

## Strategies to reduce medication errors in pediatric ambulatory settings

Mehndiratta S

Department of Pediatrics,  
LN Hospital, Delhi, India

**Address for correspondence:**  
Dr. Sumit Mehndiratta,  
E-mail: drsmehndiratta@  
gmail.com

### ABSTRACT

Worldwide, a large number of children are prescribed drugs on an outpatient basis. Medication errors are fairly common in these settings. Though this matter has been well recognized as a cause of concern, limited data is available from ambulatory settings. Medication errors can be defined as errors that may occur at any step, starting from ordering a medication, to dispensing, administration of the drug and the subsequent monitoring. The outcomes of such errors are variable and may range between those that are clinically insignificant to a life-threatening event. The reasons for these medication errors are multi-factorial. Children are unable to administer medications to themselves and also require a strict weight-based dosing regimen. The risk factors associated with medication errors include complex regimens with multiple medications. Overdosing and under-dosing (10-fold calculation errors), an increased or a decreased frequency of dosing or an inappropriate duration of administration of the medication, are frequently detected errors. The lack of availability of proper formulations adds to the confusion. The low level of literacy among the caregivers can aggravate this problem. There is a lack of proper reporting and monitoring mechanisms in most ambulatory settings, hence these errors remain unrecognized and often go unreported. This article summarizes the current available literature on medication errors in ambulatory settings and the possible strategies that can be adopted to reduce the burden of these errors in order to improve child care and patient safety. Voluntary, anonymous reporting can be introduced in the healthcare institutions to determine the incidence of these errors.

Received : 02-08-11  
Review completed : 31-08-11  
Accepted : 04-10-11

**KEY WORDS:** Adverse drug events, ambulatory pediatric patients, dosing errors, medication errors, patient safety

### Introduction

Medication errors have been recognized as an area of grave concern and are preventable adverse events in all age groups of patients. Various definitions of such errors are available from different sources. The National Coordinating Council for Medical Error Reporting and Prevention (NCCMERP) has given the following definition: "Medication error is any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the healthcare professional, patient, or consumer. Such events may be related to professional practice, healthcare

products, procedures and systems, including prescribing; order communication; product labeling, packaging, and nomenclature; compounding; dispensing; distribution; administration; education; monitoring; and use."<sup>[1,2]</sup>

According to the Institute of Medicine "Medical errors can be defined as the failure of a planned action to be completed as intended or the use of a wrong plan to achieve an aim."<sup>[3]</sup> Medication errors are recognized as one of the most common causes of adverse events. They include any error in ordering, transcribing, dispensing, administration or monitoring the effects of a medication. Ghaleb *et al.*, used a two-stage Delphi technique to develop a practitioner-led definition of a prescribing error for use in prevalence/incidence studies in pediatric practice.<sup>[4]</sup>

Inconsistencies are common in the definition of medication errors in different settings across the world. Lisby *et al.*, conducted a review to describe the extent and characteristics of definitions of medication errors in hospitals. It was found that the documented prevalence of medication errors, ranged from 2–75% and no associations have been found between definitions and prevalence.<sup>[5]</sup>

Access this article online	
Quick Response Code:	Website: www.jpgmonline.com
	DOI: 10.4103/0022-3859.93252

The process of medication is more complex in children and there is a potential for error at each step. Thus, children are more vulnerable to injury as compared to adults.

There is a clear distinction between medication errors and adverse drug reactions.<sup>[1,6-8]</sup> Adverse reactions to medications include those that are usually unpredictable, such as idiosyncratic or allergic responses, and those that are predictable and thus potentially avoidable, such as side-effects or toxic reactions that are related to the inherent pharmacologic properties of the drug. A preventable adverse event is an adverse event caused by an error or other type of systems or equipment failure.

A potential adverse event is a serious error or mishap that has the potential to cause an adverse event but fails to do so because of chance or because it is intercepted.

### **Incidence and burden of the problem**

Medication errors in ambulatory pediatric settings are fairly common. Only limited data is available about medication errors in ambulatory settings. Clinically significant events get reported as they are recognized and need active interventions, but the data about minor events is scarce as a majority of the minor events do not get reported at all or are ignored altogether. A prospective cohort study was conducted by Kaushal *et al.*,<sup>[9]</sup> by using duplicate prescription review, telephone surveys and chart reviews in six office practices in the greater Boston area over a two-month period. It was found that the rate of preventable adverse events was 3% (95% CI 3-4%) and that of non-preventable adverse events was 13%; (95% CI 11-15%). The authors found that 14% of the preventable adverse events were serious. McPhillips *et al.*,<sup>[10]</sup> conducted a study to determine the prevalence of potential dosing errors of medications dispensed to children. Automated pharmacy data from three health maintenance organizations with 1933 study subjects were used in this study. The error rate in two health maintenance organizations that were using paper prescriptions was compared with one that used electronic prescription writer. It was found that 15% of children in pediatric outpatient departments were dispensed a medication with a potential dosing error (potential overdosing in 8% and potential under-dosing in 7%). A systematic literature review using several databases was conducted to investigate the incidence and nature of dosing errors in children by Wong *et al.*,<sup>[11]</sup> Out of 16 studies that were found to be relevant, 11 studies found dosing error to be the most common form of medication error, three of the remaining studies found it to be the second most common type.

The most commonly reported errors include inappropriate medication for the condition under treatment; incorrect dosage or frequency of administration of medication; wrong route of administration; failure to recognize drug interactions; lack of monitoring for side-effects; and inadequate communication between the physician, or other members of the healthcare team, and the patient. Dosing errors were most frequent type of errors.<sup>[11]</sup>

Though many of the medication errors may be inconsequential, all these errors are a part of cascade of those events or system

failure that may lead to harm to the patient. Once these errors have been recognized, problems can then be identified in the process and corrective steps can be subsequently initiated.<sup>[12,13]</sup>

To assess the rates of medication errors in pediatric patients in ambulatory settings, the authors conducted a prospective cohort study in six pediatric outpatient offices in Massachusetts. The authors found that out of all errors identified 68% had minimal potential for harm and 26% were potentially harmful medication errors (near misses). 94% of the medication errors with minimal potential for harm and 60% of the near misses occurred at the prescribing stage. In this study, the most common types of errors were inappropriate abbreviations followed by dosing errors.<sup>[13]</sup>

A prospective cohort study was conducted by Zandieh *et al.*,<sup>[14]</sup> to determine whether there are racial/ethnic, socioeconomic, parental linguistic or parental educational disparities in children who experienced an adverse drug event (ADE) in an ambulatory setting. In this study, 14% of children experienced an ADE, of which 23% had a preventable ADE and 77% had a non-preventable ADE. In multivariate analysis, children with multiple prescriptions (odds ratio, 1.46; 95% CI, 1.01-2.11) were at an increased risk of having a preventable ADE, controlling for parental education, racial/ethnic, English proficiency, practice type, and duration of care. Another study was conducted by Oshikoya *et al.*, with the aim of identifying the types of medication errors in the pediatric outpatient prescriptions. A total of 2,000 pediatric outpatient prescriptions randomly selected from five months of prescriptions were studied. It was found that under- and over-dosage was associated with 38.0% and 18.8% drugs respectively. Also, inadequate and omissions of the mention of duration of use of the drugs were observed in 28.3% and 0.9% prescriptions respectively.<sup>[15]</sup>

The incidence of medication errors is expected to be higher in developing countries and this can be possibly attributed to the overcrowding in the outpatient departments coupled with a high level of ignorance and a low level of literacy amongst the caregivers. There is still a deficiency in the knowledge about the proper mechanisms needed in order to reduce the incidence of these errors.

### **Pediatric ambulatory setting: Characteristics**

The absence of proper reporting and monitoring systems in ambulatory settings makes it distinct from in-patient settings. While caring for in-patients, trained healthcare professionals are involved in the provision of the complete treatment and in the administration of medications. Due to the presence of close monitoring systems in intensive care settings, in most of the cases, these errors are detected before they can cause significant harm to the patient. In outpatient settings, the parents/caregivers administer medications to the children and they are not at par with the trained health care professionals. Drug dispensing is done by pharmacists and in a majority of cases there is often no mechanism for cross-checking or monitoring. Hence, the accuracy of the dose actually given to the patient is difficult to monitor. Moreover, in ambulatory settings doctors and pharmacists spend very little time with the

caregivers to assess whether they have correctly understood the medication regimen.

### **Etiology of medication errors**

Multiple factors have been implicated in the etiology of medication errors. Ignorance and lack of proper training among resident doctors, the use of abbreviations in prescriptions, illegible prescriptions, fatigue among residents, inconsistencies in different formulations of drugs available, language barriers and the lack of good communication skills, are some of the major factors that lead to these errors.<sup>[1,3,4,13-15]</sup> Parents and caregivers may find it difficult to understand how to measure the dose correctly, particularly when liquid formulations are prescribed. Dosing ability can be directly related to the literacy rates among caregivers. In a study by Yin *et al.*, a low level of health literacy, in particular reading comprehension, was associated with the use of non-standardized dosing instruments.<sup>[16,17]</sup> Similar data is available from our country.<sup>[18]</sup>

Another risk factor which is often ignored is psychological problems of residents. It might be useful to determine the prevalence of depression and burnout among residents in pediatrics and to establish whether, a relation exists, between these disorders and medication errors. A study was conducted in three urban freestanding children's hospitals in the United States. It was found that depressed residents made 6.2 times as many medication errors per resident month as compared to residents who were not depressed. It was concluded that depression and burnout are major problems among residents in pediatrics.<sup>[19]</sup>

### **Different dosing devices used and their accuracy**

Problems arise due to the availability of different delivery vehicles of drugs being used. In ambulatory settings and when administering medications at home, a variety of standardized (cups, calibrated spoons, droppers, etc.) as well as non-standardized (teaspoon, tablespoon, etc.) dosing devices are used. This leads to confusion and has been associated with higher rates of errors. Multiple formulations like drops, suspensions and double-strength formulations further tend to confuse many parents and care providers. The non-availability of all formulations in certain hospital pharmacies is another risk factor. The tablets (adult formulations) which are difficult to adequately calibrate and administer in correct doses to children have a high potential for error. The lack of proper storage of medications and the non-adherence to medication regimens by care providers, also contributes to medication errors.

The use of syringes for the measurement of a dose has been found to be one of the most accurate methods in the correct calculation of the dose and is one of the useful and practical options. The use of calibrated cups/dispensers is similarly associated with a smaller chance of error. One hundred and thirty volunteers from the waiting areas of three primary care clinics in the St. Paul, Minnesota area were interviewed to evaluate dosing errors involving liquid medications. It was found that the common errors included misinterpreting instructions, confusing teaspoons and tablespoons on a medicine cup, and

misreading a dosage chart when weight and age were discordant. It was advocated that clinicians should encourage the use of more accurate devices, particularly the oral dosing syringe.<sup>[20]</sup>

A study was conducted by Bailey *et al.*, in family medicine clinics serving low-income populations in Chicago, to determine the level of understanding among adults of dosage instructions for a liquid medication commonly prescribed for children. It was found that 28% of subjects misunderstood medication instructions. The prevalence of misinterpreting instructions among subjects with adequate, marginal, and low literacy was 18%, 34%, and 43%, respectively. Thus, inadequate and marginal literacy remained independent predictors of misunderstanding medication dosing.<sup>[21]</sup> Hence it will not be surprising that errors will be comparable to these rates in resource-poor, low-income countries like ours with high rates of poverty and illiteracy.

In another study conducted to compare the accuracy of an oral syringe with that of a dosing cup, the authors found that subjects were more likely to measure an accurate dose with an oral syringe when compared with a dosing cup.<sup>[22]</sup> If measuring techniques are correctly demonstrated, the rate of medication errors is lower, as was evident in the study conducted by McMohan *et al.*<sup>[23]</sup>

Some of the important factors attributed for medication errors have been summarized in Table 1.

### **What can be done?**

Certain strategies have been advocated to reduce the frequency of medication errors.<sup>[1,2]</sup> Dealing with the problem of medication errors in outpatients would require a different approach. Each and every unit involved in child care should have the latest reference manual for drug doses. The prescribing physicians should cross-check the dosages whenever required. Along with the prescription, it should be ensured that the parent or care provider understands the correct method of measurement of a dose and the frequency and duration for which the medication is to be given. The instructions should preferably be in a language

**Table 1: Reasons attributed for medication errors (not in order of frequency)**

Weight-based dosing
Multiple formulations with different strengths
Multiple dispensing instruments-cups/spoon/droppers, etc.
Use of abbreviations in prescriptions/illegible prescriptions
Lack of communication skills amongst doctors/language barriers
Multiple drug combinations
Physicians' fatigue/overwork
Use of off-label medications
Reconstitution of powder form of medications
Lack of uniform prescription guidelines
Lack of reporting and monitoring mechanisms
Low literacy level of parents/caregivers
Inability of children to self-administer medications
Non-availability of medication in liquid/scored tablet formulations
Untrained staff-doctors/pharmacists

the parent understands. The reconstitution of powder-based formulations and their use within the stipulated time is another area of concern and this should be properly explained to the care provider. Parents tend to use the same preparations for similar illnesses in siblings which may lead to over/under-dosing. This practice needs to be strongly discouraged.

It is well established that overwork and fatigue among residents is directly related to an increase in the frequency of errors in intensive care unit (ICU) and in-patient settings. Though the situation is not similar in ambulatory settings where working hours are shorter, burnout does occur due to the large number of patients. Hence a measure that overcomes or reduces burnout among the staff has great potential to reduce these errors.

Improved communication between healthcare providers and parents and improved communication between pharmacists and parents, whether in the office or in the pharmacy are strategies that have the greatest potential. Continuing medical education programs, training and orientation of physicians and paramedical staff involved in infant and child care and the provision of drug formularies and reference manuals are also some of the important interventions.<sup>[9,24-26]</sup>

The role of advice in medication administration in pediatric ambulatory settings was studied in a prospective cohort study of 1685 pediatric patients in Boston area. The results of this study were that the advice from both office and pharmacy were poor in quality and limited in provision. The providers often failed to offer information.<sup>[27]</sup> This highlights the importance of proper communication and advice along with prescriptions. Children with multiple medications are at an increased risk for medication errors.<sup>[14]</sup> Hence special attention has to be devoted to these cases.

A systemic literature review on educational interventions to improve prescribing by medical students and junior doctors was carried out. It was found that The WHO Good Prescribing Guide is the only model that has been widely used and has been shown to improve prescribing. The authors concluded that although the guide is based on sound principles, there is a need for further development. Therefore some restructuring of the medical education curriculum may be helpful.<sup>[28]</sup>

Computerized Physician Order Entry (CPOE) is an application in which physicians write orders online. This involves a pre-designed and well-established, structured form. The prescription is legible and cross-checks dose, drug interactions, allergic reactions, etc. In a way CPOE almost eliminates many problems associated with prescribing on paper.<sup>[29,30]</sup> Similarly, electronic patient medical records and bar-coded patient identification bracelets have shown to be beneficial. Automated pharmacy systems are also useful.<sup>[31-33]</sup> Though computer and information technology-assisted prescribing and dispensing is extremely beneficial, these techniques should be customized according to settings and financial implications, particularly in developing countries. Kirk *et al.*,<sup>[34]</sup> conducted a study to assess the rate of medication errors in predominantly ambulatory pediatric patients. This study analyzed the effect

of doses calculated by computer on the rate of medication errors of two commonly prescribed drugs—paracetamol (acetaminophen) or promethazine. The error rate was 15.7% in the children's emergency department, 21.5% for outpatients and 23.6% for discharge medication. Most errors were the result of an under-dose (64%). The dose error rate was 12.6% if the dose was calculated by a computer as compared with an error rate of 28.2% seen with traditional prescriptions. Logistical regression analysis showed that computer-calculated dosing was an important and independent variable influencing the error rate. (adjusted relative risk=0.436, 95% CI 0.336, 0.520,  $P<0.001$ ). Similarly, Potts *et al.*,<sup>[35]</sup> conducted a prospective trial involving 514 pediatric patients who were admitted to a 20-bed Pediatric Critical Care Unit in a tertiary-care children's hospital before and after implementation of CPOE. Medication errors were identified after conducting a review of all orders during the study period and were then further classified as potential ADEs, medication prescribing errors (MPE), and rule violations (RVs). After implementation, the rate of potential ADEs was reduced to 1.3 per 100 orders, MPEs to 0.2 per 100 orders, and RVs to 0.1 per 100 orders. The overall reduction in the number of errors was 95.9%. Potential ADEs were reduced by 40.9%, and MPEs and RVs were reduced by 99.4% and 97.9%, respectively.

The use of pictographic depiction is beneficial and has been proven to reduce the chances of an error. In a Randomized Controlled Trial conducted by Yin *et al.*, in an urban public hospital pediatric emergency department, the efficacy of pictogram-based health literacy intervention to decrease administration errors by caregivers of young children when using liquid medications was evaluated. With this intervention it was found that caregivers had fewer errors in observed dosing accuracy (>20% deviation from prescribed dose) compared with caregivers who received routine counseling.<sup>[36]</sup> Hence standardized prescription forms with pictographic depictions can be used. These can be particularly useful in areas with low literacy levels. A prototype prescription form is depicted [Figure 1].

Since confusion also occurs at the dispensing stage due to multiple drugs, color-coded dispensing cans can be helpful. Frush *et al.*,<sup>[37]</sup> evaluated a simple method of dosing using a color-coded concept through a randomized controlled clinical trial in the setting of a pediatric emergency centre. The trial was conducted over 101 participants divided into two groups. The conventional dosing method and a color-coded method were compared for using acetaminophen. It was found that there was a marked improvement in the caregivers' ability to correctly determine and measure an over-the-counter medication for their child using a color-coded method as compared to conventional methods.

Certain pharmacies dispense medications from larger bottles or containers after transferring them to smaller unlabelled bottles for individual patients. This practice has a high risk of error and should be abolished altogether. Improved methods of labeling medications can be used whenever feasible. It has been shown that interventions that target the ordering and administration

Name:	Date:	
S/D/of:		
Age:		
Sex:	Patient identification no.	
Diagnosis	Weight	
Formulation	Tab/Cap/Syrup	
Drug generic name	*****	
Drug brand name if required	*****	
Strength of formulation	125 mg/5 ml or 100 mg Tab, etc.	
Dose measure to be given	e.g. 4 ml or 1 Tab	
Frequency	***times	Depict by markings
Duration	***days	
To stop after/to review after	***days	
This space may be used for pictographic display of medication dose and frequency		
Special instructions: For example, To be taken on an empty stomach/in morning before breakfast/not to be taken with milk		
Allergic to: .....		
Warning: For example, This medication is to be used for topical application and is not to be taken orally		
To report urgently if.....		
_____ Signature and Name of Doctor		_____ Name of hospital/clinic/institution
This prescription is not valid after: ddmmyyyy		

**Figure 1:** Prototype template for prescription in outpatient settings

of drugs have high benefit potential. It has also been advocated that a monitoring committee needs to be established to review all pediatric prescriptions for appropriateness, adequacy and dosage accuracy before dispensing.<sup>[15]</sup>

The availability of formulations with uniform concentrations would also help as it would decrease the degree of confusion among prescribing physicians and dispensing pharmacists. The involvement of drug-controlling authorities and the collaboration between pharmaceutical companies for ensuring uniformity in preparations would be helpful. Education of the parents and caregivers is no doubt, also of prime importance as is discouraging the practice of self-medication and the use of over-the-counter drugs. Standard protocols that have been developed in accordance with hospital settings must be communicated to all those concerned with the prescription and dispensing of medications. Other helpful measures include avoiding abbreviations while writing prescriptions and providing instructions in a language that the caregiver understands. The route of administration of medications, i.e., oral vs. topical, should always be clarified to avoid hazardous situations and potential toxicity. The parent/caregiver should also be made aware of the potential side-effects of medications and when and where to report should such incidents occur. The duration after which the medication should be discontinued should be clearly mentioned in the prescription. Any known drug allergies should also be documented.

### Conclusions

It has been recommended that the best way to understand how medication errors happen and how to prevent them is to consider their etiology and classification. Errors can be classified as mistakes (knowledge-based and rule-based) and skill based (action-based or memory-based) errors. Knowledge-based errors can obviously be prevented by improving the knowledge of the prescribing physicians. Mistakes that result from bad rules can be simply prevented by improving the rules. Action-based errors can be prevented by imparting proper training to all those involved in the process of medication prescribing to dispensing. Memory-based errors are the most difficult ones to prevent and are best handled by timely detection and remedial actions.<sup>[38,39]</sup> The use of information technology holds a definite promise. Computer-assisted prescribing and medical software with references for the drug doses, overdose and under-dose alerts, drug interaction alerts etc., can be used. Information technology can substantially improve the safety of medical care by structuring actions, catching errors, and bringing evidence-based, patient-centered decision support to the point of care to allow necessary customization.<sup>[40]</sup>

In order to reduce the harm caused by these errors and improve patient safety, these errors need to be investigated to determine the extent of the problem. There are three ways to collect the relevant data—review of practice data,

**Table 2: Strategies advocated for reducing medication errors**

Legible, clear and concise prescription without unnecessary abbreviations
Use of standardized prescription templates/computer-assisted prescribing
Use of drug reference manuals/pocket guides
Pictographic depiction of dose measurement
Training of doctors and pharmacists
Color-coded dispensing
Separate dispensers for topical medications
Parent education guide/displays
Voluntary anonymous reporting
Monitoring and pharmacovigilance

self-reporting and patient surveys. A combination of all the three is most beneficial.<sup>[41]</sup> Once the burden of the problem has been identified, suitable strategies can be implemented. Medication errors can be attributed to problems with the system rather than personnel error alone, hence remedial measures should be formulated accordingly.<sup>[12,42]</sup> The various barriers to improvement include a lack of availability of uniform standards and financial constraints. Double checking of prescriptions, caution in dispensing look-alike and sound-alike medications and improved labeling techniques are recommended and are very useful strategies. Educating the parents about the right dose of medicine to be taken at the right time is helpful in preventing medication errors. Separate prescription forms and dispensing packets can be used to dispense topical medications.

Most of the strategies are simple and easy to implement and do not place any significant financial burden. Since many medication errors are preventable, the importance of adopting measures to reduce them becomes even more relevant. There is a need for formulating and implementing proper reporting and monitoring mechanisms for the detection of the prevalence of these errors across various settings. Voluntary and anonymous reporting can be implemented to gather information about the incidence and can be used to subsequently modify any practice guidelines.<sup>[43]</sup> Important strategies that can be helpful in reducing medication errors are enumerated in Table 2.

Medication errors in pediatric outpatients are grossly underreported. The potential of injury is higher in young children and infants and can result in serious morbidity and even mortality. Though advances have been made, a lot still needs to be done, particularly in developing countries like India. There is an urgent need of multicentre studies to determine the incidence and burden of errors in ambulatory settings. Healthcare institutions should formulate strategies that are appropriate to their resources and limitations. A high level of motivation among the staff and the active involvement of parents in correctly understanding the medications for their children are mandatory. If the doctors spend a little more time with the parents, it will significantly reduce these errors. These skills should be a part of the medical teaching curriculum from the undergraduate level itself. Though there is still a long way to go in this regard, the goal is not unrealistic and can be achieved through dedicated and sustained efforts. A policy draft or a

consensus statement by a panel of experts of academic bodies, would be welcome.

## References

- American Academy of Pediatrics. Committee on Drugs and Committee on Hospital Care. Prevention of medication errors in the pediatric inpatient setting. *Pediatrics* 1998;102:428-30.
- nccmerp.org [home page on the internet]. United States: National Coordinating Council for Medication Error Reporting and Prevention. What is a medication error? c1998-2011. Available from <http://www.nccmerp.org/aboutMedErrors.html> [Last cited on 2011 Sep 22].
- Kohn LT, Corrigan JM, Donaldson MS. *To Err Is Human: Building a Safer Health System*. Washington, DC: National Academy Press, 1999.
- Ghaleb MA, Barber N, Dean Franklin B, Wong IC. What constitutes a prescribing error in paediatrics? *Qual Saf Health Care* 2005;14:352-7.
- Lisby M, Nielsen LP, Brock B, Mainz J. How are medication errors defined? A systematic literature review of definitions and characteristics. *Int J Qual Health Care* 2010;22:507-18.
- World Alliance for patient Safety. WHO Draft guidelines for adverse event reporting to learning systems. © World Health Organization 2005. Available from: [http://www.who.int/patientsafety/events/05/Reporting\\_Guidelines.pdf](http://www.who.int/patientsafety/events/05/Reporting_Guidelines.pdf) [Last cited on 2011 Sep 22].
- Leape LL, Lawthers AG, Brennan TA, Johnson WG. Preventing Medical Injury. *QRB Qual Rev Bull* 1993;19:144-9.
- Bates DW, Leape LL, Petrycki S. Incidence and preventability of adverse drug events in hospitalized adults. *J Gen Intern Med* 1993;8:289-94.
- Kaushal R, Goldmann DA, Keohane CA, Christino M, Honour M, Hale AS, *et al.* Adverse drug events in pediatric outpatients. *Ambul Pediatr* 2007;7:383-9.
- McPhillips HA, Stille CJ, Smith D, Hecht J, Pearson J, Stull J, *et al.* Potential medication dosing errors in outpatient pediatrics. *J Pediatr* 2005;147:761-7.
- Wong IC, Ghaleb MA, Franklin BD, Barber N. Review Incidence and nature of dosing errors in paediatric medications: A systematic review. *Drug Saf* 2004;27:661-70.
- Leape LL, Bates DW, Cullen DJ, Cooper J, Demonaco HJ, Gallivan T, *et al.* Systems analysis of adverse drug events. ADE Prevention Study Group. *JAMA* 1995;274:35-43.
- Kaushal R, Goldmann DA, Keohane CA, Abramson EL, Woolf S, Yoon C, *et al.* Medication errors in paediatric outpatients. *Qual Saf Health Care* 2010;19: e30.
- Zandieh SO, Goldmann DA, Keohane CA, Yoon C, Bates DW, Kaushal R. Risk factors in preventable adverse drug events in pediatric outpatients. *J Pediatr* 2008;152:225-31.
- Oshikoya KA, Ojo OI. Medication errors in paediatric outpatient prescriptions of a teaching hospital in Nigeria. *Nig Q J Hosp Med* 2007;17:74-8.
- Yin HS, Dreyer BP, Foltin G, van Schaick L, Mendelshon AL. Association of low caregiver health literacy with reported use of nonstandardized dosing instruments and lack of knowledge of weight-based dosing. *Ambul Pediatr* 2007;7:292-8.
- Yin HS, Mendelshon AL, Wolf MS, Parker RM, Fierman A, van Schaick L, *et al.* Parents' medication administration errors: Role of dosing instruments and health literacy. *Arch Pediatr Adolesc Med* 2010;164:181-6.
- Ravikiran SR, Shivarajashankara YM. Dosing Ability of Indian Parents for Liquid Medication. *Indian Pediatr* 2011;48:153-4.
- Fahrenkopf AM, Sectish TC, Barger LK, Sharek PJ, Lewin D, Chiang VW, *et al.* Rates of medication errors among depressed and burnt out residents: Prospective cohort study. *BMJ* 2008;336:488-91.
- Madlon-Kay DJ, Mosch FS. Liquid medication dosing errors. *J Fam Pract* 2000;49:741-4.
- Bailey SC, Pandit AU, Yin S, Federman A, Davis TC, Parker RM, *et al.* Predictors of Misunderstanding Pediatric Liquid Medication Instructions. *Fam Med* 2009;41:715-21.
- Sobhani P, Christopherson J, Ambrose PJ, Corelli RL. Accuracy of oral liquid measuring devices: Comparison of dosing cup and oral dosing syringe. *Ann Pharmacother* 2008;42:46-52.
- McMahon SR, Rimsza ME, Bay RC. Parents can dose liquid medication accurately. *Pediatrics* 1997;100:330-3.

24. Gandhi TK, Weingart SN, Borus J, Seger AC, Petersen J, Burdick E, *et al.* Adverse drug events in ambulatory care. *N Engl J Med* 2003;348:1556-64.
25. Nielsen-Bohman L, Panzer A, Kindig D. Health Literacy: A Prescription to End Confusion. Washington, DC: Institute of Medicine; 2004.
26. Conroy S, North C, Fox T, Haines L, Planner C, Erskine P, *et al.* Educational interventions to reduce prescribing errors. *Arch Dis Child* 2008;93:313-5.
27. Lemer C, Bates DW, Yoon C, Keohane C, Fitzmaurice G, Kaushal R. The role of advice in medication administration errors in the pediatric ambulatory setting. *J Patient Saf* 2009;5:168-75.
28. Ross S, Loke YK. Do educational interventions improve prescribing by medical students and junior doctors? A systematic review. *Br J Clin Pharmacol* 2009;67:662-70.
29. Bates D. Using information technology to reduce rates of medication errors in hospitals. *BMJ* 2000;320:788-91.
30. Bates DW, Teich JM, Lee J, Seger D, Kuperman GJ, Ma'Luf N, *et al.* The impact of Computerized Physician Order Entry on medication error prevention. *J Am Med Inform Assoc* 1999;6:313-21.
31. Benjamin DM. Reducing medication errors and increasing patient safety: Case studies in clinical pharmacology. *J Clin Pharmacol* 2003;43:768-83.
32. Kaushal R, Bates DW. Information technology and medical safety: What is the benefit? *Qual Saf Health Care* 2002;11:261-5.
33. Kaushal R, Barker KN, Bates DW. How can information technology improve patient safety and reduce medication errors in children's health care? *Arch Pediatr Adolesc Med* 2001;155:1002-7.
34. Kirk RC, Li-Meng Goh D, Packia J, Min Kam H, Ong BK. Computer calculated dose in paediatric prescribing. *Drug Saf* 2005;28:817-24.
35. Potts AL, Barr FE, Gregory DF, Wright L, Patel NR. Computerized physician order entry and medication errors in a pediatric critical care unit. *Pediatrics* 2004;113:59-63.
36. Yin HS, Dreyer BP, van Schaick L, Foltin GL, Dinglas C, Mendelsohn AL. Randomized controlled trial of a pictogram-based intervention to reduce liquid medication dosing errors and improve adherence among caregivers of young children. *Arch Pediatr Adolesc Med* 2008;162:814-22.
37. Frush KS, Luo X, Hutchinson P, Higgins JN. Evaluation of a method to reduce over-the-counter medication dosing error. *Arch Pediatr Adolesc Med* 2004;158:620-4.
38. Aronson JK. Medication errors: Definition and classification. *Br J Clin Pharmacol* 2009;67:599-604.
39. Ferner RE, Aronson JK. Clarification of terminology in medication errors: Definitions and classification. *Drug Saf* 2006;29:1011-22.
40. Bates DW, Gawande AA. Improving safety with information technology. *N Engl J Med* 2003;348:2526-34.
41. Morimoto T, Gandhi TK, Seger AC, Hsieh TC, Bates DW. Adverse drug events and medication errors: Detection and classification methods. *Qual Saf Health Care* 2004;13:306-14.
42. Reason J. Human error: Models and management. *BMJ* 2000;320:768-70.
43. Suresh G, Horbar JD, Plsek P, Grey J, Edwards WH, Shiono PH, *et al.* Voluntary anonymous reporting of medical errors for neonatal intensive care. *Pediatrics* 2004;113:1609-18.

**How to cite this article:** Mehndiratta S. Strategies to reduce medication errors in pediatric ambulatory settings. *J Postgrad Med* 2012;58:47-53.

**Source of Support:** Nil, **Conflict of Interest:** None declared.

Copyright of Journal of Postgraduate Medicine is the property of Medknow Publications & Media Pvt. Ltd. and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.