REVIEW ARTICLE

Drug Saf 2009; 32 (10): 819-836
0114-5916/09/0010-0819/$49.95/0

The Causes of and Factors Associated with Prescribing Errors in Hospital Inpatients

A Systematic Review

Mary P. Tully,[1] *Darren M. Ashcroft,*[1] *Tim Dornan,*[2] *Penny J. Lewis,*[1] *David Taylor*[3] and *Val Wass*[2]

1 School of Pharmacy and Pharmaceutical Sciences, University of Manchester, Manchester, UK
2 Manchester Medical School Education Research Group, Manchester, UK
3 Liverpool Medical School Education Research Group, Liverpool, UK

Contents

Abstract

Prescribing errors are common, they result in adverse events and harm to patients and it is unclear how best to prevent them because recommendations are more often based on surmized rather than empirically collected data. The aim of this systematic review was to identify all informative published evidence concerning the causes of and factors associated with prescribing errors in specialist and non-specialist hospitals, collate it, analyse it qualitatively and synthesize conclusions from it.

Seven electronic databases were searched for articles published between 1985–July 2008. The reference lists of all informative studies were searched for additional citations. To be included, a study had to be of handwritten prescriptions for adult or child inpatients that reported empirically collected data on the causes of or factors associated with errors. Publications in languages other than English and studies that evaluated errors for only one

disease, one route of administration or one type of prescribing error were excluded.

Seventeen papers reporting 16 studies, selected from 1268 papers identified by the search, were included in the review. Studies from the US and the UK in university-affiliated hospitals predominated (10/16 [62%]). The definition of a prescribing error varied widely and the included studies were highly heterogeneous. Causes were grouped according to Reason's model of accident causation into active failures, error-provoking conditions and latent conditions. The active failure most frequently cited was a mistake due to inadequate knowledge of the drug or the patient. Skills-based slips and memory lapses were also common. Where error-provoking conditions were reported, there was at least one per error. These included lack of training or experience, fatigue, stress, high workload for the prescriber and inadequate communication between healthcare professionals. Latent conditions included reluctance to question senior colleagues and inadequate provision of training.

Prescribing errors are often multifactorial, with several active failures and error-provoking conditions often acting together to cause them. In the face of such complexity, solutions addressing a single cause, such as lack of knowledge, are likely to have only limited benefit. Further rigorous study, seeking potential ways of reducing error, needs to be conducted. Multifactorial interventions across many parts of the system are likely to be required.

It is well recognized internationally that many patients experience morbidity or mortality as a result of their medical treatment.[1-3] Adverse drug events (ADEs) resulting from the use of prescribed medicines make up the greatest proportion of the reasons for this harm.[4] ADEs can prolong hospital stay and increase the risk of mortality.[5] Preventable ADEs due to errors in, for example, prescribing or administration can result in twice the length of hospital stay and cost twice as much money.[6] Prescribing errors, independent of whether they cause harm, are common. A recent systematic review found a median prescribing error rate of 7% of medication orders, 52 prescribing errors per 100 admissions and 24 prescribing errors per 1000 patient days.[7] Healthcare policy is thus understandably focusing on ways to reduce prescribing errors and hence this burden of harm.[8]

Developing effective ways to reduce errors is dependent upon identifying and understanding their causes and the factors associated with them. Identifying the cause of an error is inextricably linked with knowing the intention of the person who committed it.[9] The action performed may have been different from that originally intended (e.g. writing temazepam instead of tamoxifen because of a distraction at the time) or may have been intended but actually wrong (e.g. not decreasing a dose in renal failure because of lack of knowledge that it was necessary). However, many published studies on prescribing errors have used professional opinions of the researchers to surmize the reasons why the errors occurred[10] rather than using empirically collected data from the prescribers. The factors associated with prescribing errors, such as type of ward, can be gleaned by others from the objective record, however, and, therefore, do not need to be obtained directly from the person committing the error. The causes of and factors associated with prescribing errors have not hitherto been reviewed systematically. Therefore, there is a need to examine the literature critically and to identify the causes of errors, based on a firm foundation of actual data.

The aim of this review is to systematically identify all informative, published evidence concerning the causes of and factors associated with prescribing errors in specialist and non-specialist hospitals, and then to collate and analyse these and draw conclusions from the findings.

1. Identification and Selection of Studies

Studies were sought that reported on the causes of and/or factors associated with prescribing errors in handwritten prescriptions written by doctors for adult and/or child hospital inpatients. Studies reporting errors specifically due to lack of knowledge, workload or stress were explicitly sought, using appropriate keywords because this was part of a programme of work to investigate prescribing errors made by first-year doctors, concentrating on the interplay between doctors' educational backgrounds and factors in the practice environment. Studies reporting medication errors more broadly were only included if they described the causes of or factors associated with prescribing errors in sufficient specific detail to allow extraction and analysis to be carried out.

Studies were identified by searching the following electronic databases for articles published between 1985–July2008: MEDLINE and MEDLINE In-process and other Non-Indexed Citations, EMBASE, Cumulative Index to Nursing & Allied Health Literature (CINAHL®), Applied Social Sciences Index and Abstracts (ASSIA), PsycInfo, Social Science Citation Index and International Pharmaceutical Abstracts. Search terms, combined using Boolean operators, included the following: 'error(s)'; 'medication error(s)'; 'near miss(es)'; 'preventable adverse event(s)'; 'prescription(s)'; 'prescrib(e/er/ers/ing)'; 'medication order(s)'; 'cause(s)'; 'causality'; 'causalities'; 'reason(s)'; 'risk factor(s)'; 'predictor(s)'; 'association'; 'knowledge'; 'stress'; 'workload'; 'work hours'; 'tired(ness)'; 'sleepiness'; 'fatigue'; 'exhaustion'; 'active failure'; 'slip(s)'; 'lapse(s)'; 'mistake(s)'; 'inpatient(s)'; 'hospital(s)' and 'hospitalization'. The reference lists of all included studies were hand searched for additional studies.

We defined 'cause' as 'reasons reported to the researchers by the prescriber, in structured or unstructured interviews, as being wholly or partially responsible for a specific prescribing error'. We defined 'factors associated with errors' as 'variables that were linked with the prevalence of specific prescribing errors by the researchers'. Studies were only included when data concerning causes and associated factors were collected empirically; studies where causality or associated factors were surmized (e.g. based on professional experience of the data collector) were excluded.

All research designs were included. Studies were not excluded due to methodological quality, but comments are given on the limitations of the study methods and therefore the confidence that could be placed on their findings. Conference abstracts were excluded because they do not contain sufficiently detailed information about causes or contributory factors. Non-English language publications were excluded because there was insufficient time and resource to translate them.

2. Data Extraction and Analysis

A data-extraction form was used to extract the following information: year and country; study period; hospital setting; methods (including type of study, sampling and review processes, profession of data collector, means of detecting error, causes and associated factors); definitions used; the causes and/or associated factors; and any other relevant information captured by the study. Two reviewers extracted relevant data from each study independently and resolved any differences through discussion. If they could not achieve consensus, a third reviewer arbitrated. Data were entered into an Excel spreadsheet for ease of handling and analysis.

The studies retrieved by the search were extremely heterogeneous. Reason's model of accident causation,[9] one of the most commonly used theoretical models when considering medical error, was used to categorize and present the data. Therefore, the data were categorized, with increasing proximity to the erroneous event, as latent conditions (such as organization processes), error-provoking conditions (such as environmental or individual factors that affected performance at the time of the error) and active failures (such as errors due to slips, lapses, mistakes and violations). Slips are errors in performing an intended action, such as intending to prescribe carbamazepine but instead writing down chlorpromazine. Lapses are errors resulting from a memory failure, such as prescribing a medication to which a patient is allergic, despite this being known. Mistakes are either rule-based

(misapplying a good rule or choosing a poor one) or knowledge-based (such as lacking or overlooking relevant information). Violations are conscious decisions to ignore the accepted rules or procedures of the organization. We did not present the data numerically (even when given in the original paper) because, for the qualitative studies in particular, this would give a misleading suggestion of quantification where none exists.

3. Literature Search Findings

The search identified 1268 articles. After initial screening of the abstracts, 1182 did not meet the inclusion criteria. The remaining 86 articles were obtained in full text and assessed for their suitability to be included. Figure 1 describes this process and the reasons for excluding retrieved articles. The main reasons for exclusion were review or editorial articles (n = 15); studies with no empirically collected data about causes of or factors associated with errors (n = 17); studies not investigating causes of or factors associated with errors (n = 12) and studies that included all types of medication error, without differentiation (n = 7). Seventeen articles, reporting the findings of 16 unique studies, were included in the review.[11-27]

3.1 Settings

Most studies were conducted in the US (7/16) or the UK (3/16). Other countries included Australia (n = 2), Belgium (n = 1), Canada (n = 1), Croatia (n = 1) and the Netherlands (n = 1). Over two-thirds were published after 2000 (11/16), and most (13/16) were conducted in university-affiliated hospitals. One study was conducted in two paediatric hospitals,[16] one in a specialist eye hospital[24] and one did not state its location.[25] The majority of studies (13/16) were carried out in single hospital sites and three studies were carried out on two sites.[15,16,20]

Six studies were carried out only in adult specialities or wards;[12,19-21,25,26] three studies included only children's specialties or were conducted exclusively in paediatric hospitals.[11,16,27] Two (reported in three articles) included prescriptions for both adults and children,[17,22,23] and the remaining five did not state the ages of the patients.[13-15,18,24]

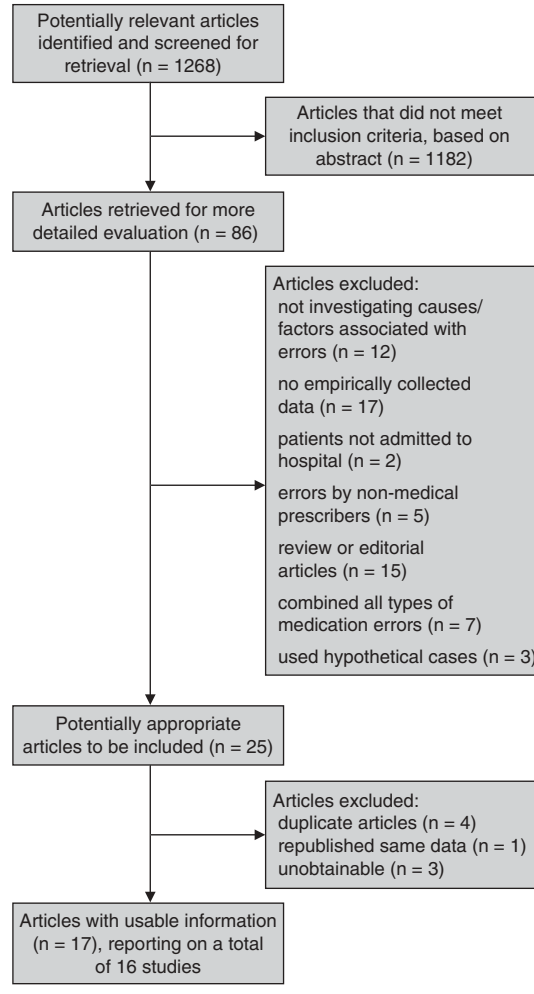

Fig. 1. Flow diagram of the screening process.

Five studies (reported in six articles) included prescriptions from all or the vast majority of wards and specialities within the study site(s).[15,16,18,22-24] The remainder only provided error data for a single ward,[11,12,19,21,25] a limited number of specialties[14,17,19,20,26,27] or a single group of doctors.[13]

3.2 Study Design

Seven studies[11,13,14,19-21,25] reported data on the causes of prescribing errors (table I) and nine studies (reported in ten articles)[12,15-18,22-24,26,27] reported

Table I. Studies reporting on the causes of prescribing errors

Study (y)	Country	Study sites	Setting	Study duration	Adults or children	Error data		Method of identification of error	Methods for collection of causes data	Who collected data	
						type of study	type of data collection			errors	causes data
Buckley et al.[11] (2007)	US	Teaching hospital (n = 1)	ICU	5 mo	C	P	Outcome-based	Observations when following one nurse around for entire shift	Observation	Pharmacists	Pharmacists
Coombes et al.[13] (2008)	Australia	Teaching hospital (n = 1)	NS	5 mo	NS	P	Process-based	NS	Semi-structured qualitative interviews, discussion with pharmacist, review of medication chart and medical records	NS	Researchers
Dean et al.[14] (2002)	UK	Teaching hospital (n = 1)	Medical and surgical specialties	8 wk	NS	P	Process-based	Asked pharmacist to inform them of any potentially serious prescribing errors made by doctors for inpatients	Semi-structured qualitative interviews, questionnaires and review of medical notes to obtain additional relevant information	Ward pharmacists	Researchers
Kopp et al.[19]a (2006)	US	Teaching hospital (n = 1)	Medical/surgical ICU	17 d	A	P	Outcome-based and process-based	Direct observation	Observation of nursing station and, therefore, all conversations about medicines	Two pharmacy residents specializing in critical care	Two pharmacy residents specializing in critical care
Leape et al.[20] (1995)	US	Teaching hospital (n = 2)	ICU (n = 5) and general medical units (n = 6)	6 mo	A	P	Outcome-based and process-based	Voluntary reports and review of medical records	Interviews of all parties with knowledge of the incident using structured form	Trained nurse investigators	Peer case investigator
Lederman and Parkes[21] (2005)	Australia	Teaching hospital (n = 1)	HIV ward	3 wk	A	P	Process-based	Observation of pharmacist doing rounds	Structured interviews	Pharmacists	Researchers
Patterson et al.[25] (2004)	US	NS	Oncology patient	NS	A	R	Outcome-based	Detected by doctor as part of usual work	Qualitative interviews with five people using the critical decision method	NS	Researchers

a The study by Kopp et al. appears in tables I and II because it contains both causality data and data relating to factors associated with errors.

A = adults; **C** = children; **ICU** = intensive care unit; **NS** = not stated; **outcome-based** = reporting findings of actual or potential patient harm; **P** = prospective; **process-based** = reporting findings from prescription review; **R** = retrospective.

Table II. Studies reporting on factors associated with prescribing errors

Study (y)	Country	Study sites	Setting	Study period	Adults or children	Error data		Method of identification of errors	Factors associated with prescribing errors		Who collected data	
						type of study	type of data collection		type of study	method	errors	factors associated with errors
Colpaert et al.[12] (2006)	Belgium	Teaching hospital (n = 1)	ICU	5 wk	A	P	Process-based	Analysis of every medication order of randomly selected patients	P	Correlations between patient characteristics, number of drug prescriptions and the number of medication prescribing errors	Clinical pharmacist	Clinical pharmacist
Fijn et al.[15] (2002)	Netherlands	Teaching hospital (n = 2)	All wards	2 wk	NS	R	Process-based	NS	P and R	A retrospective, explorative, case-control study was performed. Random samples of prescriptions with one or multiple errors were analysed for associated factors	NS	NS
Folli et al.[16] (1987)	US	Children's hospital (n = 2)	All wards	6 mo	C	P	Process-based	Usual screening of prescriptions in pharmacy	P	Data collected at same time as errors data. Conducted statistical comparisons	Clinical pharmacist	Clinical pharmacist
Hendey et al.[17] (2005)	US	Teaching hospital (n = 1)	Doctors in adult medical/surgical wards and critical care areas	1 mo	A and C	R	Process-based	Detected as part of usual screening by pharmacists	R	Performed a subgroup analysis to determine error rates based on time of day, level of training and acuity level of the unit where the order was written	Pharmacists and two research assistants	Two research assistants
Ho et al.[18] (1992)	Canada	Teaching hospital (n = 1)	All wards	25 wk	NS	P	Process-based	Detected as part of usual screening by pharmacists	P	By recording of details of the prescriber and circumstances of the error when detected by pharmacist	Dispensary pharmacists	Dispensary pharmacists

Continued next page

Table II. Contd

Study (y)	Country	Study sites	Setting	Study period	Adults or children	Error data		Method of identification of errors	Factors associated with prescribing errors		Who collected data	
						type of study	type of data collection		type of study	method	errors	factors associated with errors
Kopp et al.[19] 2006	US	Teaching hospital (n = 1)	Medical/surgical ICU	17 d	A	P	Outcome-based and process-based	Direct observation	P	Observation of nursing station and, therefore, all conversations about medicines	Two pharmacy residents specializing in critical care	Two pharmacy residents specializing in critical care
Lesar et al.[23] (1997) and Lesar et al.[22] (1997)	US	Teaching hospital (n = 2)	All wards	9 y and 1 y	A and C	P	Process-based	Detected as part of usual screening by pharmacists and patient-record review	P	Data collected from prescriptions, notes and other factors assigned by researchers during review. The statistical significance of group differences in error rates was determined	Pharmacists	Researchers and pharmacists
Mandal et al.[24] (2005)	UK	Specialist eye hospital (n = 1)	All wards	1 mo	NS	P	Process-based	Detected as part of usual screening by pharmacists	P	Non-statistical comparison	Three dispensing pharmacists	Three dispensing pharmacists
Vrca et al.[26] (2005)	Croatia	Teaching hospital (n = 1)	Different wards of the Clinic of Internal Medicine	25 wk	A	P	Process-based	Medical-record analysis	P	Non-statistical comparison	A pharmacist and physician evaluated the medication records	A pharmacist and physician evaluated the medication records
Wilson et al.[27] (1998)	UK	Teaching hospital (n = 2)	PCW and four-bed paediatric cardiac ICU	2 y	C	P	Outcome-based and process-based	Adverse incident-reporting scheme	R	Contrasts between year 1 and year 2, and between PCICU and PCW, were reported in turn as rate ratios, relative to counts of admissions, inpatient days and clinical events	Study's authors collected incident reports made by pharmacists, doctors and nurses	Errors were documented by nurses, pharmacists and doctors using standardized incident-report forms. Analysis conducted by researchers

A = adults; **C** = children; **ICU** = intensive care unit; **NS** = not stated; **outcome-based** = reporting findings of actual or potential patient harm; **P** = prospective; **PCICU** = paediatric cardiac intensive care unit; **PCW** = paediatric cardiac ward; **process-based** = reporting findings from prescription review; **R** = retrospective.

data on the factors associated with prescribing errors (table II). One study reported data on both.[19]

Most studies (13/16) collected prescribing error data prospectively and data on their causes were collected retrospectively. These causality data were collected in a variety of ways, using qualitative, semi-structured interviews,[13,14,25] structured interviews[20,21] or participant observation of interactions between the doctor and other healthcare professionals.[11,19] All but one study[21] used open questions to ascertain the cause. Data about causes were usually collected by the authors. Data on associated factors were collected at the same time as error data for eight studies,[12,15,16,18,22-24,26] and retrospectively using other data sources in two studies.[17,27] Pharmacists, physicians and nurses were the usual data collectors for errors and associated factors.

The majority of studies (11/16) were process-based, meaning that they reported the findings of healthcare professionals reviewing prescriptions, usually as part of routine work.[28] This type of study does not measure harm because the error is detected and reported to the prescriber before the medication is given to the patient. Only two were outcome-based studies,[11,25] measuring actual or potential patient harm by reporting ADEs.[28] A further three studies were both process- and outcome-based in that they investigated both incident reports (some of which included actual adverse events) and prescribing errors detected in the prescription itself.[19,20,27]

The definition of a prescribing error varied enormously. Most studies provided definitions of their own; five studies[11-14,20] used previously developed definitions by Bates et al.,[29] Dean et al.[30] or National Co-ordinating Council for Medication Error Reporting and Prevention.[31] Two studies did not state any definitions[15,21] but provided detailed data on the types of prescribing errors included. Two studies used a definition based on actual or potential patient harm.[11,20]

3.3 Reason's Model of Accident Causation

The authors of five studies used Reason's model of accident causation[9] to describe their findings, either explicitly[13,14,20] or implicitly.[11,19] We categorized the remainder similarly. The data from all seven studies that investigated causes are presented in table III, grouped by the stages of Reason's model. Table IV presents the findings from the studies that reported on factors associated with errors. All such associated factors were classified as error-provoking conditions[9] because they were not the unsafe acts themselves.

3.4 Active Failures

Active failures are the unsafe acts committed by the prescribers in contact with the patient. Therefore, all errors would be expected to be as a result of at least one active failure. Knowledge-based mistakes were the most common failure cited in five studies.[11,13,19,20,25] Prescribers told the researchers that the errors had occurred because they did not know enough either about the drug they were prescribing[13,20,25] or about the patient they were prescribing it for.[19,20] Most of the mistakes reported in these studies related to the dose of the drug prescribed. Examples given included prescribing the wrong dose of anticoagulant[11] or not knowing that a patient's co-morbidity was a contraindication for the prescribed medicine.[20] Rule-based mistakes, where there was lack of knowledge of a rule (such as how to reduce doses in renal failure), as well as the application of the wrong rule, were reported in one study as being a common active failure.[14] However, the authors acknowledged that the interviewed doctors may have used this as a "socially acceptable construction of ignorance".

Skill-based slips and memory lapses were described in five studies[11,13,14,19,20] where, for example, prescribers were interrupted during a task or were busy when they made the error. Such slips were the most common active failure in one study.[14] When directly asked, however, prescribers were not always able to explain exactly why the slips and lapses had occurred.[14]

Violations are active choices by the prescriber to ignore the formal or informal policies or guidelines they are expected to adhere to. These were reported in four studies.[11,14,19,20] Examples included prescribing by a medical student that was improperly checked[14] and doctors failing to

Table III. Main findings of studies reporting causes of prescribing errors, grouped by stages of Reason's model of accident causation[9]

Study (y)	Country	Setting	Active failures (individual unsafe acts)	Error-provoking conditions (task and environment)	Latent conditions (organizational processes)
Buckley et al.[11] (2007)	US	ICU	Knowledge-based mistakes: lack of drug knowledge Violations Slips and lapses		
Coombes et al.[13] (2008)	Australia	NS	Knowledge-based mistakes Slips	Median of 4 (2–5) per error *Prescriber:* hungry, thirsty or tired; low morale or distracted; inadequate knowledge, skill, experience or training *Working environment:* staffing levels inadequate/unfamiliar with patient *Workload:* high workload; long hours; pressure. *Healthcare team:* communication problems; remote unclear or lack of supervision; trust or assume that senior checks; decision by senior; detail by junior; weighing risks and benefits; responsibility too great *Prescribing task:* medical chart layout or location; ambiguous or unavailable guidelines *Patient:* complex problem, acute problem; communication difficulties	Low importance attached to re-prescribing Simultaneous multiple-prescribing tasks Perception of prescribing as a chore Lack of training in drug knowledge and prescribing skills Long hours scheduled Staffing numbers Need to admit specialist patients out of hours
Dean et al.[14] (2002)	UK	Medical and surgical specialties	Skill-based slips/lapses: busy or interrupted during routine tasks Rule-based mistakes: absence of knowledge of a relevant rule; application of the wrong rule Violations	182 cited about 44 errors *Individual prescriber:* skills and knowledge, including training, knowledge and experience and calculations; physical health (tired, hungry or unwell); mental health (low morale) *Working environment:* staffing, including inadequate, new or locum staff and dealing with another doctor's patient; heavy workload; physical environment *Healthcare team:* responsibility; communication, e.g. inability to read hand writing, absence of documentation; supervision *Prescribing task:* not routine, protocols *Patient:* complex clinical disease; unhelpful; language and communication problems	Attitude: prescribing not considered important; do not learn about drug doses at medical school; transcription is not prescribing; low self-awareness about making errors Culture within team: lack of questioning
Kopp et al.[19] (2006)	US	Medical/surgical ICU	Knowledge-based mistakes: lack of drug knowledge; lack of patient information Rule violations: inadequate monitoring Slips and memory lapses	*Healthcare team:* faulty interaction with other services	
Leape et al.[20] (1995)	US	ICU (n = 5) and general medical units (n = 6)	Knowledge-based mistakes: lack of knowledge of drug, interactions and doses; lack of	1 cited per error Individual prescriber: poor knowledge dissemination *Working environment:* poor staff and work	Poor allergy defence systems Lack of feedback systems Poor conflict resolution

Continued next page

Table III. Contd

Study (y)	Country	Setting	Active failures (individual unsafe acts)	Error-provoking conditions (task and environment)	Latent conditions (organizational processes)
			information about the patient Rule violations: inadequate monitoring Slips and memory lapses	assignments *Prescribing task:* lack of standardization of doses, frequencies and other procedures	
Lederman and Parkes[21] (2005)	Australia	HIV ward		1 cited for 31 errors and 2 cited for 7 errors *Working environment:* lack of access to drug information; lack of access to patient information; patient-related knowledge not delivered efficiently; slow access to information; lack of access to workstations to find information	Pharmacy systems separate from clinical services Logistical problems with knowledge transfer in prescribing Difficulties in storing data
Patterson et al.[25] (2004)	US	Oncology patient	Knowledge-based mistakes Violation: not following chemotherapy policy	All cited for 1 error *Healthcare team:* failure to communicate intents/plans behind orders; unwarranted shifts in planning at staff changeover; not rechecking after query 'are you sure?'; responsibility for patient care ambiguously distributed *Working environment:* communication quality negatively influenced by medium used	Difficult to access specialized expertize (at weekend) Reluctance to question people with greater authority

ICU = intensive care unit; **NS** = not stated.

provide all the information they knew was required on a prescription.[11] In addition, some of the active failures listed in this section could also be classed as violations of informal rules of practice, such as writing the prescription regardless of whether or not the prescriber had adequate information about the drug being prescribed.

3.5 Error-Provoking Conditions

Error-provoking conditions are related to the task and the environment at the time when the error occurs. They do not directly cause errors, but are latent risk factors for them because active failures are more likely when they are present. In the context of prescribing, these error-provoking conditions can be categorized as being related to the individual prescriber, their immediate working environment, the broader healthcare team, the prescribing task and the patient. Most studies of error-provoking conditions reported only a single condition per error, with four studies reporting multiple conditions per error.[13,14,21,25] Coombes et al.[13] and Patterson et al.[25] described in detail the interaction between multiple error-provoking conditions in creating the conditions suitable for an active failure to occur.

3.5.1 Individual Prescriber

Since errors due to lack of knowledge about specific drugs were described as one of the most common active failures, it is unsurprising that lack of training and experience of the prescriber was also reported as an error-provoking condition.[13,14,20] Junior doctors were reported as making more errors in several studies.[16,18,27] However, these findings are inconclusive because not all studies adjusted the number of errors for overall prescribing rates.[18,27] In one study, junior doctors wrote more prescriptions than their senior colleagues did, but had a similar error rate when not on call.[17] Lesar et al.[23] did not find a change in the error rates as the house-staff training year progressed, although they did not look separately at error rates for each grade of doctor. Wilson et al.,[27] on the other hand, found an increase in the number of errors reported

Table IV. Main findings of studies that explore factors associated with prescribing errors

Study (y)	Setting	Error-provoking conditions (task and environment)
Colpaert et al.[12] (2006)	ICU	*Prescribing task:* a trend toward more prescription errors with increasing number of drug orders per patient ($R^2 = 0.431$)
Coombes et al.[13] (2008)	NS	*Prescribing task:* errors with new prescriptions, median of five different factors mentioned; errors with re-prescribing, median of three different factors mentioned
Fijn et al.[15] (2002)	All wards	*Prescribing task:* univariate analysis: the number of drugs prescribed daily per prescriber, and the weekday of prescribing predictors of prescribing errors. Disappeared after multivariable analysis; multivariate analysis: preadmission drugs (OR 1.7, 95% CI 1.3, 2.3) *Patient:* multivariate analysis: individual patient characteristics were not associated with errors; multivariate analysis: medical speciality (e.g. orthopaedic surgery OR 3.6, 95% CI 2.1, 5.4), dosage form (e.g. eye preparations OR 11.1, 95% CI 4.3, 28.5), therapeutic area (e.g. cancer therapy OR 2.6, 95% CI 1.0, 6.5)
Folli et al.[16] (1987)	All wards	*Individual prescriber:* the frequency of errant medication orders declined as physicians training status increased ($p < 0.001$) *Patient:* error rate per 100 patient days was greater for paediatric ICU patients: 3.26 vs 1.52 per 100 patient days ($p < 0.001$); potentially lethal errors greatest in the paediatric ICU: 0.29 vs 0.09 per 100 patient days ($p < 0.001$)
Hendey et al.[17] (2005)	Doctors in adult medical/surgical wards and critical care areas	*Individual prescriber:* increased error rate for overnight and post-call orders in comparison to off-call physicians: 2.7% vs 1.90% (OR 1.44, 95% CI 1.06, 1.95); postgraduate year-1 physicians had a significantly higher overnight error rate compared with their off-call rate: 4.23% vs 1.90%; postgraduate year-1 physicians had a similar error rate to postgraduates year-5 physicians when off-call but rate was significantly higher overnight: 4.23% vs 0.52% *Patient:* errors rates were significantly higher on the medical/surgical wards during the overnight and post-call ($p = 0.005$). In the critical care area, the overnight and post-call error rates were significantly lower than the off-call periods
Ho et al.[18] (1992)	All wards	*Individual prescriber:* error rates associated with experience of doctors: number of errors detected = 1330; resident physicians: 479 (36%), interns: 355 (27%), staff physicians: 350 (26%), medical student interns: 146 (11%) *Patient:* wards associated with most errors: emergency unit: 11.4 per 1000 orders; medical teaching wards: 8.7 per 1000 orders; surgical wards: 8 per 1000 orders; renal ward: 6.6 per 1000 orders; geriatric/rehab: 5.7 per 1000 orders; palliative care: 5.2 per 1000 orders
Kopp et al.[19] (2006)	Medical/surgical ICU	Variables associated with preventable adverse drug events *Prescribing task:* increasing number of medicines: IRR 1.64 (1.16–2.32) per medicine *Patient:* male sex of patient. IRR 1.7 (1.1–2.62) Increasing patient age: IRR 1.01 (1.00–1.02) per year
Lesar et al.[23] (1997) and Lesar et al.[22] (1997)	All wards	*Individual prescriber:* total error rates per 1000 medication orders were highest between 0800h and 1200h, and lowest between 2400h and 0400h: 2.9 per 1000 medication orders and 1.8 per 1000 medication orders ($p < 0.001$), respectively. Serious error rates were highest between 0800h and 1200h and 1600h and 2000h, and lowest between 2400h and 0400h: 0.6 per 1000 medication orders and 0.3 per 1000 medication orders ($p < 0.001$), respectively. The error rate per 1000 orders varied significantly by month ($p < 0.001$), with the highest error rate occurring in November and the lowest in February. No significant trend in error rate occurred as the July–June house-staff training year progressed *Patient:* errors greatest for paediatric service and emergency: 5.93 per 1000

Continued next page

Table IV. Contd

Study (y)	Setting	Error-provoking conditions (task and environment)
		medication orders and 5.5 per 1000 medication orders ($p < 0.001$), respectively
Mandal et al.[24] (2005)	Eye hospital	*Individual prescriber:* no statistical comparison between errors made by different grades of doctor. All drug-related errors (defined as incorrect drug dose or timing or incorrect route of administration) were made by junior doctors (n = 15 [100%])
Vrca et al.[26] (2005)	Different wards of the Clinic of Internal Medicine	*Patient:* errors increased with increasing age. Age group 41–50 y: 1.94% of prescriptions had errors; 51–60 y: 15.5%; 61–70 y: 16.4%; 71–78 y: 24.6%
Wilson et al.[27] (1998)	PCW and four-bed paediatric cardiac ICU	*Individual prescriber:* prescription errors doubled when new doctors joined the rotation: ratio for new doctors vs no new doctors was 173 : 112 (1.55) *Patient:* errors more than 7-fold likely to occur in the intensive care setting

ICU = intensive care unit; **IRR** = incident rate ratio; **NS** = not stated; **OR** = odds ratio; **PCW** = paediatric cardiac ward.

spontaneously when junior doctors started working in a specialist paediatric centre.

Doctors described their physical or mental health during interviews, portraying themselves as tired, hungry, thirsty, unwell or with low mood at the time of the error occurrence.[13,14] This was frequently coupled with hurrying and feelings of excessive work load.[13,14] Error rates were found to be highest at the busiest time of the day for prescription writing in one study.[23] In another study, univariate analysis indicated that the daily prescribing load for individual doctors was a predictor of error rate, but this disappeared when controlling for other factors in the multivariate analysis.[15] Occurrence of errors were significantly associated with prescribing during or immediately following a night on-call, especially for first-year doctors.[17] Although the authors suggested that sleep deprivation or fatigue might have been causative factors, they also recognized that they did not measure the amount of sleep obtained or other confounders such as levels of supervision available.

3.5.2 Working Environment

The working environment was not investigated as a factor associated with error occurrence, but was raised during interview studies. Low-staffing levels at the time of the error were described in three studies as an error-provoking condition.[13,14,20] Prescribers described their physical environment as being an error-provoking condition, such as the lack of a desk[14] or access to a computer.[21] The latter contributed to lack of access to necessary drug and patient information, although this also occurred with non-computerized records.[20]

3.5.3 Healthcare Team

Issues were raised that were associated with prescribing for another doctor's patients[14] and with ambiguity about responsibility for patients,[13,14,25] including quality of supervision for junior doctors.[13] Lack of, or poor quality of, communication or documentation was a frequently mentioned error-provoking condition.[13,14,19-21,25] It was the main problem described by Patterson et al.,[25] in a detailed account of the impact of communication problems on a single severe error. Poor or no communication occurred via the telephone,[25] paper[14,25] and computers.[21] The negative impact of the medium of communication was discussed in detail by Patterson et al.,[25] for example, when colleagues on the telephone could not see that the error resulted in an overly large volume of parenteral medication being prepared, which would have been immediately obvious during the equivalent face-to-face communication.[25]

3.5.4 Prescribing Task

Non-routine[14,25] and non-standardized[20] prescribing tasks were mentioned as error-provoking conditions. Positive associations have been reported between increasing numbers of drugs prescribed and both errors[12] and preventable adverse events.[19] The layout of the prescription chart was referred to in one study,[13]

although specific details were not given. The route of administration also increased the odds of an error occurring, especially via eye drops (odds ratio [OR] 11.1; 95% CI 4.3, 28.5) and inhalation (OR 4.1; 95% CI 2.6, 6.6), as did the fact that the drug had been prescribed prior to admission to hospital (OR 1.7; 95% CI 1.3, 2.3).[15] Coombes et al.[13] found different error-provoking conditions associated with errors with new prescriptions compared with rewritten prescriptions (such as re-prescribing medication on admission or discharge). For errors with new prescriptions, the major factors identified concerned the healthcare team, the individual prescriber and the patient. For re-prescribing errors, they were related to the working environment, the task and the duration of experience of the junior doctor.

3.5.5 The Patient

Prescribing for patients with acute or complex clinical diseases,[13,14] who were unhelpful or who had language difficulties,[14] was reported by doctors as being more likely to result in errors. However, patient characteristics were variable in their association with prescribing errors. Fijn et al.[15] did not find them predictive of errors in either univariate or multivariate analysis. In other studies, however, increasing rates of errors were associated with increasing age of adult patients[26] and children,[23] and preventable adverse events were associated with increasing age and male patients.[19]

The patient's ward was considered as a broad proxy for the type and severity of the patient's medical condition. Children on intensive care units were at greater risk of errors than those on general wards.[16,27] Medical and surgical wards (particularly orthopaedic[15]) were associated with greater error rates compared with all other types of wards.[15,18]

3.6 Latent Conditions

Latent conditions are the organizational processes that create an environment where error-provoking conditions and active failures are more likely to result in prescribing errors. They were described in five studies during open questioning of the prescribers as potential causes of their errors,[13,14,20,21,25] but were not investigated in any study as possible factors associated with errors.

A reluctance to question more senior colleagues in the medical team was reported in two studies,[14,25] and poor conflict resolution was reported in another.[20] Both Coombes et al.[13] and Dean et al.[14] found that some doctors had the attitude that prescribing, especially re-prescribing, was not an important task. In some studies it was found that drug knowledge, dose selection and prescribing skills were not formally taught,[13,14] and, in one of these, there was low self-awareness among doctors that they actually made prescribing errors.[14] A lack of feedback when prescribing errors occurred was found in another study,[20] which could potentially contribute to this lack of awareness.

Other latent conditions that were described included lack of integration of clinical and pharmacy computer systems, with logistic problems in transfer of prescribing information;[21] junior doctors who had been forced to work long hours because ward rounds were early or late in the day[13] and working rotas that were organized so that there was difficulty in accessing specialist staff at the weekend.[25]

4. Discussion

Combining the evidence from the literature about both the causes of and factors associated with the prescribing errors has helped to shed greater light on why and how errors occur. However, the nature of the findings means that it was not possible to quantify the prevalence of the various causes of prescribing errors. Some studies used qualitative methods where quantification was obviously not sought.[13,14,25] Some limited their investigation to errors caused by particular error-provoking conditions, especially poor communication.[21,25] Other, quantitative, studies of causes were conducted in specialist areas, such as intensive care[11,19] or HIV treatment,[21] or only included the subset of prescribing errors that caused actual harm or were potentially harmful.[20] Similarly, several studies of the factors associated with prescribing errors were also

carried out in specialist areas, including ophthalmology[24] and intensive care.[12,27] Findings from these studies will not necessarily be generalizable to all hospital wards or to a broader range of errors. Despite this, there was some consistency with regard to the nature of the causes of and factors associated with prescribing errors that were identified by the included studies.

Knowledge-based mistakes, especially about the dose of the drug and the patient's comorbidities, were described as common in most studies and occurred across a broad range of study settings. Slips, lapses and violations were also described, but less often. Lack of training and lack of experience of the prescriber were described as error-provoking conditions, and there was some evidence to suggest that working conditions, such as busyness or fatigue, caused errors and were associated with higher error rates. Poor communication systems between healthcare professionals were also described as contributing to prescribing errors. There was some evidence to suggest that errors were more common in older patients and children on intensive care wards, and that errors increased as the number of prescribed drugs per patient increased. Latent conditions were reported in only a few studies and related particularly to the reluctance to discuss errors and lack of formal teaching or feedback within the hospitals.

Our review has a number of limitations. Relevant studies that were not indexed by the databases that we searched (and not cited by studies found) could not be included. Non-English language studies were excluded, because of limitations within our group to translate them. We also excluded abstracts due to the limited information therein. Therefore, international work or work in progress may exist that could further add to our understanding of the causes or factors associated with prescribing errors.

Many studies were excluded from the review because the data that were purported to be about the causes of errors had been surmized by the researchers (figure 1). Some of the studies provided particularly poor accounts of their methods. Consequently, the task of deciphering whether all or only some of the causality data had been collected empirically was often problematic. Although some errors could have been caused by the active failures suggested by the researchers, supposition may not have accurately identified the causes of those particular errors. Leape et al.[20] showed how a single type of medication error (the patient receiving the wrong dose) could have been caused by one of several active failures, including lack of knowledge about the drug, rule violation, faulty dose-checking procedures or slips. Although these data included administration as well as prescribing errors, they still illustrate the need to collect empirical data about the causes of each error included in a study.

Included studies exhibited various limitations dependent on the methodological approach that they took. Studies that utilized observational techniques were open to the Hawthorne effect (i.e. subjects modifying their behaviour due to the fact that they are being observed),[11,19] and doctors may have improved or altered their prescribing if they were aware that they were being observed. Those studies that incorporated interviews could also be affected by social desirability bias and doctors may have responded to questioning in a way that they perceived to be socially acceptable,[14] especially when asked about potential violations. Spontaneous reporting of errors may lead to underestimation of the prevalence of errors which, in turn, may lead to inaccuracies in interpreting the factors associated with the errors reported.[12,27] No one study examined all of the possible causes for a large number of errors and it was not possible to gauge their relative importance. The potential for confounding between some error-producing conditions (such as the number of drugs prescribed and severity of illness) was examined in only one study.[15]

Active failures due to lack of knowledge, especially regarding appropriate doses to prescribe, were very commonly described in the included studies. We have previously reported that the most prevalent type of prescribing error described in the literature is dose-related[7] and this could therefore explain this finding. Information technology, such as electronic prescribing (e-prescribing), has been shown to reduce many

prescribing errors, including dosage errors.[32] Clinical pharmacologists have expressed concerns that newly graduated doctors have not received adequate undergraduate training on prescribing[33,34] and recommend additional education in clinical pharmacology and therapeutics. New graduates themselves report feeling unprepared when they begin prescribing.[35-37] Not all doctors agree that detailed training in prescribing could be included in the undergraduate curriculum.[38] Reasons include regional variations in the specific drugs recommended in hospital formularies. However, basic principles of safe prescribing could be taught to undergraduates, supplemented by continuing education when practising.

It has been recognized that much of a junior doctor's learning occurs in the workplace, in an 'apprenticeship' model.[39,40] In one survey, junior doctors reported that they learnt safe prescribing practice by copying other physicians.[41] In contrast to the formal teaching and training that people often equate with learning, informal learning occurs as part of routine work and is often invisible and, hence, unrecognized.[42] Pharmacists routinely discuss and clarify errant prescriptions with doctors. This is a potentially powerful educational opportunity, which may go unnoticed and which should be utilized more explicitly as a feedback opportunity.

Doctors were not always aware that they had actually made prescribing errors until they were pointed out to them.[14] Elsewhere, it was found that one-third of intensive care staff did not acknowledge that they actually made errors.[43] Learning from prescribing errors is impossible if doctors neither know nor acknowledge that they make them. A pilot study has shown it to be feasible to feed information back about prescribing errors formally to medical teams to improve on this, although unfortunately not to individual prescribers.[44] Advances in training in safe prescribing have been proposed for both medical students[45-47] and junior doctors.[48,49] The impact of these interventions on the reduction of prescribing errors, however, has not been investigated.

Although the lack of undergraduate clinical pharmacology tuition has been proposed by clinical pharmacologists as the 'likely' cause of increasing patient morbidity due to prescribing errors,[34] there were many other causes reported in these studies that cast doubt on this suggestion. Tiredness, work overload and stress were all cited in multiple articles as error-provoking conditions. These were described by the doctors in one study as being more likely to contribute to an error than was lack of knowledge.[41]

Although frequently cited in these studies as an error-provoking condition, the evidence that fatigue has a causal link with clinical performance is mostly based on simulation or proxies.[50,51] No correlation has also been found between proxies for fatigue such as work hours or shift length and either medication errors[52,53] or adverse events.[54] Nonetheless, other hazardous industries, such as aviation, do not tolerate the shifts of 24–36 hours that have been (and perhaps still are[53]) common in medicine.[50] Limitations to doctors' hours of work have taken place in both the US and the UK over the past decade, implemented by the Accreditation Council of Graduate Medical Education and the European Working Time Directive, although the former's impact on working hours in the US (and potentially patient safety) may not be great.[53]

It has been suggested that fatigue may make stress more difficult to cope with.[55] The latter has also been reported as an error-provoking condition for both prescribing errors[13,14] and medication errors more broadly.[56] One study has demonstrated that prescribers who are stressed and burnt out do not show an increase in medication errors, whereas colleagues who are experiencing depression have been shown to make more medication errors.[57] Another study, where a comparison with airline pilots was made, demonstrated that doctors may be worse at recognizing the potential impact that stress could have on their performance.[43] It has been suggested that healthcare learns from the experience of aviation, where pilots have been taught how to recognize and address performance limiters such as stress and fatigue.[58] Implementation of one such method, crew resource-management training, has been shown to improve stress recognition in an obstetrics unit.[59]

The way in which employees' shared attitudes, beliefs and values impact on how they perceive

and act on patient safety issues has been called the 'safety culture' of the organization.[60] Two important aspects of that safety culture are how employees communicate about safety issues and the provision of staff education and training.[60,61] Latent conditions were described in several included studies, where junior doctors did not question potential errors by senior doctors because of potentially negative consequences[14,25] and did not receive formal postgraduate prescribing training.[13,14] 'Shooting the messenger' and denial of the problem are two of 'The Seven Deadly Sins' suggested by Inman in recognizing and addressing patient safety.[62] The Manchester Patient Safety Assessment Framework, a typological qualitative tool to assess patient safety culture in the UK, would categorize such behaviour as being part of a 'pathological' safety culture, warranting reflection and action at an organizational level.[61]

There was clear evidence from several studies[13-15,21,25] that single prescribing errors can result from the interaction of multiple error-provoking conditions. Other authors stated that they had chosen the most important error-provoking condition, whilst recognizing that there could be more than one.[20] An in-depth analysis of a single, serious error clearly highlighted the intricate ways in which several error-provoking conditions (in this case, those concerning communication, education and supervision) could combine to cause an error.[25] Even the ward the patient was on when the error occurred could represent multiple, inter-related, error-provoking conditions: it could be a descriptor of the severity of illness of the patient (such as an intensive care unit or minor surgery unit), the speciality of the prescriber (intensivist or surgeon) and the different workload intensities in the two units. This finding is not unique to prescribing errors. Multiple error-provoking conditions have been attributed to causing other types of medication errors[56] and medical errors.[63]

5. Conclusion

This systematic review shows, from a small number of empirical studies, that prescribing errors are associated with potentially multiple causes and error-provoking conditions, often acting together. Prescribers could benefit from learning both technical skills (such as the application of domain knowledge regarding individual diseases and drugs) and non-technical skills (such as how to address stress or improve intra- and inter-professional communication).

However, the complexity of prescribing error causation means that simplistic solutions or quick fixes, which address a single cause, are likely to have only limited benefit. They would also not deal with the interconnectedness of the causation system. For example, changing to a shift pattern for doctors' hours, to reduce fatigue-mediated errors, could possibly increase errors predicated by poor communication between day and night teams. Existing complex solutions have been shown to address the problem only partially. E-prescribing systems, whilst reducing many types of prescribing errors, can give rise to new types of error, such as during the process of entering and retrieving information,[46,47] and are not a panacea for reducing all prescribing errors. Multiple barriers probably need to be put in place to help prevent, or minimize, the impact of errors that make it past defences earlier in the causal chain. Further rigorous study, such as using in-depth qualitative interviews, should be conducted to investigate the multifactorial nature of error causation, especially focusing on how error reduction methods might work. It is likely that multifactorial interventions and multiple defences across many parts of the system will be required to address this problem.

Acknowledgements

The authors would like to thank the members of our Expert Reference Group, Graham Buckley, Gary Cook, Dianne Parker, Lesley Pugsley and Mike Scott, for their helpful comments on our interim analysis.

This study was commissioned by the General Medical Council to contribute to the evidence-base informing policy developments. It is part of a programme of work to explore the prevalence and causes of prescribing errors made by first-year doctors, concentrating on the interplay between doctors' educational backgrounds and factors in the practice environment. None of the authors have any conflicts of interest to declare that are relevant to the content of this review.

References

1. Kohn L, Corrigan J, Donaldson M. To err is human: building a safer health system. Washington, DC: National Academy Press, 2000
2. Chief Medical Officer. An organisation with a memory: report of an expert group on learning from adverse events in the NHS. London: Stationery Office, 2000
3. Australian Council for Safety and Quality in Health Care. Patient safety: towards sustainable improvement. Fourth report to the Australian Health Ministers' Conference. Canberra (ACT): Australian Council for Safety and Quality in Health Care, 2003
4. Leape LL, Brennan TA, Laird N, et al. The nature of adverse events in hospitalized patients: results of the Harvard Medical Practice Study II. N Engl J Med 1991; 324 (6): 377-84
5. Classen DC, Pestotnik SL, Evans RS, et al. Adverse drug events in hospitalized patients: excess length of stay, extra costs, and attributable mortality. JAMA 1997; 277: 301-6
6. Bates DW, Spell N, Cullen DJ, et al. The costs of adverse drug events in hospitalized patients. JAMA 1997; 277: 307-11
7. Lewis P, Dornan T, Taylor D, et al. Systematic review of the prevalence, incidence and nature of prescribing errors in hospital inpatients. Drug Saf 2009; 32: 379-89
8. Department of Health. Building a safer NHS for patients: improving medication safety. London: The Stationery Office, 2004
9. Reason J. Human error. Cambridge: University of Cambridge, 1990
10. Neale G, Woloshynowych M, Vincent C. Exploring the causes of adverse events in NHS hospital practice. J R Soc Med 2001; 94 (7): 322-30
11. Buckley MS, Erstad BL, Kopp BJ, et al. Direct observation approach for detecting medication errors and adverse drug events in a pediatric intensive care unit. Pediatr Crit Care Med 2007; 8 (2): 145-52
12. Colpaert K, Claus B, Somers A, et al. Impact of computerized physician order entry on medication prescription errors in the intensive care unit: a controlled cross-sectional trial. Crit Care 2006; 10 (1): R21
13. Coombes ID, Stowasser DA, Coombes JA, et al. Why do interns make prescribing errors? A qualitative study. Med J Aust 2008; 188 (2): 89-94
14. Dean B, Schachter M, Vincent C, et al. Causes of prescribing errors in hospital inpatients: a prospective study. Lancet 2002; 359: 1373-8
15. Fijn R, Van den Bemt PM, Chow M, et al. Hospital prescribing errors: epidemiological assessment of predictors. Brit J Clin Pharmacol 2002; 53 (3): 326-31
16. Folli HL, Poole RL, Benitz WE. Medication error prevention by clinical pharmacists in two children's hospitals. Pediatrics 1987; 79: 718-22
17. Hendey GW, Barth BE, Soliz T. Overnight and postcall errors in medication orders. Acad Emerg Med 2005; 12 (7): 629-34
18. Ho L, Brown GR, Millin B. Characterization of errors detected during central order review. Can J Hosp Pharm 1992; 45 (5): 193-7
19. Kopp BJ, Erstad BL, Allen ME, et al. Medication errors and adverse drug events in an intensive care unit: direct observation approach for detection. Crit Care Med 2006; 34 (2): 415-25
20. Leape LL, Bates DW, Cullen DJ, et al., on behalf of the ADE Prevention Study Group. Systems analysis of adverse drug events. JAMA 1995; 274 (1): 35-43
21. Lederman RM, Parkes C. Systems failure in hospitals-using Reason's model to predict problems in a prescribing information system. J Med Syst 2005; 29 (1): 33-43
22. Lesar TS, Briceland L, Stein DS. Factors related to errors in medication prescribing. JAMA 1997; 277 (4): 312-7
23. Lesar TS, Lomaestro BM, Pohl H. Medication-prescribing errors in a teaching hospital: a 9-year experience. Arch Intern Med 1997; 157: 1569-76
24. Mandal K, Fraser SG. The incidence of prescribing errors in an eye hospital. BMC Ophthalmol 2005; 5: 4
25. Patterson ES, Cook RI, Woods DD, et al. Examining the complexity behind a medication error: generic patterns in communication. IEEE Trans Syst Man Cybern A Syst Hum 2004; 34 (6): 749-56
26. Vrca VB, Becirevic-Lacan M, Bozikov V, et al. Prescribing medication errors in hospitalised patients: a prospective study. Acta Pharmaceutica 2005; 55 (2): 157-67
27. Wilson DG, McArtney RG, Newcombe RG, et al. Medication errors in paediatric practice: insights from a continuous quality improvement approach. Eur J Pediatr 1998; 157 (9): 769-74
28. Dean Franklin B, Vincent C, Schachter M, et al. The incidence of prescribing errors in hospital inpatients: an overview of the research methods. Drug Saf 2005; 28 (10): 891-900
29. Bates DW, Cullen DJ, Laird N, et al. Incidence of adverse drug events and potential adverse drug events. JAMA 1995; 274: 29-34
30. Dean B, Barber N, Schachter M. What is a prescribing error? Qual Health Care 2000; 9: 232-7
31. National Co-ordinating Council for Medication Error Reporting and Prevention 2008. NCC MERP index for categorizing medication errors [online]. Available from URL: http://www.nccmerp.org/pdf/indexBW2001-06-12.pdf [Accessed 2008 Sep 26]
32. Ammenwerth E, Schnell-Inderst P, Machan C, et al. The effect of electronic prescribing on medication errors and adverse drug events: a systematic review. J Am Med Inform Assoc 2008; 15 (5): 585-600
33. Maxwell SR, Cascorbi I, Orme M, et al. Educating European (junior) doctors for safe prescribing. Basic Clin Pharmacol Toxicol 2007; 101 (6): 395-400
34. Tobaiqy M, McLay J, Ross S. Foundation year 1 doctors and clinical pharmacology and therapeutics teaching: a retrospective view in light of experience. Br J Clin Pharmacol 2007; 64 (3): 363-72
35. Han WH, Maxwell SR. Are medical students adequately trained to prescribe at the point of graduation? Views of first year foundation doctors. Scott Med J 2006; 51 (4): 27-32
36. Coombes ID, Mitchell CA, Stowasser DA. Safe medication practice: attitudes of medical students about to begin their intern year. Med Educ 2008; 42 (4): 427-31
37. Heaton A, Webb DJ, Maxwell SR. Undergraduate preparation for prescribing: the views of 2413 UK medical

students and recent graduates. Br J Clin Pharmacol 2008; 66 (1): 128-34

38. Molokwu CN, Sandiford N, Anosike C. Safe prescribing by junior doctors. Br J Clin Pharmacol 2008; 65 (4): 615-6
39. Brazil E, Macnamara AF, O'Connor N, et al. Accident and emergency medicine: still a useful 'apprenticeship'? Eur J Emerg Med 2002; 9 (3): 244-7
40. Bleakley A. Pre-registration house officers and ward-based learning: a 'new apprenticeship' model. Med Educ 2002; 36 (1): 9-15
41. Garbutt JM, Highstein G, Jeffe DB, et al. Safe medication prescribing: training and experience of medical students and housestaff at a large teaching hospital. Acad Med 2005; 80 (6): 594-9
42. Eraut M. Informal learning in the workplace. Stud Contin Educ 2004; 26: 247-73
43. Sexton JB, Thomas EJ, Helmreich RL. Error, stress, and teamwork in medicine and aviation: cross sectional surveys. BMJ 2000; 320 (7237): 745-9
44. Dean Franklin B, O'Grady K, Paschalides C, et al. Providing feedback to hospital doctors about prescribing errors: a pilot study. Pharm World Sci 2007; 29 (3): 213-20
45. Scobie SD, Lawson M, Cavell G, et al. Meeting the challenge of prescribing and administering medicines safely: structured teaching and assessment for final year medical students. Med Educ 2003; 37 (5): 434-7
46. Maxwell SR, McQueen DS, Ellaway R. eDrug: a dynamic interactive electronic drug formulary for medical students. Br J Clin Pharmacol 2006; 62 (6): 673-81
47. Smith A, Tasioulas T, Cockayne N, et al. Construction and evaluation of a web-based interactive prescribing curriculum for senior medical students. Brit J Clin Pharmacol 2006; 62 (6): 653-9
48. Gage S, Roberts D, Harris J, et al. Development of an all Wales drug chart, prescription writing standards and e-learning package [abstract]. Pharm World Sci 2005; 27: A21
49. Department of Health. e-Learning safe prescribing [online]. Available from URL: http://www.e-lfh.org.uk/Projects/Safe-Prescribing.aspx [Accessed 2008 Oct 9]
50. Gaba DM, Howard SK. Patient safety: fatigue among clinicians and the safety of patients. N Engl J Med 2002; 347 (16): 1249-55
51. Weinger MB, Ancoli-Israel S. Sleep deprivation and clinical performance. JAMA 2002; 287 (8): 955-7
52. Davydov L, Caliendo G, Mehl B, et al. Investigation of correlation between house-staff work hours and prescribing errors. Am J Health Syst Pharm 2004; 61 (11): 1130-4
53. Landrigan CP, Fahrenkopf AM, Lewin D, et al. Effects of the accreditation council for graduate medical education duty hour limits on sleep, work hours, and safety. Pediatrics 2008; 122 (2): 250-8
54. Mycyk MB, McDaniel MR, Fotis MA, et al. Hospitalwide adverse drug events before and after limiting weekly work hours of medical residents to 80. Am J Health Syst Pharm 2005; 62 (15): 1592-5
55. Firth-Cozens J, Cording H. What matters more in patient care? Giving doctors shorter hours of work or a good night's sleep? Qual Saf Health Care 2004; 13 (3): 165-6
56. Nichols P, Copeland TS, Craib IA, et al. Learning from error: identifying contributory causes of medication errors in an Australian hospital. Med J Aust 2008; 188 (5): 276-9
57. Fahrenkopf AM, Sectish TC, Barger LK, et al. Rates of medication errors among depressed and burnt out residents: prospective cohort study. BMJ 2008; 336 (7642): 488-91
58. Helmreich RL. On error management: lessons from aviation. BMJ 2000; 320 (7237): 781-5
59. Haller G, Garnerin P, Morales MA, et al. Effect of crew resource management training in a multidisciplinary obstetrical setting. Int J Qual Health Care 2008; 20 (4): 254-63
60. Kirk S, Marshall M, Claridge T, et al. Evaluating safety culture. In: Walshe K, Boaden R, editors. Patient safety: research into practice. Maidenhead: Open University Press, 2006: 173-84
61. National Patient Safety Agency. MaPSaF [online]. Available from URL: http://www.npsa.nhs.uk/nrls/improvingpatientsafety/humanfactors/mapsaf/ [Accessed 2008 Oct 22]
62. Inman WHW, Weber JCT. The United Kingdom. In: Inman WHW, editor. Monitoring for drug safety. 2nd ed. Lancaster: MTP Press Ltd, 1986: 13-47
63. Wu AW, Folkman S, McPhee SJ, et al. Do house officers learn from their mistakes? JAMA 1991; 265 (16): 2089-94

Correspondence: Dr *Mary P. Tully*, School of Pharmacy and Pharmaceutical Sciences, University of Manchester, Stopford Building, Oxford Road, Manchester, M13 9PT, UK.
E-mail: mary.tully@manchester.ac.uk