluded, hence 4274 prescriptions were analysed. Most prescriptions were issued by paediatricians (including neonatologists and paediatric surgeons) and/or junior doctors. The error rate in the children's emergency department was 15.7%, for outpatients was 21.5% and for discharge medication was 23.6%. Most errors were the result of an underdose (64%; 536/833). The computer calculated dose error rate was 12.6% compared with the

traditional prescription error rate of 28.2%. Logistical regression analysis showed that computer calculated dose was an important and independent variable influencing the error rate (adjusted relative risk = 0.436, 95% CI 0.336, 0.520, $p < 0.001$). Other important independent variables were seniority and paediatric training of the person prescribing and the type of drug prescribed.
Conclusions: Medication error, especially underdose, is common in outpatient, emergency department and discharge prescriptions. Computer calculated doses can significantly reduce errors, but other risk factors have to be concurrently addressed to achieve maximum benefit.

Background

Medication errors are an important cause of hospital-based morbidity and mortality. Most medication error studies to date have been conducted in adults and only a small number have assessed errors in the paediatric population. Furthermore, the paediatric studies that have been conducted have mainly quantified errors in the inpatient setting;[1] there is very little data available on paediatric outpatient and emergency department medication errors and none on discharge medication. This deficiency is of concern because medication errors are more common in children[2,3] and there is a suggestion that the risk of adverse drug events, as a consequence of a medication error, is higher in children than in adults.[4]

Most medication errors occur at the time of writing the prescription.[2,3] The majority are dose errors and it has been shown that many doctors cannot reliably perform accurate dose calculations.[5-7] Vigilance is the main tool used to minimise medical errors but a significant proportion of these errors still escape detection, which results in potential or actual adverse drug events.[5,8] Computer calculated doses can further reduce medication errors;[9] however, these studies have mainly been done with warfarin and intravenous medications and very few have involved paediatric patients.[1,10,11] Those that did examined antibacterial prescriptions in the critical care setting and chemotherapy drug calculations in a paediatric oncology service.[12,13] None have studied the effect in a general paediatric setting.

Objective

This study was designed to assess medication errors in predominantly ambulatory paediatric patients and the effect of computer calculated doses on the error rates of two commonly prescribed drugs.

Methods

This was a prospective cohort study performed in the paediatric service at the National University Hospital, Singapore, between March 2003 and August 2003.

A computer clinical decision support system (prescription generation and monitoring drug interactions and patient allergy) had been used since 2000 to prescribe medication in the outpatient clinic, children's emergency department and upon hospital discharge. Only inpatient prescription charts remained handwritten. A computer calculated dose program was developed by the paediatric medical and pharmacy departments. This enabled the computer clinical decision support system to generate computer calculated doses for paracetamol (acetaminophen) and/or promethazine while taking into account dose limits, dose form, weight and/or age of the child. These drugs were chosen because they are commonly prescribed and are a frequent source of medication errors.[14] In addition, each represented a different computing challenge. The paracetamol algorithm was based solely on the patient's weight, whilst the promethazine algorithm took into account both the weight and the age of the patient as promethazine is contraindicated in children <6 months of age.

The hospital's existing computer clinical decision support system was reprogrammed in March 2003 so that doctors could choose the traditional prescription method or the enhanced method of computer calculated dose when prescribing paracetamol or promethazine. To ensure proper use of the system, the department staff were required to attend a training session and this was reinforced by information disseminated by e-mail.

Before any prescription could be generated, the patient's weight had to be entered (figure 1). The entered weight was assessed against age-related normal values for Singapore and a warning was issued if it was outside the expected range. If this warning was ignored, the option to use the computer calculated dose program was removed.

The traditional method of prescribing involved typing the prescription into the appropriate fields. The computer calculated dose method was activated if the doctor (i) chose it from a pick list or typed the drug name; and (ii) picked the drug form from a pick list (figure 1). The computer would first calculate the dose based on 10 mg/kg for paracetamol or 0.2 mg/kg for promethazine. This was then adjusted for the dose form (i.e. tablet, syrup etc.) for ease of administration, while keeping within the defined dose limits. The dose limits were 10–15 mg/kg, with a maximum total daily dosage of 60 mg/kg/day, for paracetamol and 0.2–0.5 mg/kg for promethazine (no total daily dosage defined). For example, in a 17kg child, the calculated dose for paracetamol based on 10 mg/kg is 170mg. The computer would then take into account the dose form prescribed. If syrup (120mg/5mL) was chosen, the computer would then recommend a dose of 7.5mL (i.e. 180mg or 10.6 mg/kg). If tablets (500 mg/tablet) were prescribed, the computer would recommend half a tablet (i.e. 250mg or 14.7 mg/kg).

Fig. 1. The traditional prescription method involved either typing the drug name and dose into the drug column or picking the drug from a list without specifying the dose form (upper panel). The computer calculated dose method was activated when the drug name was typed in the drug column (or it was chosen from the pick list) and the form of drug was also chosen from a list (lower panel). **BMI** = body mass index; **BSA** = body surface area; **G6PD** = glucose 6-phosphate dehydrogenase; **QDS** = four times a day; **SUSP** = suspension.

The recommended computer calculated dose could be altered by the doctor. A warning was issued if the altered dose was outside the dose limits. However, if this warning was ignored, the altered dose would still be prescribed. Hence, the computer calculated dose method could still give rise to a medication error.

Details of every single prescription were prospectively collected using the computer database, regardless of the mode of prescription used. This included the mode of issuing the prescription (computer calculated or traditional method); the date, time and location where the prescription was issued; the identification, age and weight of the patient; the name, dose form, dose, frequency and duration of the drug; the identification of the doctor and the issuing and/or ignoring of warning messages. If there were multiple medications issued to a patient, each medication was considered as a stand-alone prescription. The information was imported into Microsoft® Excel 2002 and data were analysed using SPSS version 12.0.

A medication error was defined as having occurred if there was an underdose (below the dose-limits), an overdose (above the dose limits), no frequency of administration specified, no dose given or excessive total daily dose. The statistical tests used in univariate analysis were χ^2 or Fisher's exact test for non-continuous variables and T-test for continuous variables. A step-wise logistical regression model was used to identify independent variables that influenced the risk of a medication error.

Results

From March to August 2003, 4281 prescriptions were issued to children (<16 years of age) for paracetamol and promethazine. Seven prescriptions (0.16%) were excluded from analysis as the patient

Table I. Characteristics of study population

Parameter	Subset	Overall	CCD	TRAD	p-Value[a]
No. of prescriptions issued [% (n)]		100.0 (4274)	55.8 (2381)	44.2 (1893)	<0.001
Training of doctors who issued prescriptions [% (n)]	Paediatricians	83.9 (3584)	52.7 (1888)	47.3 (1696)	<0.001
	Non-paediatricians	16.1 (690)	71.4 (493)	28.6 (197)	
Seniority of doctors issuing prescriptions[b] [% (n)]	House officer 43 (24.6)	20.1 (861)	45.9 (395)	54.1 (466)	<0.001
	Medical officer 56 (32.0)	37.2 (1588)	78.1 (1240)	21.9 (348)	
	Registrar 35 (20.0)	22.3 (953)	43.0 (410)	57.0 (543)	
	Associate consultants 11 (6.3)	5.7 (242)	49.2 (119)	50.8 (123)	
	Consultant 30 (17.1)	14.7 (630)	34.4 (217)	65.6 (413)	
Location where prescription was issued [% (n)]	Children's emergency	45.6 (1948)	62.0 (1208)	38.0 (740)	0.749
	Outpatients	23.4 (1002)	43.3 (434)	56.7 (568)	
	Discharge medication	31.0 (1324)	55.8 (739)	44.2 (585)	
Drug prescribed [% (n)]	Paracetamol (acetaminophen)	80.6 (3445)	59.1 (2036)	40.9 (1409)	<0.001
	Promethazine	19.4 (829)	41.6 (345)	58.4 (484)	
Recipient of prescription	Age (y)	Mean 5.9 Range 0.05–16 SD 4.49	Mean 5.9 Range 0.05–16 SD 4.5	Mean 5.6 Range 0.08–16 SD 4.3	0.063
	Weight (kg)	Mean 22.6 Range 2.7–150 SD 15.47	Mean 22.9 Range 2.7–111.5 SD 15.6	Mean 21.3 Range 2.9–150 SD 16.0	0.005

a Comparing the distribution between the CCD and TRAD methods.

b 175 in total as four doctors were promoted during study.

CCD = computer calculated dose; **TRAD** = traditional prescription.

weight was clearly erroneous, hence 4274 prescriptions were analysed.

The 4274 prescriptions were written for 3347 children, giving an average of 1.28 prescriptions per child (range 1–10). They were issued by 171 doctors, with the median prescription per doctor being 5 (range of 1–255). 39.2% of doctors were paediatricians (defined as paediatricians, neonatologists or paediatric surgeons), whilst 60.8% were non-paediatricians (defined as doctors in other disciplines).

Paediatricians issued 83.9% (3584) of the prescriptions and 79.6% (3402) were issued by junior doctors (houseman, medical officers and registrars) [table I]. The sample size of the computer calculated dose group and the traditional prescription method group were similar. Most doctors, at different times, prescribed using both systems, with only 30 doctors (136 prescriptions in total) not using the computer calculated dose method at all. Of these doctors, 17 wrote only one prescription and the other 13 wrote a median of three prescriptions.

The overall medication error rate was 19.5% (833/4274). Most medication errors were due to underdose (64%; 536/833), with the remainder due to no frequency specified (21%; 177/833), overdose (8%; 68/833), excess total daily dose (5%; 40/833) and no dose specified (1%; 12/833) [table II]. The magnitudes of the errors are shown in table III.

The error rate in the computer calculated dose system was 12.6% (299/2381) compared with 28.2% (534/1893) in the traditional method (table II). All medication errors in the computer calculated dose system were the consequence of doctors manually adjusting the computer calculated dose and ignoring the alert messages when a medication error occurred. The error rate in paracetamol prescriptions (20.8%; 715/3445) was higher than promethazine prescriptions (14.2%; 118/829). Paediatricians made fewer errors than non-paediatricians (18.4% vs 25.1%, respectively). Medical officers made the least amount of errors (6.5%; 103/1588). The error rate in children's emergency was 15.7% (305/1948), outpatient setting 21.5% (215/1002) and discharge medication 23.6% (313/1324).

Independent variables influencing the rate of medication error were identified by logistical regression (table IV). The independent variables that influenced the rate of medication error were seniority (where the risk of medication error was lowest for medical officers), mode of drug entry (where the risk of medication error was lower in the computer calculated dose group than the traditional method group), type of drug prescribed (where the risk of medication error was lower for promethazine prescription than for paracetamol prescription) and whether the doctor had received formal paediatric training or not (where the risk of medication error was lower in paediatric trained doctors than non-paediatric trained doctors). The place of prescription, day of the week and month were not significant independent variables.

Discussion

This study assessed paediatric medication errors of two commonly prescribed drugs in predominantly ambulatory patients. The overall error rate was 19.5%, with most errors being the result of an underdose (64%). The computer calculated dose method was an important and independent variable influencing the risk of a medication error. Other important independent variables were the prescribing doctor's seniority and paediatric training and the type of drug prescribed.

There are very few studies to compare our results with. Outpatient medication dose errors have received little attention despite the shift from inpatient to ambulatory care and the rising incidence of deaths from medication error.[15] Only one study has assessed the prevalence of outpatient medication errors (error rate of 10.1% for drug dose and 2.4% for missing doses).[16] Two reports have examined medication errors in paediatric emergency departments. One examined incident reports over a 5-year period for medication and fluid infusion error and found 33

Table II. Medication error rates in computer calculated dose (CCD) versus traditional prescription methods (TRAD)

Parameter	Subset	Overall error rate [% (n/total n)]	CCD error rate [% (n/total n)]	TRAD error rate [% (n/total n)]
Total		19.5 (833/4274)	12.6 (299/2381)	28.2 (534/1893)
Drug prescribed	Paracetamol (acetaminophen)	20.8 (715/3445)	12.9 (263/2036)	32.1 (452/1409)
	Promethazine	14.2 (118/829)	10.4 (36/345)	16.9 (82/484)
Location where prescription was issued	Children's emergency	15.7 (305/1948)	6.9 (83/1208)	30.0 (222/740)
	Outpatient	21.5 (215/1002)	13.6 (59/434)	27.5 (156/568)
	Discharge medication	23.6 (313/1324)	21.2 (157/739)	26.7 (156/585)
Training of doctors who issued prescriptions	Paediatrician	18.4 (660/3584)	10.9 (206/1888)	26.8 (454/1696)
	Non-paediatrician	25.1 (173/690)	18.9 (93/493)	40.6 (80/197)
Seniority of doctor who issued prescription	House officer	29.5 (254/861)	30.9 (122/395)	28.3 (132/466)
	Medical officer	6.5 (103/1588)	4.5 (56/1240)	13.5 (47/348)
	Registrar	26.0 (248/953)	15.6 (64/410)	33.9 (184/543)
	Associate consultants	17.4 (42/242)	11.8 (14/119)	22.8 (28/123)
	Consultants	29.5 (186/630)	19.8 (43/217)	34.6 (143/413)
Type of medication error	Underdose	12.5 (536/4274)	9.0 (215/2384)	17.0 (321/1890)
	Overdose	1.6 (68/4274)	1.0 (25/2384)	2.3 (43/1890)
	Excess total daily dose	0.9 (40/4274)	0.1 (2/2384)	2.0 (38/1890)
	No dose	0.3 (12/4274)	0.2 (4/2384)	0.4 (8/1890)
	No frequency	4.1 (177/4274)	2.2 (53/2384)	6.6 (124/1890)

Table III. Magnitude of errors

Drug	No. of errors	Mean + SD (mg/kg)	Range (mg/kg)
Underdose (per dose)			
Paracetamol (acetaminophen)[a]	427	8.99 ± 1.73	0.02–9.98
Promethazine	109	0.14 ± 0.03	0.10–0.20
Overdose (per dose)			
Paracetamol	65	18.9 ± 2.8	15.1–25.0
Promethazine	3	0.57 ± 0.05	0.56–0.63
Excess total daily dose			
Paracetamol	40	66.9 ± 11.3	60.2–129.0

a Only 19.8% of these children had weights ≥50.0kg

incidents, of which the commonest error was incorrect dose (30%).[17] Another study, a retrospective review of the charts of 1532 children treated during 12 randomly selected days, reported an error rate of 10.1%.[14] There are no reports on error rates of discharge medication.

The error rates reported in these studies are lower than the rate observed in our study. This can be attributed to important methodological differences. First, medication error data in previous papers were ascertained by manual reporting or review of prescriptions (often retrospectively). Ours was based on prospective computer captured data and was more likely to be comprehensive and free from transcription error. Second, the use of a strict and consistent definition of medication error also meant that there was no ascertainment bias. In this study, 15 mg/kg of paracetamol was regarded as a correct dose, whereas 15.1 mg/kg was regarded as an overdose. A physician or pharmacy would be less likely to report 15.1 mg/kg as an error as it is not likely to result in clinical harm. Moreover, our definition of 60 mg/kg/day as the maximum total daily dosage was also very strict. The recommendations for maximum total daily dosage vary, ranging from 60 to 90 mg/kg/day. If we had used the upper limit of 75 mg/kg/day, the number of prescriptions exceeding the total daily dose would have dropped from 40 to 3. Similarly, if we had used 90 mg/kg/day, the number would have decreased to just one. Third, underdose is often considered less of an error than overdose (particularly in medications for symptomatic relief) and may have been under-reported in other studies. Fourth, our study population was also not comparable to those in previous reports because ours was drawn from outpatients, the children's emergency department and discharge medication and involved only two drugs.

Although computer calculated doses and error checking were independent factors in reducing medication errors, there was still a significant error rate. This was due to staff manually adjusting the computer calculated dose and ignoring alert messages when a medication error occurred. The reason for such behaviour is not clear. It may be that the alert message was poorly worded or that staff were insufficiently informed or mistrusted the computer calculated dose. One remedy would be to prevent staff from over-riding the computer program, but this may well lead to an overall rejection of the system if it is seen to be too rigid and over-riding of 'clinical freedom'. Thus, the challenge includes making computer calculated dose programs user-friendly and acceptable to the staff, as well as effective in preventing medication error.

Paediatric training was also an important factor – presumably those not involved full time in managing paediatric patients are less aware of dose considerations and, therefore, are more prone to making medication errors. Although the seniority of the doctor was an independent variable, there was no linear correlation, i.e. error rates did not decrease as the seniority of the doctor increased. It was reassuring to note that medical officers who issued the largest proportion of prescriptions had the lowest error rates. Consultants, on the other hand, appeared to have a relatively high error rate. Perhaps consultants, who were the most senior in their training, were less likely to be perturbed by minor variations from the recommended doses. The influence of the type of drug on medication error rate suggested that doctors were intrinsically cautious with the drug that was perceived to be 'more dangerous' and thus made fewer errors. Hence, this study gave us knowledge of other risk factors for medication error and has allowed us to target additional training and resources for those at the greatest risk.

This study has limitations. First, it only addressed the error rate of two drugs. This means that the error rates applicable to these drugs may not be representative of all paediatric medications. However, this was intentional as it was important to ensure that the computer clinical decision support system was robust and effective before applying the system across more medications. Second, it would have been more useful if all inpatient prescriptions rather than just inpatient discharge medications were assessed. This was not possible as computerised inpatient prescriptions in our hospital will not be available until 2006. Third, this study did not address the effect of lowering medication error rates on reducing adverse drug events. Although previous inpatient studies showed that the amount of adverse drug events arising from medication errors is around 1–2%, this proportion is highly dependent on the definition of medication error.[18,19] Robust information on adverse drug events are difficult to achieve in an inpatient setting and even harder in the outpatient setting as reporting is voluntary and is likely to be under-representative. In addition, adverse drug event reporting is not designed to capture the effects of an underdose, the most common type of medication error in our study. Hence, although Ghandi et al.[20] showed that computer calculated doses did not reduce adverse drug events, in our situation this method may improve the therapeutic effectiveness for our patients by reducing the underdose events.

Conclusion

In conclusion, this study has shown that the computer calculated dose method is an important factor in reducing medication error. In addition, it has also identified other risk factors for medication errors and enabled a multi-prong approach to reducing paediatric medication errors.

Given the demonstrable benefit of using a computer clinical decision support system with the computer calculated dose enhancement, our department has agreed to further modification of the computer clinical decision support system. Important improvements to be made to the system include: (i) removing the choice of using the traditional method in prescribing these two drugs; (ii) improving the wording of the alert messages so that the prescribing physician is made aware of the gravity of the medication error that may result if the alert is ignored; (iii) identifying doctors with higher error rates and encouraging them to adhere to alert messages and to prescribe within the agreed ranges; and (iv) develop-

Table IV. Logistical regression[a]

Factor (reference group)	Adjusted odds ratio	95% CI	p-Value
Drug entry (computer calculated dose method cf traditional prescription method)	0.436	0.336, 0.520	<0.001
Drug (promethazine cf paracetamol)	0.504	0.401, 0.634	<0.001
Department (non-paediatricians cf paediatricians)	1.581	1.251, 1.998	<0.001
Seniority (medical officer cf house officer)	0.218	0.167, 0.284	<0.001
Seniority (registrar cf house officer)	1.064	0.847, 1.338	0.593
Seniority (associate consultant cf house officer)	0.659	0.448, 0.968	0.033
Seniority (consultant cf house officer)	1.360	1.059, 1.747	0.016
Weight (per kg increase in weight)	1.051	1.040, 1.063	<0.001
Age (per year increase in age)	0.909	0.874, 0.946	<0.001
Constant	0.291		<0.001

a −2 Log likelihood 3636.6. Hosmer and Lemeshow test of goodness of fit p-value is 0.112.

cf = compared with.

ing computing algorithms and extending the computer calculated dose system to cover the drugs that account for 80% of all paediatric prescriptions. The effect of these changes will be the subject of a further report.

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J Packia, HM Kam, B Ong and RC Kirk designed the computer program and assisted in data collection. RC Kirk and DL Goh collated the data and performed the statistical analysis. All authors contributed to the writing or editing of the paper.

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