

Incidence of medication errors and adverse drug events in the ICU: a systematic review

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ABSTRACT

Background Medication errors (MEs) and adverse drug events (ADEs) are both common and under-reported in the intensive care setting. The definitions of these terms vary substantially in the literature. Many methods have been used to estimate their incidence.

Methods A systematic review was done to assess methods used for tracking unintended drug events in intensive care units (ICUs). Studies published up to 22 June 2007 were identified by searching eight online databases, including Medline. In total, 613 studies were evaluated for inclusion by two reviewers.

Results The authors selected 29 papers to analyse; all studies took place in an ICU, were reproducible and reported ICU-specific rates of events. Rates of MEs varied from 8.1 to 2344 per 1000 patient-days, and ADEs from 5.1 to 87.5 per 1000 patient-days. The definitions of ADE and ME in the studies varied widely.

Conclusions Much variation exists in reported rates and definitions of ADEs and MEs in ICUs. Some of this variation may be due to a lack of standard definitions for ADEs and MEs, and methods for detecting them. Further standardisation is needed before these methods can be used to evaluate process improvements.

INTRODUCTION

The rate of medication errors (MEs) and adverse drug events (ADEs) for patients admitted to the intensive care unit (ICU) is greater than that for patients admitted to general medical wards¹ for several reasons. First, ICU patients receive more medications than patients on other hospital wards.^{1,2} Second, most medications in the ICU are given intravenously, and calculation of infusion rates is often required; both of these characteristics may create more opportunities for error.² Third, most patients in the ICU are sedated and are therefore unable to identify potential errors themselves.² Fourth, patients in the ICU have little physiological reserve, potentially increasing risks of harm from medication-related errors. It is thus important to have methods to accurately measure rates of MEs and ADEs in the ICU.

The Institute of Medicine (IOM) provides definitions for MEs and ADEs.³ MEs are any errors occurring in the medication-use process. Examples of this are wrong dosage prescribed or wrong dosage administered.³ An ADE refers to any injury due to a medication.³ Although ADEs are often caused by errors, this term does not necessarily mean that an error occurred; an example of this is a patient in whom an allergic reaction to a drug occurred who was not known to have any allergies.³ A preventable

ADE occurs when an ADE results from a preventable ME (ie, any error in the prescribing or transcribing of a medication order, or in the dispensing, administration or monitoring of a medication).⁴

Many different definitions and methods for tracking MEs or ADEs have been used in the ICU setting. The purpose of our study was to systematically review the published literature regarding MEs and ADEs that occur in the ICU, specifically highlighting the differences in event rates as a function of the terms used to define events and the techniques used for detection.

METHODS

Literature search

We searched for all relevant studies published before 22 June 2007, when the final search took place. Studies were identified using Medline (1950–present), Embase (1980–present), Biosis (1969–present), CINAHL (1982–present), IPA (1970–present), DARE (1996–present), CDSR (1995–present) and ACP Journal Club (1991–present) Databases.

For the Medline search, we used the following strategy: MeSH terms ‘intensive care units’ and ‘intensive care’ and multipurpose words ‘intensive care’ and ‘icu\$’ were used. To identify a wide range of methods for collection of MEs, MeSH terms ‘medication errors’ and ‘adverse drug reaction reporting systems’ were used. Also, multipurpose terms ‘((medication or drug or prescri\$) adj2 (error\$ or mistake\$)), (incident\$ or voluntary\$) adj2 report \$’ and ‘adverse drug event\$’ were used. The ultimate search strategy was the union of ICU terms and the ME terms. The search was restricted to articles published in English. Comparable searches were run in the other databases.

Inclusion/exclusion criteria

To be included, studies had to take place in an ICU, have original data, describe a method of measuring MEs or ADEs, include a rate of ME or ADE occurrence, and have sufficiently detailed methods so that the study could be replicated. Articles were excluded if they did not provide numerical ME or ADE rates, or if the rates provided were pooled with wards other than the ICU. We also excluded abstracts from conferences, letters, comments, opinion pieces and editorials.

All abstracts were reviewed by two investigators (AW and KL). Full manuscripts of any potentially eligible studies were obtained. Any disagreements in each round were resolved by discussion between the two reviewers and evaluation by the senior authors (PD and NA) as necessary.

Data abstraction

Study data were grouped by the methods used to detect MEs or ADEs. Voluntary reporting systems involved ICU staff using a paper or computer-based system to provide details of a potential or actual unintended medication events. Prescription review involved a pharmacist reviewing medication orders and documenting errors found. Observational techniques involved a trained observer following a prescription for some portion of the process from when it was written to its administration to examine the process for errors. Trigger tools involved a review of patient records, with either chart review or computer programs for evidence of indications of ADEs such as antidote use, or electrolyte abnormalities that could be due to medications. Multifaceted methods combined several of the aforementioned techniques.

Information was collected on the type of ICU studied, the country in which the study took place, the type of hospital (academic vs community), the number of centres involved, the definition of events measured, the methods used to detect events and the event rates detected.

In studies involving more than one ICU or where a pre-post design was used, weighted averages were calculated for each individual study when possible to provide a single rate of MEs or ADEs per 1000 patient-days. This was done by multiplying the rate for each separate group by the fraction of the total number of patient-days examined in that group. The rates were then added together to obtain an overall weighted average. Studies with the same units of measurement (eg, ADE/1000 patient-days) were grouped together for comparison.

RESULTS

The initial literature search yielded 613 abstracts. After review of these abstracts, 174 full articles were obtained. Forty-five articles were excluded because they did not have original data, 37 because they did not report relevant outcomes, 14 because the severity of the events was not reported, four because results combined ICU and non-ICU specific data, four because the methods did not provide enough information to replicate the study and 41 for two or more of the above reasons. In the end, 29 articles remained for analysis.^{1 5–32}

All of the studies came from first-world countries, and most (24/29) took place in an academic tertiary care hospital (table 1). Specifics of the durations of studies, countries of origin, types of ICUs and methods of study are summarised in table 1.

The studies were grouped by the outcome reported (eg, ADEs, preventable ADEs) as shown in tables 2–5. The predominant methods of event detection in the studies were prescription review (n=7) and multifaceted techniques (n=7), followed by observational techniques (n=6), voluntary reporting (n=5), trigger tools (n=3) and comparison of two of the previously mentioned methods (n=1). The majority of these studies had different definitions of the events being measured. There was substantial variability in event rates, regardless of the specific outcome; in general, there was a one to two order of magnitude difference in rates across studies even when the same type of event was reported. For instance, the range of ADE/1000 patient-days ranged from 2.4 to 87.5 (table 2).^{1 5–12} Not unexpectedly, MEs were more common than ADEs, and more events were identified when multifaceted methods of detection were used.

DISCUSSION

We found a wide variation in reported rates of medication-related events. We believe that much of this large variability was

Table 1 Characteristics of studies included

Type of hospital	
Academic/tertiary referral centre=24	
Community=1	
Mixed=1	
Unspecified=3	
Country of origin	
USA=17	
UK=4	
Australia=1	
Canada=2	
Other=5	
Type of ICU studied	
Medical ICU=2	
Surgical ICU=1	
Paediatric ICU=4	
Neonatal ICU=1	
Mixed ICU=6	
Other=2	
>1 of above=11	
Unspecified=2	
No of centres in each study	
1=22	
2=3	
≥3=4	
Length of study	
≤1 month=9	
>1–12 months=14	
>1 year=6	
Method of error detection	
Observation=6	
Prescription review=7	
Multifaceted=7	
Voluntary reporting=5	
Trigger tool=3	
Two methods compared=1	
No of ICU beds studied	
1–10=2	
11–20=10	
21–30=3	
>30=7	
Unspecified=7	

ICU, intensive care unit.

due to differences in: (1) definitions of the same type of event and (2) methods used to detect events.

MEs compared with ADEs

MEs include any error from prescribing through to administration and monitoring of a drug but which do not necessarily cause harm. Conversely, ADEs indicate that patient harm has occurred. Because most MEs do not result in harm, it is logical that MEs are more frequent than ADEs. To illustrate this, Rothschild *et al* found the rate of MEs to be 129.5/1000 patient-days, while the rate of ADEs was only 37.6/1000 patient-days.¹²

Although MEs do not lead to harm in many cases, they provide the unique opportunity to identify the need for system changes, which have the potential to prevent harm to patients. Measuring ADE rates is also useful, since this identifies actual situations in which patients are harmed and also allows for change for safer policies.

Variability in definitions of events

Another reason for variability among the studies was the diversity of definitions used for the same type of event. For example, 14 studies included in this paper reported MEs per 1000 patient-days as an outcome (table 3).^{1 7 8 12 16–25} Two of these studies provided no definitions for this term, while the 12 other studies each used a different definition. Some studies focused on only one aspect of the medication process (eg, prescribing or administration), while others focused on all aspects. Nevertheless, even in the 10 studies that looked at all aspects of the process, there was still substantial variation in the definitions of MEs among these studies (table 3).^{1 8 12 16–22} Some authors defined MEs similar to how we have done (errors in drug prescribing, transcription, dispensing, administration and monitoring),^{8 12 21} while other authors provided more vague definitions such as 'potential or

Table 2 Description of studies that presented rates of adverse drug events (ADE) per 1000 patient-days, potential adverse drug events (PADEs) per 1000 patient-days and ADEs per 100 medication orders written

Reference	Type of ICUs	Method of study	Description of method	Definition of ADE	ADEs/1000 patient-days
5	MICU, SICU	Trigger tool	ADEs were identified by extraction from the ADE programme database, retrospective screening of ICD codes and reviewing antidote use and potentially drug-related electrolyte disturbances	Injury resulting from drug treatment	2.4
6	Not specified	Trigger tool	Charts were chosen randomly, and IHI trigger tool was applied using predesigned data collection forms. Charts were reviewed for 20 min, and if a trigger was detected only the portion of the chart relevant to it was reviewed. Severity of the adverse events was classified.	Medication related adverse event	20
7	SICU	Prescription review	The ICU pharmacist analysed every medication order of randomly selected patients during study period.	Medication prescribing errors that cause harm to patient	87.5
1	2 MICU, 3 SICU	Multifaceted	Nurses and pharmacists were asked to report incidents using logs. A trained nurse visited each unit at least twice daily on weekdays and solicited information from staff concerning all actual or potential drug related incidents. A study nurse briefly reviewed all charts at least daily on weekdays.	A preventable injury resulting from medical intervention related to a drug	5.1
8	2 CSICU, 2 CS stepdown unit	Multifaceted	Pump-related transaction data were obtained from smart pump log downloads. Log reports included pump alerts. In addition, error reports were collected by chart review, solicited staff reports, hospital incident reports and a computerised ADE surveillance monitor.	Injury due to a medication	6.1
9	2 MICU, 3 SICU	Multifaceted	Nurses and pharmacists were asked to report incidents using logs. A trained nurse visited each unit at least twice daily on weekdays and solicited information from staff concerning all actual or potential drug related incidents. A study nurse briefly reviewed all charts at least daily on weekdays.	Injury resulting from medical intervention related to a drug	14.4
10	MICU, CCU	Multifaceted	Two investigators identified incidents by review of medical records in which they examined all progress notes, orders and lab results. Pharmacist interventions were also tracked on a form.	Injury related to use of a medication	29.8
11	CCU	Multifaceted	Nurses and pharmacists were asked to report incidents using logs. A trained nurse visited each unit at least twice daily on weekdays and solicited information from staff concerning all actual or potential drug related incidents. A study nurse briefly reviewed all charts at least daily on weekdays.	An injury resulting from the administration of a drug	33
12	MICU, CCU	Multifaceted	Primary method of data collection was direct continuous observation. Voluntary and solicited reports were also used to identify incidents. Computerised ADE detection was also used to monitor events. Also, guided chart abstraction by trained research nurses was performed.	Any injury due to medical management, rather than the underlying disease	37.6
1	2 MICU, 3 SICU	Multifaceted	Nurses and pharmacists were asked to report incidents using logs, a trained nurse visited each unit at least twice daily on weekdays and solicited information from staff concerning all actual or potential drug related incidents, and a study nurse briefly reviewed all charts at least daily on weekdays.	PADE definition Incident with a potential for injury related to a drug	PADEs/1000 patient-days 13.5
8	2 CSICU, 2 cardiac surgery stepdown unit	Multifaceted	Pump-related transaction data were obtained from smart pump log downloads. Log reports included pump alerts. In addition, error reports were collected by chart review, solicited staff reports, hospital incident reports and a computerised ADE surveillance monitor	ME that had the potential to cause harm but did not because it either was intercepted before reaching the patient or reached the patient and because of luck did not cause harm	23.8

Continued

Table 2 Continued

Reference	Type of ICUs	Method of study	Description of method	Definition of ADE	ADEs/1000 patient-days
13	Surgical/trauma ICU	Trigger tool	All patients admitted during a 3-month period were monitored for abnormalities in their potassium, magnesium, liver enzymes, blood glucose, serum creatinine and platelet count. Once identified, they were categorised as possibly, probably or definitely caused by a drug used in the patient. They were also classified in terms of severity on a scale from no change in outcome to death.	Drug-related hazardous condition: a biochemical response to a drug that has the potential to cause clinical injury	47 DRHCs/1000 patient-days
14	Mixed PICU	Observation of entire medication process	One nurse was picked randomly at the start of each shift and followed to observe prescriptions from writing to administration	Not provided	ADEs/100 orders 3.6
15	Mixed ICU	Observation of entire medication process	Two pharmacy residents recorded activities related to medication use process using standardised data collection sheets. The observers followed the entire medication process from prescription writing to administration.	An injury or patient harm occurring as the result of a medication intervention; can be preventable or non-preventable	4.3

CCU, critical care unit; CSICU, cardiac surgery intensive-care unit; ICU, intensive care unit; ME, medication error; MICU, medical intensive care unit; PICU, paediatric intensive care unit; SICU, surgical intensive care unit.

preventable ADEs' or 'all events where treatment or observation differed from a planned one'.^{1 18}

ADE was used as an outcome in 11 studies (table 2).^{1 5–12 14 15} Although one study did not provide a definition for this term,¹⁴ nearly all the others had a common theme—patient injury. Nine of these definitions defined ADE as injury or harm caused by a medication, while one gave a vague definition of 'medication-related adverse event'.⁶ Overall the concept of ADE among studies was more consistent than that for MEs. Nevertheless, it would still be useful to have a standard definition for an ADE, as this would likely reduce the substantial variability in rates among studies.

The reason for this diversity of definitions is likely related to that fact that no standard definition is accepted by all the major organisations related to medication safety. For example, the IOM definition of ME is different from that of the National Coordinating Council for Medication Error Reporting and Prevention, while the Agency for Healthcare Research and Quality does not provide a definition for this term. Standardisation of definitions between these important groups would likely set a precedent for researchers in this area. The IOM definitions were used most commonly in papers included in this study, perhaps suggesting they may be accepted more readily by the research community.

Variability in methods of detecting events

In general, multifaceted methods for measuring events were associated with higher rates of event detection. However, when studies using multifaceted methods were compared, substantial differences in ME rates were found, varying from 18.6 to 146.1 per 1000 patient-days.^{1 8 12 16} The studies which reported 18.6 and 22.1 MEs per 1000 patient-days did not include observation, whereas the studies that reported 129.5 and 146.1 MEs per 1000 patient-days included observation methods.^{1 8 12 16} The study by Rothschild *et al* reported 129.5 MEs/1000 patient-days, but only 37.6 ADEs/1000 patient-days, suggesting that the addition of observation may increase the sensitivity of detecting errors, but is not associated with an increased detection of harm.¹²

For ADEs, rates in these studies ranged from 5.1 to 37.6 ADEs per 1000 patient-days.^{1 8–12} Three of these studies used similar

methods, involving voluntary and solicited incident reporting and daily chart review during weekdays.^{1 9 11} Despite this commonality, rates were 5.1, 14.4 and 33 ADEs per 1000 patient-days.^{1 9 11} The study which reported 5.1 ADEs/1000 patient-days included only preventable events, whereas the other two studies included all events that caused patient harm.¹ The reason for variation between the latter two studies may be partly because the studies were done in different types of ICUs.^{9 11} The fourth study by Rothschild *et al* that reported 37.6 ADEs/1000 patient-days incorporated direct continuous observation into their methods, in addition to voluntary and solicited incident reporting and daily chart review during weekdays.¹² This difference in methods used to detect adverse events likely accounts for the higher detection rate of the latter study.

Substantial variation in event rates was also seen with voluntary reporting methods. Reasons for this variation include the anonymity of reporting, the hospital safety culture, the staff education on incident reporting and the presence of a non-punitive policy related to reporting. In six studies using voluntary reporting, which measured MEs/1000 patient-days, all reported having non-punitive incident reporting systems, and four out of these six papers described educational programmes for staff and strategies to encourage staff to report incidents.^{17–22} The error rates in these studies still ranged from 8.8 to 241 MEs/1000 patient-days.^{17–22} Paradoxically, the study that reported 241 MEs/1000 patient-days did not describe any intervention to encourage reporting, while the study that reported 8.8 MEs/1000 patient-days described a strategy to encourage staff to report even trivial incidents.^{17 22} This paradox was likely related to the difference in terms used to define events. In the study reporting 8.8 MEs/1000 patient-days, the definition of ME was specific (ie, a dose of medication that deviates from the physician's orders which reaches the patient).¹⁷ Conversely, in the study reporting 241 MEs/1000 patient-days, ME was defined much more broadly as a 'mistake made at any stage of the provision of a pharmaceutical product to a patient'.²² Observation techniques involve study personnel watching nurses prepare and administer medications and recording any discrepancies from what is ordered in the patient's chart. The rates of observed errors in medication preparation and

Table 3 Description of studies that presented rates of medication errors (MEs) per 1000 patient-days

Reference	Type of ICU	Method of study	Definition of ME	MEs/1000 patient-days
1	2 MICU, 3 SICU	Multifaceted	Nurses and pharmacists were asked to report incidents using logs, a trained nurse visited each unit at least twice daily on weekdays and solicited information from staff concerning all actual or potential drug-related incidents, and a study nurse briefly reviewed all charts at least daily on weekdays	18.6
8	2 CSICU, 2 CS stepdown unit	Multifaceted	Pump-related transaction data were obtained from smart pump log downloads. Log reports included pump alerts. In addition, error reports were collected by chart review, solicited staff reports, hospital incident reports and a computerised ADE surveillance monitor.	22.1
12	MICU, CCU	Multifaceted	Primary method of data collection was direct continuous observation. Voluntary and solicited reports were also used to identify incidents. Computerised ADE detection was also used to monitor events. Also, guided chart abstraction by trained research nurses was performed.	129.5
16	MICU, CCU	Multifaceted	A team of two nurse chart reviewers and six physician observers collected data on errors made by interns, which was supplemented by voluntary reports and a computerised event-detection monitor	146.1
17	NICU, PICU	Voluntary reporting	Written incident reports were submitted by persons who noticed the errors. All incident reports are reviewed anonymously by a pharmacy manager and possible corrective measures are discussed in monthly quality assurance meetings. The non-punitive nature of the review is emphasised, and ICU personnel are encouraged to send reports even when errors seem trivial. Patient injuries are classified on a 1–4 severity scale.	8.8
18	Mixed ICU	Voluntary reporting	An incident registration form was developed without any patient ID except for sex and age. The person reporting was allowed to remain anonymous but the professional status was requested. The seriousness of the errors was evaluated by four ICU staff members. Prior to starting the reporting process, staff were informed of incident reporting during meetings and with the internal newsletter. They were asked to report errors no matter how small.	11.4
19	NICU	Voluntary reporting	Errors were identified using critical incident forms. The forms were analysed monthly by a multidisciplinary risk management group and graded according to severity. Non-punitive system.	14.7
20	MICU	Voluntary reporting	A locally developed, card-based reporting programme available to hospital physicians and staff. The SAFE card solicited core info about patient safety events and could be anonymous if desired. The intervention involved encouraging the non-punitive nature of the programme and open communication about safety.	64

Continued

Table 3 Continued

Reference	Type of ICU	Method of study	Definition of ME	MEs/1000 patient-days
21	2 multidisciplinary ICUs	Voluntary reporting	The research team attempted to familiarise the staff with the concept of incident reporting, and to describe the non-punitive nature of the study. The incident reporting form requested the location, reporter's profession, type of unintended event, severity of unintended event and the time of day it was detected.	90.9
22	Paediatric cardiac ICU	Voluntary reporting	ME report forms were filled out and analysed. Info collected: profession of reporter, location of event, type of error (supply, administration, prescription), details of event, including clinical consequences. Anonymous. Non-punitive.	241
23	ICU, PICU, NICU	Prescription review	Pharmacists reviewed prescriptions for therapy and prescription errors, and filled out a standardised form when they were found, which categorised their actions in response to the error, and the clinical significance of the error	8.2 (1.6=clinically significant errors)
24	Multidisciplinary ICU	Prescription review	A pharmacist reviewed the nursing MAR for the previous 24 h period and compared it with the physician's orders in the patients chart and recorded all doses on a patient data collection sheet. The patient's TISS score was available for the exact date/time of error, as were ICU deaths.	497.5 (no mistakes resulted in significant patient harm)
7	SICU	Prescription review	ICU pharmacist analysed every medication order of randomly selected patients during study period. An independent panel evaluated the severity of the events.	2344 (all) 519 (serious)
25	MICU	Observation of medication administration	Pharmacy residents observed nurses' administration of medications. The nurses knew the purpose of the study. The length of observation was 5 h/day, during the heaviest period of medication preparation/administration. All observations were noted, then later compared with original physicians' orders, manufacturers' data and data available in the literature. Potential clinical significance was evaluated by an ICU physician.	1500
21	2 multidisciplinary ICUs	Observation of entire medication process	Two medical residents acted as observers. They filled out standard form during morning shifts for 14 days. The form requested the location, reporter's profession, type of unintended event, severity of unintended event and the time of day it was detected. The staff were unaware of the observation.	78

ADE, adverse drug event; ICU, intensive care unit; MAR, Medication Administration Record; SAFE, Safety, Actions, Focus Everyone; TISS, Therapeutic Intervention Scoring System.

administration varied substantially (2.8, 7%, 8.8% and 33.9% of the total number of nurses' activities) after wrong time errors were excluded.^{25–28} Although the techniques described in these four studies were similar, the definition of medication prepara-

tion and administration errors differed. For instance, the study by Calabrese *et al* gave a vague definition ('any preventable event that may cause or lead to inappropriate medication use or patient harm'),²⁶ while the study by Tissot *et al* gave a specific

Table 4 Description of studies that presented errors as a percentage of observed medication preparations and numbers of drug administrations with errors

Reference	Type of ICU	Method of study	Description of methods	Preparation and administration error definition	Percentage of observations with errors (wrong time errors excluded)
26	SICU, MICU, mixed ICUs	Observation of medication preparation and administration	Pharmacists at all by one involved institutions did the observation. All observers used the same definitions and collected data on a standardised form. Intravenous and oral medications were included and only regularly scheduled medications were monitored. Data collection occurred twice daily, once in the morning and once in the afternoon on every patient in the ICU. Errors were sorted based on type and patient outcome. Nurses were not aware of the observation.	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	2.8 (1% of errors resulted in temporary harm)
25	MICU	Observation of medication preparation and administration	Pharmacy residents observed nurses' administration of medications. The nurses knew the purpose of the study. The length of observation was 5 h/day, during the heaviest period of medication preparation/administration. All observations were noted, then later compared with original physicians' orders, manufacturers' data and data available in the literature. Potential clinical significance was evaluated by an ICU physician.	Wrong drug preparation, dose error, wrong administration technique, physicochemical compatibility error	7 (no patient harm is mentioned in study)
27	NICU, PICU	Observation of medication preparation and administration	Pharmacy resident performed 18–12 h shifts, half day and half night. The nursing staff did not know the purpose of the observation. The observer recorded each medication dose, dosage form, frequency and route of administration, and other pertinent information on the monitoring form. Intravenous fluids and prn medications were not included in the study, but intravenous infusions were. The medications were recorded as prepared and administered correctly or incorrectly. When the drugs involved were capable of causing potential serious effects, the errors were classified as 'serious.'	Unauthorised dose, omitted dose, wrong dose, wrong route of admin, wrong rate of administration, wrong preparation of a dose, wrong dosage form, wrong time of administration ($> \pm 30$ min from scheduled time)	8.8 (no patient harm mentioned in study)
28	Not specified	Observation of medication preparation and administration	Administration errors were detected by using the disguised observation technique; nurses were unaware of the purpose of the study. A pharmacist followed nurses preparing and administering drugs in both hospitals on five consecutive days from 07:00 to 22:00. All observations were noted on data-collection forms and were compared with actual medication orders afterwards. Observations were also compared with general nursing protocols. Errors were categorised by type and severity.	Any error in the preparation and administration of drugs by nurses, that is, a deviation from written, printed or verbal medication orders; a deviation from drug information sheets provided by the manufacturer or from the information in a handbook on injectable drugs; or deviation from general nursing procedures used in the hospital.	33.9 (no patient harm mentioned in study)

ICU, intensive care unit; Prn medication, medications as needed.

definition including 'wrong drug preparation, dose error, wrong administration technique and physicochemical compatibility error' (table 4).²⁵ This wide variety of definitions could account in part for the diversity of error rates.

Studies that used prescription review showed that 2.2–11.2% of orders were associated with a ME (table 5).^{24 29–31} All methods involved pharmacists reviewing prescriptions and recording errors identified. Studies that reported lower error rates (2.2, 5.4, 5.9%) provided specific definitions of MEs, whereas the study by Ridley *et al*, reporting 11.2%, used a more vague definition of 'prescriptions which did not follow standards given by the British National Formulary'.^{24 29–31} When ME rates were reviewed, they were 8.2, 497.5 and 2344 per 1000 patient-days

for the three prescription review studies that reported these data.^{7 23 24} The methods used in two out of three studies were similar.^{7 23} The other study involved a pharmacist reviewing the medication administration record for the past 24 h and comparing it with doctors' orders.²⁴ This difference, as well as the inconsistency in the definition of ME (table 3), may have contributed to the observed variation in rates.

Recommendations for methods of tracking MEs and ADEs

The IOM currently recommends different means of monitoring ADEs or MEs depending on what the institution hopes to achieve from the measurements.³ The recommendations are not specific for ICUs. If the institution wishes to track errors resulting in

Table 5 Description of studies that presented percent of orders written with a medication error (ME) or adverse drug event (ADE)

Reference	Type of ICU	Method of study	Description of methods	ME definition	Percentage of orders with an ME
24	Multidisciplinary ICU	Prescription review	A pharmacist reviewed the nursing MAR for the previous 24 h period and compared it with the physician's orders in the patients chart and recorded all doses on a patient data collection sheet. The patient's TISS score was available for the exact date/time of error, as were ICU deaths.	Drug administered to wrong patient, wrong dose, wrong medication, wrong route of administration, wrong time, patient has allergy to prescribed medication, omission of a medication, error in infusion rate, improper administration, administration of the wrong dosage form	2.2 (none of these resulted in significant patient harm)
29	General ICU	Prescription review	Details of all MEs identified by the ICU clinical pharmacist, in the course of his normal prescription review, were prospectively recorded. MEs were assessed by type and patient outcomes.	Prescribing decision or prescription writing process resulted in either an unintentional significant reduction in the probability of treatment being timely and effective or an unintentional significant increase in the risk of harm when compared with generally accepted practice	5.4 (no patient harm mentioned)
30	PICU	Prescription review	ICU ward pharmacist recorded the prescriptions determined to be in error, noting type of error, drug and the person who prescribed the drug. An ICU doctor then classified the type and severity errors.	Dose error, intravenous compatibility error, drug interaction, administration error	5.9 (0.5=significant error)
31	Not specified	Prescription review	All drug prescriptions were reviewed daily during the study period and errors identified by comparison with standards given in the British National Formulary. Errors were categorised by nature and clinical outcome.	Prescriptions which did not follow standards given by the British National Formulary were considered in error	11.2 (no patient harm mentioned)
32	9 PICUS	Prescription review	MEs were detected using three levels of surveillance. Pharmacists reviewed orders before entering them into computer system and the PICU nurse reviewed orders before transcription. An oversight team acted at each hospital to try and standardise the process across the hospitals involved	ADE definition Not provided	Percentage of orders written resulting in ADE 0.09

ADE, adverse drug event; ICU, intensive care unit; ME, medication error.

ADEs, chart review, voluntary and prompted self-report systems, and computer-generated ADE tracking are key recommendations.³ However, if the institution wishes to detect as many errors as possible in order to identify system problems to be fixed, observation, in addition to chart review and voluntary and prompted self-report, is recommended.³ Although advantages and disadvantages of each method are discussed, no gold standard is presented as the best method for tracking MEs or ADEs.

Our study confirmed that observation methods are very sensitive for detecting MEs and would be useful for the reasons noted above. We found that multifaceted techniques seemed to provide the most consistent tracking of ADEs, perhaps due to their rigorous nature of study. If the institution has the resources available to implement this type of approach, it seems quite useful in identifying errors associated with patient harm.

Utility of this study

The variability in error rates that we have observed in this review likely far outweighs the actual variation in MEs among ICUs. A recent review by Moyon *et al* confirms the frequency and severity of errors in the ICU, and confirms the importance of identifying system failures leading to MEs, so that these systems can be redesigned for improvement of patient outcomes.³³ For this to occur reliably, standard definitions of MEs and ADEs must be adopted, and the methods for measuring rates of errors and adverse events should become standardised. These changes are also important in benchmarking these rates

among different ICUs. There is a trend towards pay for performance healthcare currently; benchmarking may facilitate financial benefits for certain institutions if they have low event rates. All these reasons support the urgency to develop means for standardised reporting of MEs and ADEs.

CONCLUSION

There is wide variation in the definitions and rates of MEs and ADEs in ICUs, and in the methods used to detect them. Review of the literature showed that the ADE had a more reproducible definition than ME, as ADE denotes patient harm, while the interpretation of an ME can vary widely. Further standardisation of outcome definitions and methods of detecting errors must be done before the best methods for tracking ICU MEs and ADEs can be established.

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