LEADING ARTICLE

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Clarification of Terminology in Medication Errors

Definitions and Classification

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Abstract

We have previously described and analysed some terms that are used in drug safety and have proposed definitions. Here we discuss and define terms that are used in the field of medication errors, particularly terms that are sometimes misunderstood or misused. We also discuss the classification of medication errors. A medication error is a failure in the treatment process that leads to, or has the potential to lead to, harm to the patient. Errors can be classified according to whether they are mistakes, slips, or lapses. Mistakes are errors in the planning of an action. They can be knowledge based or rule based. Slips and lapses are errors in carrying out an action – a slip through an erroneous performance and a lapse through an erroneous memory. Classification of medication errors is important because the probabilities of errors of different classes are different, as are the potential remedies.

1. Background

"*C'est pire qu'un crime; c'est une faute (it is worse than a crime; it is an error).*"

— Marquis de Talleyrand

The assumption that drug therapy is a safe and straightforward process is at odds with the everyday experience of prescribers and patients. It is a truism that no effective remedy is without potential adverse effects, even when it is used as intended and in an optimum way. We have previously described and analysed some terms that are used in drug safety and have proposed definitions.[1] One potential source of compromised safety in drug therapy that we did not cover is error in prescribing or drug administration. Therefore, in this article we consider the terms that are used to describe errors in the use of medicines that are or could be harmful.

Classifications of error can be contextual, modal, or psychological.[2] Contextual classification deals with the specific time, place, medicines and persons involved. Modal classification examines the ways in which errors occur (e.g. by omission, repetition, or substitution). We have concentrated on psychological classification, as it explains the events rather than merely describing them.

As before, we have taken the novel approach of commenting on competing definitions, discussing problems and identifying logically the reasons for the definitions we have proposed, using published examples from clinical practice. The relation between adverse events, adverse drug reactions and medication errors is shown in figure 1.

Some have argued that primary consensus is necessary to achieve good definition. We disagree. Many of the definitions that have been proposed in

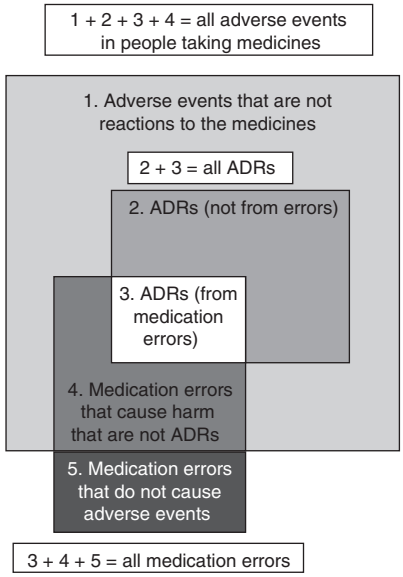

Fig. 1. A Venn diagram showing the relationship between adverse events, adverse drug reactions (ADRs) and medication errors.[1] The sizes of the boxes do not reflect the relative frequencies of the events illustrated.

this field have been fabricated by committees, and many of them are unsatisfactory. When they have been published they have been handed down as *ex cathedra* statements, without any indication of the thought processes that have gone into producing them. In addition, as others have pointed out, because disagreement within such committees is rife, consensus in healthcare is reached only on "bland generalities that represent the lowest common denominator of debate and are embalmed as truths."[2]

Nevertheless, we invite comments about our proposed definitions, and we hope that ensuing discussions will result in the acceptance of definitions that have been through a rigorous process of formulation.

2. Definition of a Medication Error

2.1 Previous Definitions

A medication error has been defined as "a dose administered to the patient that deviates from the physician's orders, such as an omission, wrong dosage, or unauthorized drug. An example would be when one patient was given one of the doses intended for another."[3] A more succinct version is: "A medication error [is] defined in general as a dose administered differently than as ordered on the patient's medication record."[4] We assume that the authors who proposed this definition meant that an error was an act of administering a deviant dose, rather than the dose itself. However, this restrictive definition examines only the part of the process that is subsequent to the writing of the prescription. It also classifies as 'errors' what are in fact corrections to errors perpetrated by the prescriber, who in any case might not be a physician. For example, if a nurse deliberately (and correctly) administered digoxin 250μg rather than the digoxin 250mg that a physician had prescribed, that would be an 'error' as defined.

Other authors, perhaps aware of this problem, have sought to enlarge on the possible range of deviation: "We [define] an intravenous drug error as a deviation in preparation or administration of a drug from a doctor's prescription, the hospital's intravenous policy [sic], or the manufacturer's instructions."[5] Yet there may be times when deviation from the hospital's policy or the manufacturer's instructions does not constitute an error, and others in which an error is committed even when all three are in accord.

In 1993 the American Society of Hospital Pharmacists (now the American Society of Health-System Pharmacists [ASHP]) published a definition of medication errors as "episodes in drug misadventuring that should be preventable through effective systems controls involving pharmacists, physicians and other prescribers, nurses, risk management personnel, legal counsel, administrators, patients, and others in the organisational setting, as well as regulatory agencies and the pharmaceutical industry."[6] Although this definition clearly implicates the system in errors, rather than imputing error to the actions of individuals, the term "misadventuring" is opaque, being an unusual coinage the meaning of which is not clear. Insofar as it is a gerund intended to mean "misadventure" it is ambiguous. Furthermore, "misadventure" is defined in the *Oxford En-*

glish Dictionary as either "bad luck or misfortune" or "an ill-conceived, misguided, or regrettable enterprise." Thus, under the second of these definitions, "episodes in misadventuring" could refer, for example, to the misuse of recreational drugs, which is clearly not the intention of the definition. Furthermore, a later publication makes it clear that "medication misadventure" includes unexpected harm as a result of immunological and so-called idiosyncratic responses.[7]

Kaushal et al.,[8] in a study of paediatric medication errors, defined them as "errors in drug ordering, transcribing, dispensing, administering, or monitoring." They also distinguished between errors (which are preventable), rule violations (also preventable) and other adverse events that are not preventable. This definition sets out the scope of the processes to be considered in investigating medication errors, but does not state explicitly what constitutes an error.

The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) has provided an even more inclusive definition: "A 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 labelling, packaging and nomenclature; compounding; dispensing; distribution; administration; education; monitoring; and use."[9] This definition has now been adopted by the ASHP.

The problem with this definition is that it states that any preventable event that leads to harm from a medicament must be an error. However, that is not so. Events are preventable both when they result from error (e.g. when maternal acne is treated with aromatic retinoids and fetal malformation results) and when they are a consequence of the careful and rational decision to use a drug that causes unavoidable harm (e.g. when a cytotoxic drug causes bone marrow suppression). "Any preventable event" could include the latter, since avoiding use of the drug would prevent the harm.

Dean et al.,[10] seeking a pragmatic definition of prescribing errors, asked 34 'judges' to undertake a Delphi exercise to decide whether specific acts constituted prescribing errors, and from their iterative responses devised the following definition: "A clinically meaningful prescribing error occurs when, as a result of a prescribing decision or prescription writing process, there is an unintentional significant (1) reduction in the probability of treatment being timely and effective or (2) increase in the risk of harm when compared with generally accepted practice."

This definition implies that only "clinically meaningful" outcomes are of interest in the field of medication errors. However, it is desirable that all errors be detected, if possible, and examined, even when they are not of clinical importance, because the occurrence of an error indicates a weakness in the system, which might on a future occasion lead to an error of clinical relevance. Furthermore, it is conceivable that an error that does not harm the individual patient could harm others. For example, the administration of too high a dose of an antibiotic may cause no harm to the individual but may encourage the emergence of resistant organisms. Finally, we prefer the idea of an attainable standard rather than "generally accepted practice," because generally accepted practice may be poor.

2.2 A Proposed Definition

We have therefore proposed the following definition of a medication error:[11] "A medication error is a failure in the treatment process that leads to, or has the potential to lead to, harm to the patient."

2.3 Notes on the Definition

We use the word 'failure' to signify that the process has fallen below some attainable standard.

The 'treatment process' starts after the decision to adopt treatment for symptoms or their causes, or to investigate or prevent disease or physiological changes (and so includes not only therapeutic drugs but also, for instance, oral contraceptives, hormones used in replacement therapy, and radiographic contrast media). It includes the prescribing, transcribing (when relevant), manufacturing or compounding,

dispensing and administration of a drug. It also includes the monitoring of therapy, because faulty monitoring can lead to a failure to alter therapy when required, or to an erroneous alteration. However, it is not directly concerned with success or failure in reaching the therapeutic goal. Our definition does not specify who makes the error; it could be a doctor, a nurse, a pharmacist, a carer, the patient, or another. Nor does it specify who is responsible for preventing errors.

Our definition has been amended and adopted by the Australian Council for Safety and Quality in Health Care as "failure in the (drug) treatment process that leads to or has the potential to lead to, harm to the patient and includes an act of omission or commission."[12,13] Yu et al.[14] examined this and other definitions that were found by searching the Internet rather than the medical literature. They established 'functional meaning' by presenting four scenarios and determining which would constitute an error under each of the definitions. Our definition, as amended by the Australian Council for Safety and Quality in Health Care, was the only definition that categorised all error scenarios, and only error scenarios, as such.

We merely comment that the addition of the phrase "and includes an act of omission or commission" does little to clarify our original definition, because errors require one or the other.

3. Classifying Medication Errors

3.1 Previous Classifications

Classifying errors allows observers to identify broad categories of error, to quantify them, and, if the classification is related to some underlying model of the way in which errors occur, to predict and prevent them.[15] Several attempts have been made to classify medication errors.

A model of drug therapy, such as the one outlined by Barker et al.,[16] consists of a linear sequence: diagnosis → prescription written → prescription received and processed (by a pharmacist) → drug dispensed → drug administered → patient receives drug → 'patient gets well'.

The outcome at each stage is 'error' or 'no error'. This scheme makes several basic facts plain.

- There are many steps in the process.
- The sequence often involves several different people, each with different types of expertise and training.
- At each step there is scope for several errors.
- Errors at any step can potentially be injurious.
- Although, in some cases, an error made at one step could be found and corrected during a later step, others can escape detection until harm is done.

The scheme also suggests some ways in which the number of errors could be reduced, the propagation of errors from one step to the next could be held in check, and harm could be prevented. An obvious example is the problem that the doctor's handwriting is so bad that it is misread by the dispensing pharmacist or nurse. The use of computer-generated, typed prescriptions makes illegibility less likely, and reduces the chances of an error in dispensing as a result of misreading.

Parenthetically, some errors can be propagated through the system (e.g. writing the wrong dosage), whereas others are bound to be discovered before administration (e.g. omission of the drug name). When an error occurs late in the process (e.g. confusing syringes that contain different drugs just before injection), there are few or no subsequent checks, and this makes recovery from the error difficult or impossible.

Others have considered three major groups of errors, namely those made in prescribing, dispensing and administering drugs.[17] Each group was subdivided into several specific categories. At this rather more detailed level, each step in the process can be examined to see what errors could occur. Such lists can appear repetitive. For example, dose omitted, frequency omitted, route omitted, and prescription unsigned have all been classified as separate categories of error.[18] A more aetiological, or theological, classification might regard all these as sins of omission.

Hynniman et al.[19] suggested three explicit categories:

- errors of omission, when a dose that should have been given was not;
- errors of commission, when a dose was given incorrectly;
- discrepancies, when difficulties occurred in the process but did not lead to errors in dosing.

This classification may be difficult to use in practice.[20]

Other possible subcategories include 'wrong drug', 'wrong dosage form', 'wrong frequency', 'wrong patient', and 'wrong route', all of which could be classified as identification errors.[3,21] In a Japanese psychiatric hospital, 'wrong patient' errors were the most common of this type.[13]

The ASHP[6] listed the following sources of error:

- ambiguous strength designation on labels or in packaging;
- drug product nomenclature (lookalike or soundalike names);
- equipment failure or malfunction;
- illegible handwriting;
- improper transcription;
- inaccurate dosage calculation.

These are in fact mostly not medication errors, but factors that make such errors more likely to occur. The same list included an interesting category of 'compliance error', perhaps better termed 'adherence error', defined as "inappropriate patient behaviour regarding adherence to a prescribed medication regime." Deliberate failure on the patient's part to take the medicine would be a rather different form of therapeutic problem from those normally viewed as medication errors. Barber[22] has argued that intentional non-compliance can still constitute an error, e.g. when a patient takes a 'drug holiday' because of a fear of addiction. This might be an example of applying the wrong rule for the drug in question, and therefore can be classed as a mistake. This is a particularly strong example, because a systems failure in giving the patient sufficient knowledge to use the drug appropriately leads to a mistake and potential harm.

The NCC MERP proposed classifying errors into one of nine categories, according to the harm they caused, which is the so-called Medication Error Index.[23] For example, category A included "circumstances or events with the capacity to cause error," category G included "an error that resulted in permanent patient harm," and category I included errors that resulted in death. However, this classification is not very helpful in terms of prevention, because it deals with outcomes, not causes. The same could be said of the two-way classification of prescription errors proposed for general practice, in which errors in dose, pack size, drug name or formulation, and availability are classified from "trivial" through minor and major nuisance ("doctor contact required") to "potentially serious to the patient."[24]

Bates et al.,[25] in a paper on adverse events related to drugs, classified events by three criteria: the severity of the incident, the degree to which it could have been prevented, and whether it represented an error. By implication, they also decided whether adverse events in which a drug was implicated were potential or actual. They defined potential adverse drug-related events as "incidents with potential for injury related to a drug." As an example, they cited administration of a penicillin to a patient with a known penicillin allergy, who does not in fact suffer a reaction. They added that potential adverse drug-related events "included drug errors intercepted before the order was carried out." They found – unsurprisingly – that potential adverse events were usually preventable, and implied that all preventable adverse events were errors. In other words, they regarded it as erroneous not to prevent an adverse effect when it could be prevented.

The most elaborate system of coding medication incidents, which was developed by the Australian Patient Safety Foundation, has a branching structure with 827 separate specifications over 12 levels.[26] Among what might be termed 'sins of omission,' 'non-administration of indicated and/or intended medication' can be subdivided into five further categories, including 'no accessible route for administration.' This, in turn, is further subdivided several times to indicate, for example, that a problem involving staff led to the failure to administer a prescribed medicine because the drugs chart was mis-

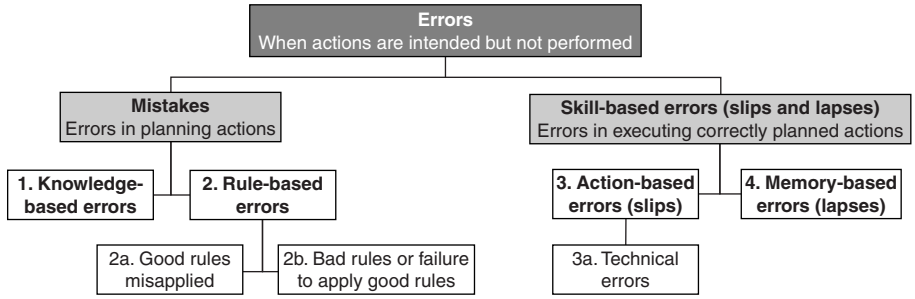

Fig. 2. The classification of medication errors based on a psychological approach.

read. The authors of this system recognised that to prevent incidents from recurring, it is necessary to have an understanding of the nature of the errors and any contributing factors.

3.2 A Proposed Classification

We agree that a classification that informs a preventive approach to medication errors is desirable. The approach we propose relies on a psychological analysis and is illustrated in figure 2.[27]

Following the work of psychologists on errors,[15,28] we have described the following classification of medication errors:[11,27] mistakes (knowledge-based and rule-based errors) and skill-based errors (action-based errors [slips, including technical errors] and memory-based errors [lapses]).

Psychologists consider an error to be a disorder of an intentional act, and they distinguish between errors in planning an act and errors in its execution. If a prior intention to reach a specified goal leads to action, and the action leads to the goal, then all is well. If the plan of action contains some flaw (e.g. planning to give a medicine to a child, but failing to realise that children require different doses from adults), then that is a 'mistake'. If an error occurs in carrying out the action, then that is a 'slip' or a 'lapse'.

3.2.1 Mistakes

Mistakes can be subdivided into those that are the result of ignorance (knowledge-based errors) and those that are the result of a failure to apply a guiding principle (rule-based errors). Knowledge-based errors can be related to any type of knowledge – general, specific, or expert. For example, it is general knowledge that penicillins can cause allergic reactions. Knowing that your patient is allergic to penicillin is specific knowledge. Knowing that fluampicil contains penicillins is expert knowledge. Ignorance of any of these facts could lead to a knowledge-based error. Rule-based errors can further be categorised as either (a) the misapplication of a good rule or (b) the application of a bad rule or the failure to apply a good rule.

3.2.2 Slips

A slip is an action-based error – a form of human error that is defined as "the performance of an action that was not what was intended."[29] A slip of the pen, when a doctor intends to write chlorpromazine but distractedly writes chlorpropamide, is an example. Lapses are covert slips, particularly errors of memory. Slips and lapses are errors that are the result of failures of skill, e.g. picking the wrong medicine from a shelf, or administering the medicine to the wrong Mr Brown when two patients have the same surname.

3.2.3 Technical Errors

Technical errors have been defined as occurring when "an outcome fails to occur or the wrong outcome is produced because the execution of an action was imperfect."[30] They are therefore a subset of slips (skill-based errors), being the result of a failure of skill, e.g. in the insertion of a cannula or in performing stellate ganglion blockade. Even processes such as making up infusions can be beset by technical errors. In one study, two of three infusions of acetylcysteine contained amounts of drug that differed by >10% from the appropriate dose.[31]

Norman[29] developed a classification of slips, based on their presumed causes. Underpinning this classification is the theoretical view that actions are controlled by a form of knowledge called a schema, which is an organised memory 'template'. Slips can occur as early as that point at which an intention to act is formed, if the situation that demands action is misclassified, so the wrong schema is chosen. A practical example might be starting cardiopulmonary resuscitation when the patient was merely asleep. There can also be slips in acting according to the schema, an important example being the 'capture' of one schema by the sequence of actions belonging to another, more familiar, schema. The classic example is of the man who went to his bedroom to change for dinner, and subsequently found himself in bed in his pyjamas.[28] So, a prescriber who habitually used pethidine 100mg as a postoperative analgesic might specify the dose of morphine as 100mg as the result of such a capture error. Errors in carrying out the sequence of events specified in the schema, such as omitting or duplicating a step, are a further important class of slips. An example would be when a nurse, having already added potassium chloride 20 mmol/L to a bag of infusion fluid, forgot having done so and added more potassium chloride. In addition, there can be faults in activation of the schema that lead to slips. For example, when several things are happening at the same time, two schemata can become confused. Lewis Carroll refers to the verbal phenomenon in his preface to *The Hunting of the Snark*:

"For instance, take the two words 'fuming' and 'furious'. Make up your mind that you will say both words, but leave it unsettled which you will say first. Now open your mouth and speak. If your thoughts incline ever so little towards 'fuming', you will say 'fuming-furious'; if they turn, by even a hair's breadth, towards 'furious', you will say 'furious-fuming'; but if you have the rarest of gifts, a perfectly balanced mind, you will say 'frumious'."

An expansion of the ideas of rule-based and skill-based errors is founded on the psychological notion that, if they can, people recognise a pattern and act according to a schema applied to the pattern, rather than calculating or analysing each new problem separately. This leads to 'strong but wrong' errors, when people are strongly impelled to use a familiar strategy, even if it is applied in the wrong circumstances.

Examples of important medication errors under the headings in this classification are given in table I.

3.3 Prevention of Medication Errors Through Classification

Counting errors cannot prevent them. An aetiological classification, in which errors are divided into mistakes (knowledge-based and rule-based errors) and skill-based errors (action-based slips and memory-based lapses), may help to do so (table II). Here we show how such distinctions are not simply semantic.

Table I. A psychological classification of errors, with examples of medication errors in each category[a]

Type of error[b]	Examples
Mistakes	
Knowledge-based	Giving penicillin, without having established whether the patient is allergic
Rule-based	
mistakenly applying a good rule	Injecting diclofenac into the lateral thigh (the usually preferred site for intramuscular injection) rather than the buttock (which is preferred for diclofenac)
applying a bad rule or failing to apply a good rule	Using excessive doses of captopril (as was done during early use of the drug)
Skill-based errors	
Action-based (slips)	Intending to write 'chlorpromazine', but instead writing the more familiar 'chlorpropamide'; scrawling 'chlorpromazine', which is misread as 'chlorpropamide'; picking a bottle containing chlorpromazine from the pharmacy shelf when intending to take one containing chlorpropamide
technical errors	Putting the wrong amount of acetylcysteine in an infusion bottle
Memory-based (lapses)	Giving penicillin, knowing the patient to be allergic, but forgetting

a For detailed discussion and more examples see Reason.[28]

b Mnemonic: KRAM (knowledge, rule, action, memory).

Table II. Possible strategies for reducing errors of different types at different stages of the treatment process[27]

Potential strategy for avoiding error	Stage of treatment process	Examples	Consequences
Knowledge-based errors			
Improved teaching;[32] computerised decision-support systems[33]	Deciding to treat	Being unaware of value of sodium bicarbonate in amitriptyline poisoning[34]	Death from arrhythmia
	Writing the prescription	Being unaware of the interaction between warfarin and azapropazone	Warfarin toxicity[35]
	Dispensing the medicine	Failing to know that chloroform and chloroform water are different	Poisoning with chloroform[36]
	Preparing for administration	Not knowing that paraldehyde dissolves plastic syringes[37]	Difficulty of administration
	Administering the medicine	Being ignorant of the course of the sciatic nerve	Sciatic nerve palsy from intramuscular injection[38]
	Monitoring the treatment	Taking blood for lithium concentration into a heparin tube, unaware that it contains lithium heparin	Erroneous lithium concentration[39]
	Adjusting or ceasing treatment	Continuing after 2 weeks to give amiodarone at the loading dose	Amiodarone poisoning
Rule-based errors: misapplying a good rule			
Improved teaching; computerised decision-support systems	Deciding to treat	Instituting cardiac massage in a patient who has fainted	Alarm, chest trauma
	Writing the prescription	Prescribing oral treatment in a patient with dysphagia	Aspiration or failure to treat
	Dispensing the medicine	Withholding necessary treatment while checks are made	Delay in necessary treatment
	Preparing for administration	-	-
	Administering the medicine	Giving an intramuscular injection of diclofenac into the thigh	Skin necrosis[40]
	Monitoring the treatment	Taking a blood sample at the time of trough lithium concentration	Misleading serum lithium concentration
	Adjusting or ceasing treatment	Giving a short course of antibacterial treatment	Undertreating some infections
Rule-based errors: applying a bad rule or failing to apply a good rule			
Systematic examination of and improvement to rules	Deciding to treat	Prescribing amoxicillin for sore throats	Rash in a patient with glandular fever[41]
	Writing the prescription	Printing drugs chart without space to record allergies	Failure to record significant allergy
	Dispensing the medicine	Dispensing intravenous vincristine and intrathecal methotrexate together	Opportunity for confusion; death[42]
	Preparing for administration	Using multidose vials	Contamination, malaria, death[43]

Continued next page

Table II. Contd

Potential strategy for avoiding error	Stage of treatment process	Examples	Consequences
	Administering the medicine	Not taking alendronate tablets with water	Oesophageal damage[44]
	Monitoring the treatment	Monitoring for agranulocytosis when giving carbimazole	Extra trouble, but no likelihood of benefit
	Adjusting or ceasing treatment	Prolonging antibacterial treatment unnecessarily	Increased bacterial resistance[45,46]
Action-based errors (slips)			
Increased checking systems to detect	Deciding to treat	-	-
slips; increased 'triangulation' when	Writing the prescription	Distractedly writing chlorpropamide for chlorpromazine	Hypoglycaemia[9]
drug, patient and condition are specified; increased use of unique[47]	Dispensing the medicine	Dispensing 5mg vials of vincristine in place of 1mg vials	Death[48]
identifiers or barcodes	Preparing for administration	Drawing up dopamine, not doxapram	Cardiac arrest[49]
	Administering the medicine	Injecting into an intravenous cannula a drug intended to be given by nasogastric tube	Infection, poisoning, thrombosis
	Monitoring the treatment	Making a warfarin clinic appointment for 3 months, not 3 weeks	Uncontrolled warfarin treatment
	Adjusting or ceasing treatment	Stopping warfarin treatment after 3 months for recurrent deep vein thrombosis	Recurrent thromboembolism
Technical slips			
Checklists; computerised reminders;	Deciding to treat	-	-
'fail-safe' systems	Writing the prescription	Writing illegibly, so that 'Daonil®' (glibenclamide) is dispensed for 'Amoxil®' (amoxicillin)	Hypoglycaemia, brain damage[50]
	Dispensing the medicine	Dispensing the wrong strength or concentration of drug	Undertreatment or toxicity[51]
	Preparing for administration	Failing to mix infusion to which potassium was added[52-54]	Hyperkalaemia
	Administering the medicine	Giving intravenous injection extravascularly	Pain, loss of efficacy, tissue damage
	Monitoring the treatment	Failing to measure blood pressure correctly[55]	Overtreatment or undertreatment
	Adjusting or ceasing treatment	Failing to switch off an intravenous giving set	Air embolism;[56] overdose[57]
Memory-based errors (lapses)			
Increased skills training	Deciding to treat	Forgetting that the patient is allergic to penicillin	Anaphylaxis
	Writing the prescription	Omitting a date on which to stop treatment	Poisoning or unnecessary treatment
	Dispensing the medicine	Leaving a bottle of tablets on the counter when dispensing	Treatment failure
	Preparing for administration	Forgetting to wipe the rubber septum of a drug vial	Infection
	Administering the medicine	Forgetting to check the allergy wristband	Anaphylaxis
	Monitoring the treatment	Forgetting to arrange a warfarin clinic appointment	Uncontrolled warfarin treatment
	Adjusting or ceasing treatment	Forgetting to stop clopidogrel treatment after 12 months	Unnecessary risk and expense

Mistakes that are the result of applying bad rules, or misapplying or failing to apply good rules, could be prevented by improved rules. Anticoagulation with warfarin provides an example of gradually evolving rules. Until the 1980s, empirical dosing with warfarin was common. At first, treatment was begun with a dose of 1.5 mg/kg.[58] Later, 'low-dose' schemes emerged. Three successive daily doses of 10mg, or in more conservative circles two daily doses of 10mg and a third day's dose of 5mg, were administered, and a measure of blood clotting was made on the fourth day. Adaptive schemes in which measurements of clotting were made after each dose, and the next dose adjusted according to the result, gradually came into use, such as a nomogram for a scheme in which an initial dose of 10mg was adjusted according to the results of measuring the international normalised ratio.[59] Such schemes increase the safety of warfarin treatment, but cannot fully account for interindividual variation as a result of genetic differences from normal, in particular in the enzymes responsible for the metabolism of warfarin and in the enzyme that it inhibits, vitamin K epoxide reductase. Recent studies involving cytochrome P450-2C9 and vitamin K epoxide reductase complex 1 haplotypes[60-62] have shown that more sophisticated rules might improve matters still further.

Some mistakes arise from inadequate knowledge. In the context of drug therapy, safe working requires knowledge of the drug, the patient, and co-existing factors, including other treatments and concurrent illnesses. This presents a major challenge. Modern drugs, such as HMG-CoA reductase inhibitors ('statins'), are widely used, but few prescribers will be fully aware of contraindications to their use (e.g. porphyria), potential adverse reactions (e.g. paraesthesia) and significant drug interactions (e.g. reduction of serum concentrations of simvastatin by bosentan).

Some progress can be made by ensuring that medical students and other prescribers are taught the basic principles of therapeutics[63] and are tested on their practical application.[32] However, the demands for information and the need for reminders of rules and possible dangers at every stage in the prescribing process have encouraged the development of computerised decision-support systems (CDSSs) for prescribers. These systems can certainly train prescribers to make fewer errors.[33] However, they may not protect patients. As the authors of a review of over 100 studies concluded: "Many CDSSs improve practitioner performance. To date, the effects on patient outcomes remain understudied and, when studied, inconsistent."[64]

Training can help in the specific instance of technical (skill-based) slips. The more practice one has at tying shoelaces or playing the bassoon, the less likely is a simple technical error. However, not all slips and lapses can be avoided by exhortation or education, because they result from the subversion of unconscious processes. Some straightforward solutions, such as checklists, can help. Otherwise, systems can only be made safe from slips and lapses by designing them to be resistant to error and by adding checks and controls. This has proved to be a major challenge in healthcare, and the difficulties of making systems fail-safe explain the large number of medication errors that continue to occur.

Thus, the classification of medication errors on the basis of the underlying psychological mechanisms can suggest strategies that help to reduce their occurrence.

4. Conclusion

The nomenclature surrounding drug safety needs to be clear and unambiguous, so that patients, prescribers, manufacturers and regulators can all understand each other. In particular, it needs to make clear how adverse events and drug therapy are related to one another, how they are best classified, and their frequency, intensity and seriousness.[1] Medication errors, which can lead to adverse drug reactions, require their own clear definitions and mechanistic classification. We have proposed here a definition of medication errors and a system of classification based on a psychological approach.

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