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CLINICAL BRIEF

Liquid Drug Dosage Measurement Errors with Different Dosing Devices

Pradnya Joshi[1] · Sandeep B. Bavdekar[1]

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Abstract
An observational study was carried out to determine the magnitude of dosing errors made by parents, the most-preferred drug delivery device and the association of age, gender, education of the caregiver and number of children with the proportion of accurate doses. After enrolment, parents of children aged 6–60 mo were instructed to measure 5 ml of syrup paracetamol using any of the devices (stainless steel spoon, disposable plastic syringe, dosing cup with etched markings) displayed. The quantum of measured dose was confirmed using a calibrated glass cylinder. Error was defined as over 10% variation around the prescribed dose. Of 386 participants, 72 (18.65%) committed error, with 58 (15.02%) and 14 (3.62%) committing mild and moderate errors, respectively. Measuring cup (270, 69.95%) was the commonest device chosen. Use of syringe was associated with greater accurate measurements ($P < 0.05$) with only 3 (3.57%) committing error compared to 18 (56.25%) and 51 (18.88%) committing error with spoon and cup, respectively. On multivariate analysis, device was the only factor significantly associated with accuracy in measurements.

Keywords Administration · Oral · Parents · Medication errors · Patient safety

Introduction

Infants and children should receive the right doses of liquid formulations so that they get optimum dose for therapy without the risk of exposure to undue toxicity. Several parents make errors in measuring the drug volumes [1–5] and this is dependent on the measuring device used and on health literacy. The present study was carried out to determine the magnitude of dosing error made by caregivers, its association with caregivers' age, gender and education and the number of children in the household and to determine the most preferred measuring device. It is hoped that the study results would be useful in planning corrective and educational strategies.

Material and Methods

The observational study was carried out in a public hospital, Mumbai in 2015 after obtaining approval from the ethics committee and parents or caregivers of children (aged under-5 y) were enrolled after obtaining written informed consent.

After noting down the caregiver's demographic characteristics, the participant was requested to measure 5 ml of syrup paracetamol using any of the following dosing instruments: a stainless steel household spoon (capacity 5 ml), a disposable plastic syringe (5 ml, I-JECT with numbered dosing calibration mark at 1 ml and at every 1 ml thereafter, least count 0.1 ml), or a dosing cup with etched markings at 2.5 ml, 5 ml and 10 ml. No instructions or demonstration regarding the use of any of the dosing instruments was provided. The accuracy of the measured dose was determined by a single observer using a graduated measuring cylinder (10 ml glass cylinder, BOROSIL®). The dosing errors were classified as: No error: ± 10% [6], Mild error: ± 11–20%, Moderate error: ± 21–40%, Severe error: ± over 40%.

Using nMaster 2.0 [7], the sample size was estimated to be 386 covering the entire dosing error range reported in the published literature. Qualitative data was represented in the form of frequency, mean and SD and percentage. SPSS 18.0 was used to perform a frequency analysis of demographic characteristics and dosing errors. The Pearson chi-square test was performed for the difference in dosing error rates.

✉ Sandeep B. Bavdekar
sandeep.bavdekar@gmail.com

[1] Department of Pediatrics, TN Medical College and BYL Nair Charitable Hospital, Mumbai, India

Table 1 The mean, standard deviation, median and inter-quartile range of study participants' parameters

Device and no. of participants	Amount measured (ml)			Error		
	Mean+/-SD	Median, IQR	Range (ml)	Total ($n = 72$)	Mild ($n = 58$)	Moderate ($n = 14$)
All ($n = 386$, 100.00%)	5.10+/−0.40	5.0, 0.60	4–6.2	72 (18.65)	58 (15.03)	14 (3.62)
Spoon ($n = 32$, 8.29%)	5.10+/−0.41	5.2, 0.60	4–6.2	18 (56.25)*	10 (31.25)	8 (25.00)
Cup ($n = 270$, 69.95%)	5.10+/−0.40	5.0, 0.60	4–6.2	51 (18.89)*	45 (16.67)	6 (2.22)
Syringe ($n = 84$, 21.76%)	5.10+/−0.42	5.05, 0.60	4.4–5.6	3 (3.57)*	3 (3.57)	0

*: Statistically significant difference: $P = 0.000$; Pearson χ^2 test ($\chi^2 = 42.412$; df = 2)

IQR Inter-quartile range; Mild error: 5 ml± 11–20%; Moderate error: 5 ml± 21–40%

Results

All the 386 participants who were enrolled, completed the study. Majority (270, 69.95%) of the participants chose the measuring cup (Table 1). The mean amount of medicine (5.1) measured by the study population and by those using spoon, cup or syringe was similar. Overall, 72 (18.65%) participants committed an error with 14 (3.63%) of them committing moderate error. None of the participants committed severe error. Syringe-use was associated with the least proportion of participants committing error (3, 3.57%) and all of them committing only mild error.

Although, a significant association was noted between the proportion of participants committing error and educational status, number of children and measuring device used (Tables 1 and 2); multivariate analysis could confirm such an association only between the proportion of participants committing error and the measuring device used.

Discussion

As reported in several other studies [8–10], measuring cup is the most frequently selected measuring device, but it is the syringe that accounts for the least proportion of inaccurate doses. Spoon, chosen by only 8% of participants, performed the worst. The choice of device and not factors like age, gender, education or the number of children are associated with the proportion of doses measured accurately. Several studies (Table 3) have tended to confirm that syringe is associated

Table 2 Association between various participants' characteristics and error in dose measurement: Results of univariate analysis

Participants' characteristics		Error	Pearson's Chi-square test; *P* value
Gender	Male ($n = 162$, 41.97%)	25 (15.43)	$P = 0.167$;
(M:F= 0.72: 1)	Females ($n = 224$, 58.03%)	47 (20.98)	$\chi^2 = 1.098$; df = 1
Age (years)	18–22 ($n = 28$, 7.25%)	8 (28.57)	$P = 0.349$;
(Mean: 35± 19.41)	23–30 ($n = 191$, 49.48%)	30 (15.70)	$\chi^2 = 3.288$; df = 3
	31–40 ($n = 135$, 34.97%)	27 (20.00)	
	>41 ($n = 32$, 8.29%)	7 (21.87)	
Educational status	Illiterate ($n = 12$, 3.10%)	6 (50.00)	$P < 0.001$;
	Literate, no formal education ($n = 8$, 2.07%)	5 (62.50)	$\chi^2 = 44.4$; df= 6
	Up to 4th standard ($n = 21$, 5.44%)	12 (57.14)	
	4th to 10th standard ($n = 185$, 47.93%)	29 (15.67)	
	10th– less than graduate ($n = 110$, 28.50%)	16 (14.54)	
	Graduate ($n = 49$, 12.69%)	4 (8.6)	
	Post-graduate ($n = 1$,0.26%)	0 (0.00)	
No. of children	Up to 2 ($n = 267$, 69.17%)	38 (14.23)	$P = 0.00036589$;
	3–4 ($n = 110$, 28.50%)	29 (26.36)	$\chi^2 = 15.826$; df = 2
	>5 ($n = 9$, 2.33%)	5 (55.56)	

$P < 0.05$: statistically significant

Table 3 Summary of selected studies: proportion of participants demonstrating satisfactory/ acceptable measurement of drug dose with different devices studied

Author's name; Year of publication; No. of participants	Percentage of participants demonstrating satisfactory measurement of drug dose									
	Hsp	Syr	Drp	MC	MCp	MCe	SyB	Dsp	DB	SpB
Madlon-Kay DJ et al.; 2000 [9]; 130	–	92.0	–	85.0	–	–	–	92.0	–	–
Sobhani P et al.; 2008 [8]*; 96	–	66.7	–	14.6	–	–	–	–	–	–
Ravikiran SR et al.†; 2011 [11]; 310	–	75.8	58.7	–	–	76.0	–	–	–	–
Yin HS, et al.†; 2010 [1]; 302	–	91.4	94.4		30.5	50.2	90.7	86.0	–	–
Ryu GS, et al.‡; 2012 [4]; 300	50.0	100.0	–		69.3	52.9	–	–	93.6	96.0
Present Study*; 2015; 386	43.8	96.43	–	81.1	–	–	–	–	–	–

*: The study considered the satisfactory or 'no error' category as being 10% around the ordered dose

†: The study considered the satisfactory or 'no error' category as being 20% around the ordered dose

‡:Although the study considered <5% around the ordered dose as 'no error' category, the figures for error have been provided with 'up to 10%' around the ordered dose as 'no error category' since these figures were provided in the publication

DB Dispensing bottle; *Drp* Dropper; *Hsp* Household teaspoon; *MC* Measuring cup; *MCe* Measuring cup with etched margins; *MCp* Measuring cup with printed markings; *SpB* Spoon with bottle adapter; *SyB* Syringe with bottle adapter; *Syr* Syringe

with higher greater proportion of accurate doses [1, 2, 4, 8, 9, 11]. In some studies [1, 4, 11], spoon or syringe with bottle adapter and dispensing bottle have provided results similar to syringe. However, these devices were not included in the current study as such devices are not commonly available and are unlikely to be chosen and used by the population that we serve. Although, some studies have found an association between higher proportion of participants committing error and lower educational status [4, 9, 11, 12], lower health literacy [1], gender [4], parental age [4] and number of children [4]; present study did not find any association between participants' error and various factors studied. Measuring device used was the only factor significantly associated with the participants' error and this has been reported in several studies [1, 2, 4, 8, 9, 11–13], as well.

Table 4 Recommended interventions for improving measurement of dose of liquid preparations

Doctors should prescribe liquid doses in terms of 'ml' and not in terms of 'teaspoons' or 'tablespoons'.
Organize education sessions for caregivers. These can be attended by caregivers while awaiting their turn in the out-patient department or after a liquid drug preparation has been prescribed to the child.
Explain the pros and cons of various dose measuring devices.
Discourage caregivers from using household spoons for measuring doses explaining their shortcomings such as: varying volumes of spoons, no markings for doses smaller than 5 ml, confusion with tablespoon can cause disasters.
Explain the limitations of measuring cups in measuring doses that have not been marked up on the cup (*e.g.*, 3 ml, 3.5 ml).
Explain the advantages of using plastic disposable syringe as a dose measuring device.
A commercially-available oral syringe can be reused after appropriate cleaning (wash barrel and plunger separately in warm soapy water, allow to dry ensuring that individual components are dry before storage or re-use).The cost of one-time purchase of a syringe (INR 5/ USD 0.07) is 'money well-spent'.
Demonstrate the technique of using syringe as a dose-measuring device and of cleaning the syringe after use.
Demonstrate the technique of using a measuring cup as a dose measuring device, of cleaning the cup after use for caregivers who intend to use them for doses that are marked up on the measuring cup.
Modify the content of the education session as per local needs that have been identified through surveys or studies carried out at the institution.

The study has identified three main problems: Household spoons are still used for measuring doses; mild to moderate errors do occur with measuring cups and spoons but only mild errors occur with syringe. These can be tackled through interventions listed in Table 4.

Performing the study with one of the highest sample sizes used for similar studies, using standardized definitions for "no error" and various levels of errors, mimicking "real life" situation by asking participants to freely choose the preferred device are some of the methodological strengths of the study. The authors used a single non-fraction dose of a single medication to provide a level-playing field for all devices. The 5 ml-dose was chosen, as the volume of a single swallow in infants aged 15-18mo is 4.5 ml [14]. Doses such as 0.5/ 3.5 ml would have put spoons and measuring cups at obvious disadvantage. Hence, authors believe that single dose, single drug and limited number of devices tested cannot be construed as limitations of the study. Given the fact that caregivers bringing children to pediatric wards and outpatient departments were enrolled, authors believe that the present results are generalizable to the population catered to by public hospitals. However, every institution can identify the specific problems of (and the possible interventions for) the population it serves by performing similar studies.

Authors' Contributions PJ: Literature search, data acquisition, analysis and interpretation, writing the initial draft, finalization of the manuscript draft and approval of the final manuscript draft; SBB: Conceptualization of the study, literature search, data analysis, significant intellectual inputs for improvement of the draft manuscript, approval of the final version of the manuscript and will publicly defend the article.

Compliance with Ethical Standards

Conflict of Interest None.

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