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Liquid medication dosing errors: a pre–post time series in India

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Abstract

Objective To evaluate the influence of pharmacist intervention on the level of parental dosing measurement errors and paediatrician dosage prescribing in a clinic in India.

Setting and study design The study was conducted at Srujan Hospital for Sick Children, India. It used a time series design with two groups of patients. Group 1 involved 175 children prescribed paracetamol and assigned to usual care. Following an educational intervention for the hospital paediatricians, including feedback on dosages prescribed for Group 1 and promotion of a dosing chart, 162 patients were recruited to the intervention group (Group 2). Parents in Group 1 received paracetamol suspension and verbal instructions from hospital staff (standard care). Parents in Group 2 were provided with a syringe with a line marking the prescribed dose and its use was demonstrated to them by the pharmacist. Data on the dosages prescribed and measurement accuracy by parents were obtained for both groups.

Main outcome measures Measurement of correct dosages by parents, and prescribing of appropriate dosages by paediatricians.

Results In Group 1, 85 of 175 parents (48.6%) measured the correct dose (±0.5 ml) and paediatricians prescribed appropriate dosages in 67 of 175 cases (38.2%). In Group 2, 160 of 162 parents (98.7%) measured the correct dose and paediatricians prescribed appropriate dosages in 160 of 162 cases (98.7%), showing statistically significant improvements in both indicators ($P < 0.001$). When the impact of prescribing and dosing correctness was combined on an individual patient basis, 76 of 175 (43.4%) were appropriate in Group 1, and 160 of 162 (98.7%) were appropriate in Group 2. There was a statistically significant improvement ($P < 0.001$) in appropriate dosing outcome between the two groups.

Conclusion Pharmacist intervention through patient education, including the use of a syringe, significantly improved parents' dosing accuracy. Pharmacists' feedback resulted in a reduction in physicians' prescribing errors in a country where pharmacist involvement is currently minimal.

Introduction

In 1975, the American Academy of Paediatrics Committee on Drugs described unacceptable levels of inaccuracies in administering liquid medication by household spoons.[1] When first recommended 27 years ago, the use of an oral dosing syringe was described as novel and innovative. Subsequently, a range of liquid medication dosing devices have become widely available, each of which has its advantages and disadvantages.[2]

A study reported from poison control centres in the United States found two major causes of dosing errors using the dispensing cups which were commonly provided attached to liquid medication: first, the assumption that the entire cup was the unit of measure, and secondly the misinterpretation that one cupful was the recommended dose.[3] Household measuring devices, such as teaspoons and tablespoons, are not recommended for measuring drugs because they are neither accurate nor consistent. The volume contained in a household teaspoon has been reported to range from 2.5 to 9.7 ml.[1,4,5] Research has suggested that parents may be confused about differences among teaspoons, tablespoons and dose cups.[3,6,7] Problems can also result from spillage and from medication left in or on the measurement device rather than being

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administered to the child.[2,8] After receiving reports of inappropriately marked plastic dosing cups, the Food and Drug Administration began a public education campaign in 1994 to increase health professional and consumer awareness of dosing hazards with liquid medicines.[9]

In 1975, when the oral dosing syringe was introduced, 75 per cent of parents used a household teaspoon or other measuring device when dosing liquid medication.[4] A study from Israel in 1989 reported that 80 per cent of children were still given medications by a household teaspoon.[10]

Optimal administration of liquid medications to children requires the delivery system to be effective, safe, and acceptable to the parent. It also needs to deliver the dose correctly to the child once measured. Traditional techniques for administering paediatric oral liquid medications are not optimal because of the variability of the volume measured, incomplete delivery of the dose, or infant resistance and refusal.[1,2,5,8,11,12]

Oral dosing syringes are considered the best device for the delivery of liquid medication.[2] They can accurately measure liquids and may reduce drug dosage errors if the syringe is marked correctly and parents are trained.[8,11] Their advantages include accuracy, availability in various sizes and relatively low expense. The syringe permits the user to direct the delivery of the medication to the side of the mouth of an infant or small child, thus minimising spillage. It also reduces the risk of possible gagging and aspiration of medication.[13]

This study was designed to evaluate the accuracy with which parents administered a paracetamol suspension prescribed for pyrexia, and to identify if the dose was medically appropriate for pyrexia for each patient. The objectives were: (i) to study the impact of a liquid measurement device and pharmacist intervention on parent dosing accuracy and (ii) to evaluate the effect of pharmacist intervention on physician prescribing of paediatric paracetamol dosages using an education programme.

Methods

Study design

The study used a time series design with two groups of patients. Group 1 patients and families received usual care. An intervention was then delivered to the hospital's paediatricians. They were given feedback on Group 1 patients, together with a paediatric dosing chart for paracetamol by weight. Group 2 parents received individual dosing education.

Setting and patient population

Children less than 10 years of age diagnosed with pyrexia and prescribed paracetamol suspension by a doctor were the subjects for the study. Patients received care in the Srujan Hospital for Sick Children (SHSC), Andhra Pradesh, India. SHSC is a 60-bed paediatric hospital. It is the only paediatric hospital for a small town and 15 villages (approximate population 100,000). SHSC has a pharmacy where most of the patients have their medications dispensed. To participate in the study, the patient's prescription had to be filled at the hospital pharmacy. The study sample was recruited during the hospital visiting hours, ie, 7am to 9am, 12 noon to 4pm and 6pm to 9pm. The researcher is a qualified pharmacist in India and spoke medical Telugu. All nursing assistants in the hospital were bilingual. The nursing assistants notified the researcher whenever the diagnosis of pyrexia was made and a paracetamol suspension was prescribed. As the weight for most children was not given on the prescription, the researcher weighed each patient in Group 1 and recorded it. In Group 2, the nursing assistants weighed each patient and the weight was recorded in the patient notes before the paediatrician wrote the prescription. The hospital does not normally employ a qualified pharmacist or nurses.

Data collection

Data collected included patient details (age, weight and sex), parent details (type of carer, level of education, number of children and order of the child in the family), prescription details (drug name, dose prescribed and number of doses prescribed) and measurement details (volume of paracetamol suspension prescribed, volume measured by the parent, difference between prescribed and measured volume, and the device used for measurement).

Group 1

All potential subjects attending the hospital over a one-week period were asked to participate. Parents received the prescription, paracetamol suspension and verbal instructions from the hospital staff, the usual care practised at SHSC. Data were collected directly from the patient's prescription. The parents were asked to give the first dose of paracetamol suspension to the patient in the presence of the researcher. The researcher had a range of measuring devices available, including household teaspoons, dosing spoons, droppers, measuring cups and syringes. The parent was asked to select and use the item most similar to what they usually used for the measurement of the dose. The researcher then measured that dose volume to the nearest 0.5 ml, using a calibrated syringe to suck up the dose, and confirmed the volume by expulsion into a measuring cylinder calibrated to 0.1 ml to validate the syringe. If the parent measured an incorrect dose, the researcher reinforced the verbal instructions previously given, the dose measurement was corrected and the researcher demonstrated how to measure the dose. Parents were counselled on the advantages of oral dosing syringes and asked if they wanted to use a syringe to administer the medicine. If they were interested, the syringe was labelled with a "⊥", with the line showing the mark for the prescribed dose. This gave a clear instruction of the dose volume to the parent. Use of dosing cups attached to the medication, where selected, was discouraged.

The intervention

The paediatricians received feedback of Group 1 results for paracetamol dosages. A dosing chart was provided to the prescribers showing the appropriate dose (in ml) of paracetamol suspension according to weight.

Group 2

All potential subjects attending the hospital over a one-week period following the intervention were asked to participate. Each patient was weighed and the weight data were provided to the paediatrician before prescribing the dose. Parents received the prescription for paracetamol suspension, and the intervention included the marked syringe as previously described, verbal instructions and a demonstration by the researcher. The researcher explained to parents the advantages of using the oral dosing syringe. If they were prepared to volunteer, they were asked to measure the dose. As in Group 1, where an incorrect dose was measured, the dose was corrected. Any patient that had participated in Group 1 of the study was excluded from Group 2.

Pharmacy survey

A survey of 16 pharmacies located in the area was conducted to identify the type of devices general practitioners (GPs) were recommending to measure the dose of children's medicines. The researcher visited all the pharmacies and asked what devices were provided with paediatric suspensions. Each pharmacy was located near to a GP's clinic. Most of the patients in the study visited a GP, and had their medicines dispensed at one of the 16 pharmacies located nearby.

Definitions

In this study an "appropriate volume measurement" was classified as a volume within ± 0.5 ml of the recommended volume. An "appropriate dose" was classified as one prescribed within ± 25 per cent of the recommended dose. An "educated person" was defined as one who could read, write and speak any of the 18 languages listed in the constitution of India. A "person without formal education" was defined as one who could not read or write but could speak any of the 18 languages listed in the constitution of India.

Data analysis

Physicians' prescribing of antipyretic dosages was evaluated against Australian National Therapeutic Guidelines (ANTG) for paracetamol.[14] The stated dosage is: paracetamol 15 mg/kg/dose orally, every 4 to 6 hours, to a maximum of 90 mg/kg/day. Paracetamol dosage was calculated according to the product of the weight of the patient and the recommended dose per kilogram.

Statistical evaluations

Data for age differences were tested by using Students' t-test, and other population data were differentiated using χ^2 analysis. Difference in choice of device used, number of children, order of the child, and educational status of the parent for the appropriate measurement of liquid medication and physician prescribing were evaluated by χ^2 analysis. Other parametric data differences were tested using Student's t-test. Outcomes of the study were communicated to the pharmacy and relevant units at SHSC. Based on $\alpha = 0.05$ and $\beta = 0.2$ and a 20 per cent change in prescribing and dose measurement, the outcomes required a minimum sample of 80 patients in each group to achieve statistical significance.

Ethical issues

As this study involved an analysis of patients' prescription data, ethical issues arose in relation to confidentiality and release of data. A unique non-patient identifiable code was allocated to each prescription to enable re-identification if necessary since the hospital holds a duplicate copy of prescriptions. The coded data were kept secure in accord with National Health and Medical Research Council guidelines[15] and only aggregated data were released from the research. Informed consent of parents was not obtained, because the study was regarded as a quality assurance audit to determine the number of patients using measuring devices correctly. The treatment was within the standard of care for pyrexia.[14] The Curtin University of Technology Ethics Committee approved this study.

Results

The study population is summarised in Table 1 and consisted of 337 children. Of the parents, 220 had received no formal education and 117 were educated. There was no significant age or gender difference between the two groups. The parents in Group 2 were all mothers, whereas in Group 1, mothers attended for 157 children and fathers for five. Although a significant difference is evident in Table 1 this only arises from the zero in one of the Group 2 fields.

Of the educated parents, in Group 1, 19 were educated to primary level, 32 to secondary level and seven to tertiary level. In Group 2, 27 were educated to primary level, 29 to secondary level and three to tertiary level.

Group 1 consisted of 63 parents with one child, 80 with two, 31 with three, and one parent had five children. In Group 2, 57 parents had one child, 75 had two, 23 had three and seven had five children. There was no significant difference in these data between Groups 1 and 2 ($P = 0.130$).

In Group 1, 113 children were the first child in their family, 47 were the second child, and 15 were the third child. In Group 2, 106 were the first child, 42 were the second child and 14 were the third child. There was no

Table 1 Influence of pharmacist intervention (Group 2) compared with usual care (Group 1) for dosing measurement accuracy and appropriate dose prescribing.

	Group 1	Group 2	*P*
Number	175	162	0.103
Gender	88F, 87M	68F, 94M	0.190
Mean age (years)	3.45	3.44	0.756
Parent involved	170 mothers, 5 fathers	162 mothers	0.017
Parent's education	117 NFE	103 NFE	0.528
Measurement device used	Dispensing cup	Oral syringe	< 0.001
Accurate dose measurement	85 (48.6%)	160 (98.7%)	< 0.001
Appropriate dose prescribed	67 (38.2%)	160 (98.7%)	< 0.001
Overall appropriate dose administered	76 (43.4%)	160 (98.7%)	< 0.001

NFE = no formal education.

significant difference in these data between Group 1 and Group 2 ($P = 0.981$).

In Group 1, the device initially selected by all parents to measure the paracetamol suspension was the measuring cup. This device was often attached to the closure of the bottle.

Parents' dosing

The outcomes of parent dosing measurements are listed in Table 1. In Group 1, 85 measured the dose accurately (±0.5 ml), 58 measured 0.6 to 1 ml above or below the recommended dose, 7 measured 1.1 to 1.5 ml above or below the recommended dose, 10 measured 1.6 to 2 ml above or below the recommended dose, 14 measured 2.1 to 2.5 below the recommended dose and one patient measured 2.6 to 3 ml above the recommended dose. In Group 2, 160 parents measured the dose accurately, one measured 0.6 to 1 ml above the recommended dose and another 1.1 to 1.5 ml above the recommended dose. There was a statistically significant improvement from Groups 1 to 2 ($P < 0.001$).

Paediatrician prescribing

In Group 1, paediatricians prescribed appropriate doses for 67 patients, 26–50 per cent above or below the recommended dose for 31 patients, 51–75 per cent above or below the recommended dose for 34 patients, 76–100 per cent above the recommended dose for 19 patients, 101–150 per cent above the recommended dose for 13 patients, and 151–200 per cent above the recommended dose for five patients. Six patients received doses that were more than double to five-fold the recommended dosages. In Group 2, two patients were prescribed doses 26–50 per cent below the recommended dose and 160 were prescribed an appropriate dose, with a significant improvement from the pre-intervention to post-intervention groups ($P < 0.001$).

Overall appropriateness

In evaluating the overall appropriateness of the dose administered (combination of paediatrician prescribing and parents' measurement), 76 patients received an appropriate dose in Group 1 and 160 in Group 2, a statistically significant improvement ($P < 0.001$). Some additional appropriate doses were fortuitously achieved as a result of incorrect measurements of inappropriate doses. Irrespective of the parent's educational status, order of the child in the family, and number of children in the family, there was a marked improvement in the measurement of the appropriate dose.

Pharmacy survey results

None of the 16 pharmacies located in this rural area supplied or sold an oral dosing syringe. The eight GPs practising in the area appeared not to be aware of this device, and did not make any recommendations for its use. All the pharmacies were supplying either dosing spoons or dispensing cups.

Discussion

This study showed that irrespective of educational status or parents' previous experience of medicine use with other children, intervention by a pharmacist can markedly improve the accuracy of measurement. Thus pharmacist intervention involving parental and targeted physician education can be effective in improving the appropriateness of medication prescribing and dosing in a developing country. The study results are similar to a recent study by McMohan and colleagues of 90 English-speaking and Spanish-speaking families, 100 per cent of whom dosed medication correctly when given instructions and a syringe marked with a line at the prescribed dose.[11]

In this study, ±0.5 ml was deemed an acceptable measurement error as the suspension is viscous. This is a high percentage error at low dosages (eg, 2 ml) but is

acceptable at common dose volumes of 5 to 10 ml. The designated dosage error of ± 25 per cent was based around common variability allowed in dosage forms and bioequivalency studies. In India national guidelines are not available to prescribers. It is noted however that the dosage errors are unlikely to result from the use of a different dosage standard since the results show wide variability, presumably arising from the doctor not knowing the child's weight.

In this study, 54 per cent of the children in Group 1 received doses above those recommended. Of particular concern were six children who were prescribed more than double to five-fold the recommended dose. In addition to the immediate concern, medically prescribed dosages of medicines, such as paracetamol, that are easily purchased might lead to these dosages being continued beyond the supply provided from the hospital consultation.

Several very high dosages (150 mg/kg/day to 250 mg/kg/day) were prescribed for Group 1 patients in this study. In 1991, Penna and Buchanan[16] reported seven deaths and 11 cases of hepatotoxicity associated with paracetamol. Survival was usually seen in those children with hepatotoxicity due to paracetamol doses of greater than 150 mg/kg/day for two to eight days.[16] However, toxicity has been reported rarely with therapeutic doses when administered over several days in children who have concurrent illnesses such as fever, vomiting, and diarrhoea.[17]

A study conducted by Mattar, Markello and Yaffe found that difficulties with administration of liquid medications occurred with 28–40 per cent of children.[4,18] Because traditional oral liquid medication delivery devices may cause problems with drug administration, these devices may adversely affect compliance.[18] It is harder to administer the dose to a child with a dispensing cup than with an oral dosing syringe. There is a greater chance of spillage of the liquid during administration with the dosing cup than with the syringe.

Using a dosage syringe for drug administration requires correct placement of the liquid in the cheek pouch of the patient's mouth. If the liquid is placed too close to the front of the mouth, the medication can be expelled. If the liquid is administered too close to the back of the throat or administered too rapidly, the patient may choke or aspirate.[2,19] None of the patients in this study choked or aspirated during the trial administration, probably because the researcher demonstrated use of the oral dosing syringe and reinforced the dosing instructions.

Mattar *et al*[4,18] found that when no dispensing device was given, 71 per cent of parents used a teaspoon. In this study, all parents said that they normally used dispensing cups for measuring the suspension. This practice can be eliminated through better parent education and by providing labelled measuring devices.

Even though oral dosing syringes have been available in developed countries since 1975, none of the 16 pharmacies surveyed were supplying them and local physicians appeared to be unaware of the device. There is a need for pharmacist and GP education on the benefits of using oral dosing syringes.

Herman and Rodowskas[20] have suggested that programmes intended to improve the quality of drug use and patient care can succeed only if practitioners adopt a positive attitude towards such programmes. It has also been reported that attitude was the strongest predictor of whether or not pharmacists performed some clinical pharmacy activities.[21] The attitudes of pharmacists and physicians to policies is likely to be one of the important factors that may affect their compliance with, and hence the ultimate effectiveness of, such policies.[22]

Although several studies have evaluated the accuracy of measuring medicines in various devices, this study has linked this with the prescribing of appropriate doses. It is only through this combination that administration of an appropriate dose can be ensured. Inappropriate doses might lead to either drug toxicity or treatment failure.

It should be noted that the hospital in the study does not employ a pharmacist or qualified nurses. Although the interventions made with prescribers and parents produced positive changes, the sustainability of these changes is unknown.

Conclusion

This study showed that the doses of paracetamol given to children in India may be inappropriate because of prescription of incorrect doses or administration of incorrect quantities. The study showed that dosing by parents from rural areas of a developing country can be improved by use of an oral dosing syringe and pharmacist education on its use. Furthermore, the study showed that feedback to prescribers with provision of a dosage chart and information on each child's weight significantly improved the appropriatenesss of prescribed doses. Health care professionals should ensure that parents understand liquid medication dosing procedures. Irrespective of parents' educational status, number of children and order of the child, pharmacist intervention through patient education significantly improved parents' accurate dosing and physicians' prescribing of an antipyretic suspension in India, where pharmacist involvement thus far is minimal. This study supports the roles that pharmacists can perform in developing countries in improving the quality of use of medicines.

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