

# Medication errors in the practice of paediatric anaesthesia – a narrative review

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## Abstract

Medication error has emerged as a significant problem in healthcare, especially in the past 2 decades. In anaesthesia, the paediatric age group is particularly at risk of such events because of complex age- and weight-based drug calculation, drug formulations, serial dilutions, and often limited staff experience in handling such patients.

We searched PubMed, Cochrane, and Google Scholar for literature on medication errors in paediatric anaesthesia in children (< 18 years of age). Two authors searched for the articles independently, and a third author sorted any consensus differences. A total of 2979 articles were retrieved. We studied primary outcomes, the results, and conclusions of the various studies. A total of 21 relevant articles were selected finally.

Following preventive strategies like colour coding, accurate dose calculations, verification by a second individual, and checking and encouraging self-reporting can improve perioperative safety in the paediatric population to a significant extent.

**Key words:** medication errors, paediatric, anaesthesia, drug error, patient harm, error reduction strategies.

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A medication error can be defined as an event that can lead to patient harm while the drug is partly under the control of the health care professional. Most of the time, this is preventable. Medication error can result either from incorrect dosage (which is the most commonly reported type) [1], wrong dilution [2], wrong drug, wrong administration technique or/route [1], wrong time, faulty preparation, wrong patient, expired product, or mislabelling [3, 4]. Medication error is the third most common cause of inpatient mortality after respiratory and cardiovascular causes [1]. There is an estimated one medication error in every 133 anaesthetic procedures [3]. These figures underestimate the real problem because under-reporting is prevalent in all healthcare systems. However, it remains one of the preventable iatrogenic causes of patient harm.

Paediatric anaesthesia is prone to more such errors than in adults. This might be due to varying age groups, weights, doses, drug formulations, serial dilutions of drugs to reach the appropriate quantity for weight, and changes in pharmacodynamics and pharmacokinetics in paediatric patients due to the immaturity of their organ systems. The anaesthesiologist is responsible for drug prescription, preparation, and administration.

Medication errors could increase morbidity and mortality and healthcare costs [3, 5]. This also negatively impacts the general public's confidence in healthcare professionals and health organisations. Additionally, it is associated with an additional burden for the healthcare professionals themselves, who must bear legal proceedings, shaken self-confidence, reputation at stake, and even in extreme cases manslaughter [3].

In this narrative review, we have tried to analyse the existing literature on the incidence and nature of medication errors and various available guidelines to reduce them and assess their effectiveness.

## MATERIAL AND METHODS

PubMed, Google Scholar, and Cochrane electronic databases were searched. The keywords searched were “medication error”, “drug error”, and “paediatric anaesthesia”. The study population for which we explored the literature were children less than 18 years of age and in the English language. A total of 2979 articles were retrieved on children and medication errors. NG and SG were the 2 authors who reviewed the articles independently. They identified the authors, year and country of publications, the study design, and the age and number

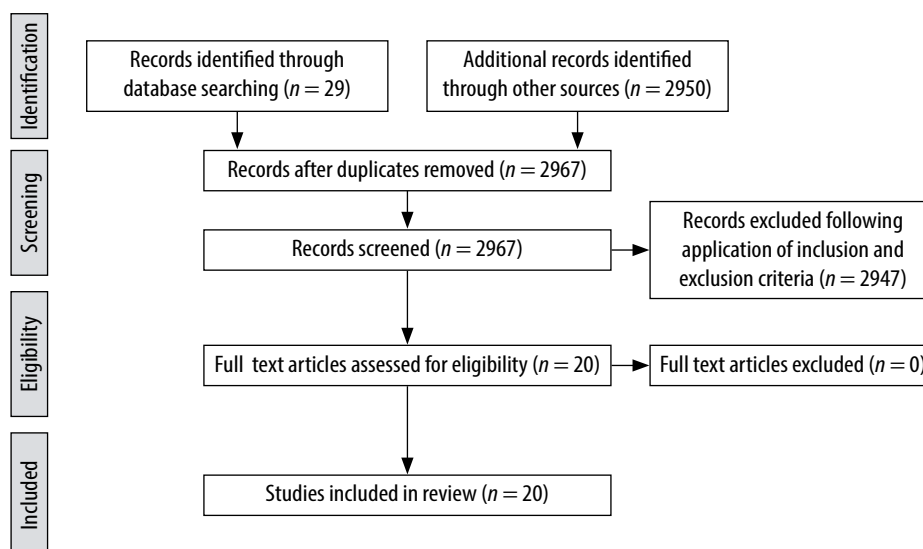


FIGURE 1. Flowchart of study selection

of patients included in the studies. They also studied their primary outcomes (assess incidence, causes, and measures to minimise medication errors in children), the results, and conclusions of the various studies. A total of 21 relevant articles (Figure 1) were selected. It included 9 review articles, 6 observational studies, 3 quality control programs, 2 letters to the editor, and one editorial article (Table 1).

## RESULTS

We have summarised all the essential details and made a detailed interpretation of the results (Table 1). We have attempted to identify significant and valuable interventions, summarising potential means to improve patient safety related to drug errors.

## DISCUSSION

It is perceived that medication errors occur commonly, but the exact rate is uncertain. There are 2 review articles on the estimation of the incidence of medication error. Bratch *et al.* [6] tried to find the error rates based on 5 different method types. However, Feinstein *et al.* [7] found the meta-analytic estimate of the medication error rate across all studies to be 0.08%, or 1 out of 1250 anaesthetics. This is far too low for the expected value, which is consistent with the findings of Leahy *et al.* [8], who showed 105 medication errors among 287,908 cases. It suggests improper error reporting and a need for a more effective methodology to collect data. We have included 2 letters to the editor, highlighting the same problem of underreporting the actual number of events [9, 10]. The problem, therefore, is far more extensive than these data would indicate.

Drug errors are reported to be more common during drug administration (53%), compared with those due to prescription (17%), preparation

(17%), and transcription (11%) [3]. The maintenance phase of anaesthesia is the most common stage at which medication error occurs, which accounts for 42% of the total error. In terms of incidence, it is followed by the induction phase (28%) and the beginning of surgery (17%) [3]. A prospective incident monitoring study in 2017 reported the incidence of medication error to be about 2.6%, with the drugs most commonly involved being opioids and antibiotics. Wrong dosage was the most frequent type of error (67%) [4].

Usually, such errors do not occur for a single reason [5], but from a chain of seemingly minor events, which, when combined, can lead to significant patient harm. This can happen at multiple steps, from prescription, preparation/formulation (especially serial dilutions for paediatric dosages) [2], administration, lack of communication, incomplete knowledge, inexperience [3, 11] (or sometimes overexperience), environmental factors like a hectic schedule, too many patients in hand, or fatigue [4] as well as patient factors like deranged renal function. Another important cause of these errors is cultural barriers and management failure among staff, which sometimes leads to a need for proper adherence to protocols. More evidence is needed about the exact causes of these errors.

Some drugs are inherently more harmful, and their improper use due to lack of knowledge could lead to substantial harm. For example, the sole presence of an epidural route of drug administration can lead to serious errors because drugs meant to be injected epidurally are sometimes inadvertently injected via the intravenous route, and vice versa, leading to potentially catastrophic outcomes.

Seniority can lead to overconfidence in one's capabilities and disregard for fundamental principles

TABLE 1. Details of various articles on medication errors in chronological order

Author, year, country	Study design	Age group	No. of patients/studies	Outcomes/objectives	Results	Conclusions
R.P. Mahajan, 2011, United Kingdom	Editorial article	Age not specified	–	Measures to reduce medication error.	Error-reducing strategies must take into account all the factors that can lead to error. They are not being truly implemented.	We need to address various barriers that prevent the implementation of measures to reduce medication errors.
Alan F. Merry, 2011, New Zealand	Review article	Paediatrics (age not specified)	95 articles	To identify new approaches to the prevention of medication error in paediatric anaesthesia.	The review highlights various preventive strategies to reduce medication error, modified from previously existing studies.	It is required that each institution accept these strategies and implement a standardised approach to enable every practitioner to engage in them.
J.F. Welte, 2017, France	Prospective observational study	Ten nurse anaesthetists in 6 hospitals specialising in paediatric surgery	248 samples analysed	To determine the degree of variation between the measured concentration of drugs prepared by trained nurses according to local dilution protocols from target concentration.	The measured concentration was > 10% of the target concentration in 70% of samples and > 30% of the target in 23%. The experience of nurses had no significant effect on error rates.	Dilution errors are quite common, independent of the staff's experience, thereby stressing prefilled syringes and two-person adequate/double-check during preparation.
Lauren Lobaugh, 2017, USA	Report of quality improvement initiative	Paediatric population (age not specified)	2087 adverse events	To describe and characterise reported medication errors to find patterns amenable to preventive strategies.	Of 2087 reported adverse events, 276 were medication errors, the most caused being the administration of the wrong dose. 97% of the errors were preventable.	This characterisation of medication errors will guide preventive strategies. Some of the common mistakes can be eliminated.
Jost Kauffmann, 2017, Germany	Narrative review	Paediatrics (age not specified)	42 studies	To review existing recommendations and current evidence on preventive strategies to enhance patient safety in paediatric anaesthesia.	They have graded the evidence of existing interventions on their effectiveness and feasibility.	Most highly effective strategies are very simple and require low cost and labour.
Lizabeth D. Martin, 2017, USA	Quality improvement project	Paediatric population	133 h of anaesthesia observation	To conduct failure mode and effect analysis to identify steps leading to medication error systematically. Implement targeted countermeasures and evaluate their efficacy in reducing errors.	The median medication error rate decreased from 1.56 to 0.95 per 1000 anaesthetics.	Standardisation of medication handling processes by anaesthetists in the operating room can decrease medication errors and improve patient safety.
Ronald S. Litman, 2017, USA	Review article	Age not specified	33 articles	To identify new solutions to reduce wrong route medication errors.	The universal use of the Leur connectors has resulted in several mishaps of drugs administered through the wrong routes.	Introducing differently designed connectors that are physically incompatible for different routes can help curb this problem.
C. Garitel, 2017, France	Prospective incident monitoring study	< 18 years undergoing general anaesthesia	1400 reports	To determine the incidence, predictive factors, and characteristics of medication error.	Out of 1400 reports, there were 37 reported medication errors. Opioids and antibiotics were the most frequently involved drugs. The incorrect dose, most commonly due to dilution error, was the most common cause.	

Author, year, country	Study design	Age group	No. of patients/ studies	Outcomes/objectives	Results	Conclusions
Max Feinstein, 2018, USA	Systematic review	Paediatrics (age not specified)	13 articles	To determine the frequency of medication error and its meta-analytic estimate in paediatric anaesthesia.	Meta-analytic estimate of medication error rate across all the studies was 0.08% or 1/1250 anaesthetics.	The result is significantly lower than expected. Further research should focus on better methodologies for estimating the incidence.
Izabela Leahy, 2018, USA	Retrospective analysis	Paediatric population	287,908 cases under anaesthesia	To characterise the frequency, type, and outcome of anaesthetic medication error. To describe targeted error reduction strategies and measure the effects of such interventions.	105 medication errors out of 287,908 cases were identified. Incorrect doses (55%) and incorrect medication (28%) were the most frequent errors. Logistic regression indicated a 13% reduction per year in medication errors.	There was a statistically significant reduction in medication errors after a formalised medication safety program.
Jost Kaufmann, 2018, Germany	Letter to the Editor	Paediatrics (age not specified)	21 references	They are underreporting medication errors in paediatric patients.	There is a vast gap between the actual medication error versus the reported incidence of error in paediatric patients.	Anaesthetists should accept their susceptibility to errors and bring about an attitude shift towards better incident reporting to improve patient safety.
Brian J. Anderson, 2018, New Zealand	Review article	Paediatrics (age not specified)	97 articles	Through a thorough review of the literature, I tried to assess the current state of medication errors.	Various countermeasures to reduce medication errors, based on the understanding of the cause of these errors, have been identified and are being implemented.	Implementation of these strategies should be an institution-wide commitment. Only then can we achieve sustainable and worthwhile improvement.
Z.A. Burton, 2018, United Kingdom	Letter to the Editor	Paediatrics (age not specified)	162 paediatric anaesthetist participants.	To identify the incidence, possible causes, potential solutions, and pitfalls of medication errors.	Due to the failure to identify drug errors and reluctance to self-reporting, there is a large gap between the true incidence and the reported medication error rate.	Considerable underreporting of actual incidence is present. There is a need for cultural change that allows honest dialogue and encourages learning from mistakes.
Megha Kanija, 2018, USA	Quality improvement project	Paediatrics (age not specified)	633 checklists analysed	Primary outcome assessed checklist compliance.	The percentage of compliance with the safe administration checklist of acetaminophen increased to 97%.	Checklist usage significantly reduced errors involving acetaminophen. Effective communication among all healthcare providers is essential.
Jennifer Bekes, 2021, USA	Narrative review	Paediatric population	17 articles	To characterise the frequency, type, and outcome of anaesthesia medication errors. Describe successful error reduction strategies described in the literature.	Incorrect doses (77%) and incorrect medication (35%) constitute the most common errors. Standardised labelling and pre-filled syringes are some of the most effective error-reduction strategies.	Need to devise better methods for collecting data on drug errors, and error reduction strategies should be standardised and implemented nationwide with their effects being carefully evaluated.

TABLE 1. Cont.

Author, year, country	Study design	Age group	No. of patients/studies	Outcomes/objectives	Results	Conclusions
Ravinder Bratch, 2021, United Kingdom	Integrative review	Not specified	30 studies	To determine the frequency of medication errors by evaluating various methods used to estimate these errors.	By retrospective recall, drug error was found to be 1 in 5 anaesthetics. In self-reports, there is admitted rate of 1 in 200. On observation, the error was present in almost every anaesthetic. Large databases indicate a 10% error in anaesthesia incidents reported. Wrong dose/wrong drug was the most common error across all the method types.	Studies concerning medication errors are very heterogeneous. Standardised reporting is recommended for the calculation of the frequency of error precisely.
Jost Kaufmann, 2022, Germany	Narrative review	Paediatric (age not specified)	20 articles	To highlight the most critical pragmatic measures and recommendations for medication safety in paediatric emergencies.	They developed formal expert consensus-based guidelines after a proper review of the existing guidelines from the literature	Properly implementing these consensus-based guidelines can prevent patient harm due to medication errors.
Joshua Biro, 2022, USA	Structured review	Not specified	1647 articles were collected	To extract and compare definitions of patient safety-related terminology in anaesthesia to examine the scope of this variability and inconsistencies.	Medication error category, which encompasses the greatest number of terms had widely variant definitions representing fundamentally different concepts.	Creating a standardised set of definitions for patient safety-related terminology in the context of anaesthesia would aid in our ability to learn from the literature and build a body of knowledge in this area.
Armin Pourhosseini, 2022, Iran	Prospective cross-sectional study	Not specified	12 different wards and 1350 doses of drug administration	The incidence rate and type of medication errors were the primary outcomes.	About one-third of the physician orders were defective, and about 69% of drugs were erroneously administered due to errors detected as wrong route, omission, wrong dose, wrong time, and unauthorised dose.	Clear instructions and protocols should be implemented for hospital technicians, nurses, and physicians to avoid irreparable detriments caused by medication errors.
Melanie M. Stipp, 2022, USA	Data analysis	—	237 anaesthesia clinicians	To evaluate perioperative medication-related incidents (medication errors (MEs) and adverse medication events (AMEs) identified by 2 different reporting methods (self-report and direct observation) and to compare the types and severity of incidents determined by each method.	The types of MEs identified by direct observation differed from those identified by self-report ( $P = 0.005$ ). Specifically, the most frequent kinds of MEs determined by direct observation were labelling errors ( $n = 37$ ; 24.2%), wrong dose errors ( $n = 35$ ; 22.9%), and errors of omission ( $n = 27$ ; 17.6%). The most frequent types of MEs identified by self-report were wrong dose ( $n = 5$ ; 50%) and wrong medication ( $n = 4$ ; 40%).	Future work should focus on strategies to increase the number of incidents captured by self-report, particularly errors of omission, monitoring errors, wrong timing, and inadvertent boluses.
Deemah Nassir Aldossary, 2022, Saudi Arabia	Cross-sectional survey	—	300 anaesthesia clinicians	Assessment of the occurrence of anaesthetic drug errors in Saudi Arabia and determination of contributing factors, reporting strategies, and clinicians' opinions of the preventive measures.	The 2 primary factors that caused drug errors were haste (60.3%) and heavy workload (60.3%). On reporting drug errors, 77.7% of respondents identified the fear of medicolegal issues as the most common barrier to reporting errors.	Policymakers need to unify the syringe labelling practice, and future research needs to focus on what makes a nonpunitive culture to encourage reporting errors.

to improve patient safety, thus leading to errors. Therefore, accepting equal susceptibility to errors amongst senior medical staff is imperative. This is a pre-requisite before any preventive measures can be incorporated [9].

Many methods have been adopted in different hospitals to study medication errors. In 1978 Cooper introduced critical incident reporting in anaesthesia to improve safety [5]. A similar study in 1993, the Australian Incident Monitoring Study (AIMS), was based on a critical incident reporting system, prospectively, which concluded the incidence of medication error to be 7.2%, none of which were fatal [5]. However, the incident reporting system underreports the exact number of cases because the practitioners tend to recall only those that resulted in adverse drug reactions. Moreover, what constitutes an error remains subjective. In 2017, a survey was conducted amongst the anaesthetists who attended the Association of Paediatric Anaesthetists of Great Britain and Ireland (APAGBI) annual meeting [10]. Its purpose was to identify the incidence of drug error, reporting behaviours and potential improvement strategies. There was a considerable difference in reporting mistakes among the anaesthetists, which underestimated the actual incidence because there was reluctance amongst the anaesthetists to self-report. Another concern was that practitioners fail to recognise that there has been an error unless it results in actual patient harm. Many incidents are usually underreported due to the fear of being blamed or due to legal aspects. To reduce the underreporting of critical incidents, there should be a 'no blame' ('no fault') drug error reporting and review system [12]. Other methods like overt or disguised observation [13] and prospective drug charts by pharmacists can be applied for better monitoring of drug errors [14]. An initiative was undertaken by the Society of Paediatric Anaesthesia (SPA) under the name 'Wake Up Safe'. They tried to describe and characterise the medication error. Most events occurred during administration, and an incorrect dose was the most common cause. Seniority and experience did not affect the error rate [12].

Bratch *et al.* [6] conducted an integrative review of the literature on the type of methods used to study drug errors during anaesthesia and tried to estimate the error rates. Thirty studies were included in this review, and 5 types were identified: retrospective recall, self-reporting, observational, large databases, and observing for drug calculation errors. Employing retrospective recall, 1 in 5 anaesthetists admitted having encountered a medication error over the course of their careers. In self-reports, the rate was 1 in 200 anaesthetic procedures. However, in observed practice, drug error was found in

almost every anaesthetic. In large databases, drug error constituted ~10% of anaesthesia incidents reported. The wrong drug and the wrong dose were the most common errors among the 5 methods. These studies were too heterogeneous to be compared, and the exact frequency of errors was uncertain. Thus, standardising the error reporting protocols in hospitals would help achieve more consistent databases for better research.

Strategies to reduce medication errors should focus on all the possible causes of error, ranging from patient-dependent to those arising from faulty organisational systems. Because the anaesthesiologist is responsible for all steps, from diagnosing the problem to drug administration, they should be actively involved in recognising all the risk factors and developing measures and protocols to mitigate them. The anaesthesiologist should participate in improving the managerial and operational glitches in the system to reduce drug errors.

Specific recommendations as given in published literature are as follows [3, 8, 15–17]:

**Information:** Establishing good communication between the teams to have all the information regarding the preoperative assessment to postoperative care and management. Availability of weight-based drug dosing for paediatrics, information on drug allergies, side effects, and drug interactions should be present [18]. Regular staff training in the causes and prevention of medication errors and building computer-based programs with built-in paediatric pharmacological databases for drug prescriptions can be done.

**Communication:** Encouraging double-checking electronic prescriptions and 2-person electronic prescriptions, and minimising the use of abbreviations should be practised.

**Standardised packaging and presentation:** Ensuring standardised storage of drugs in the Operating Theatre, with proper labelling and colour coding, using prefilled, labelled syringes, and standardising protocols for drug preparation.

**Environment:** Staff to remain more concentrated during drug preparation and administration, utilising 'sterile cockpits' where moments of silence are supported by the surgical team while the drug is being handled [18], shorter working hour shifts, staff awareness and education, computerised infusion pumps with alarms correctly set for dosages according to weight.

**Equipment:** Use of standard syringe pumps with pre-fed drug information and weight-based dosage range. Use differently designed connectors for different routes to prevent tubing misconnection and administration of the wrong drug through the wrong route [20].



**Calculation errors:** Encourage the use of readily available tabular or electronic weight-based references for drug dosing [19].

**Quality assurance and risk management:** Proper documentation of all the events and critical incidents of all errors or those nearly missed, whether the patient was harmed or not. Require a proper system to analyse them and conduct regular audit sessions to learn from past mistakes and monitor progress [12, 15, 21].

Including error case studies during trainee orientation [24].

Zero tolerance initiative, where the head of anaesthesiology meets with the practitioner who failed to comply with the above medication administration policy, to understand where the pitfall is. The goal is to create a transparent environment in which the practitioners are comfortable enough to report errors and take responsibility for their mistakes [15].

Martin *et al.* [24], at a freestanding Academic Children's Hospital, undertook a five-year quality improvement project based on FMEA (failure mode effect analysis), which was initially used in the aviation industry. Every step involved in a procedure is deconstructed and carefully evaluated for possible errors that could lead to the failure of the intended procedure. FMEA was performed in the operative room by a multidisciplinary team. A bundle of 5 targeted countermeasures were identified, including the medication tray to prevent vial swap, the medication cart top template designed to standardise the organisation of medication syringes, and syringe labelling with proper colour coding, infusion double check, and medication practice guidelines posted in every operating room. It was observed that the median medication error rate decreased from 1.56 to 0.95 per 1000 anaesthetics after the intervention.

Kanija *et al.* [22] initiated a quality improvement project based on FMEA at Cincinnati Children's Hospital and Medical Centre following an increase in the dosing errors of acetaminophen in the paediatric population. This project also highlighted the importance of proper communication between anaesthesia providers, PACU nurses, and parents/families.

Kaufmann *et al.* [23] reviewed existing recommendations and current evidence on preventive strategies to enhance patient safety in paediatric anaesthesia and summarised the recommendations for reducing the rate of medication errors. Apart from the already accepted strategies, they highlighted the importance of specialist standards with expertise in paediatric anaesthesia to improve the competency needed for regular lectures and courses addressing awareness of drug safety to enhance vigilance and safety culture [24].

Bekes *et al.* [1] compiled data from studies done on medication errors, their frequency, type, and outcome among paediatric patients over the past 10 years (2009 to 2019) and highlighted some of the successful error-reduction strategies described in the literature. They found that standardised labelling and prefilled syringes are the most effective of all strategies, giving a 65% and 53% reduction in error, respectively. Other effective strategies are double verification (41%), using drug library/electronic-based references (35%), and quality improvement safety analysis (35%). These error-reduction strategies must be standardised and implemented nationwide.

## CONCLUSIONS

Perioperative safety in paediatric anaesthesia has always been challenging, with drug errors being one of the major concerns. Preventive strategies like drug labelling, colour coding, accurate dose calculations, and 2-person checking should be implemented. Encouraging healthcare professionals to undertake self-reporting might help determine the exact cause of the errors and prevent such mistakes in the future, thereby improving patient safety.

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