REVIEW ARTICLE

Drug Safety 2009; 32 (5): 379-389
0114-5916/09/0005-0379/$49.95/0

Prevalence, Incidence and Nature of Prescribing Errors in Hospital Inpatients

A Systematic Review

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

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 affect patient safety throughout hospital practice. Previous reviews of studies have often targeted specific populations or settings, or did not adopt a systematic approach to reviewing the literature. Therefore, we set out to systematically review the prevalence, incidence and nature of prescribing errors in hospital inpatients. MEDLINE, EMBASE, CINAHL and International Pharmaceutical Abstracts (all from 1985 to October 2007) were searched for studies of prescriptions for adult or child hospital inpatients giving enough data to calculate an error rate. Electronic prescriptions and errors for single diseases, routes of administration or types of prescribing error were excluded, as were non-English language publications. Median error rate (interquartile range [IQR]) was 7% (2–14%) of medication orders, 52 (8–227) errors per 100 admissions and 24 (6–212) errors per 1000 patient days. Most studies (84%) were conducted in single hospitals and originated from the US or UK (72%). Most errors were intercepted and reported before they caused harm, although two studies reported adverse drug events. Errors were most common with antimicrobials and more common in adults (median 18% of orders [ten studies, IQR 7–25%]) than children (median 4% [six studies, IQR 2–17%]). Incorrect dosage was the most common error.

Overall, it is clear that prescribing errors are a common occurrence, affecting 7% of medication orders, 2% of patient days and 50% of hospital admissions. However, the reported rates of prescribing errors varied greatly and this could be partly explained by variations in the definition of a prescribing error, the methods used to collect error data and the setting of the study. Furthermore, a lack of standardization between severity scales prevented any comparison of error severity across studies. Future research should address the wide disparity of data-collection methods and definitions that bedevils comparison of error rates or meta-analysis of different studies.

In recent years, the extent and impact of adverse events in healthcare settings has made patient safety a key aspect of healthcare policy. Specifically, the Harvard Medical Practice study found adverse events in at least 3.7% of admissions,[1] mostly associated with the use of medication. Adverse drug events (ADEs) can prolong hospitalization,[2] increase mortality risk 2-fold[2] and cause an estimated 7000 deaths/year in the US alone.[3] Moreover, a US study in 1997 estimated that ADEs cost a single teaching hospital $US5.6 million, $US2.8 million of which was preventable.[4] In the UK, preventable ADEs cost an estimated £750 million nationwide.[5]

The negative impact of preventable ADEs has thus stimulated attempts to understand the nature and extent of medication errors. They can occur at the prescribing, dispensing and administration stages of drug use, but are most likely to arise in prescribing.[6] Research into the prevalence or nature of prescribing errors has found no consistent pattern in the number or types of errors, or medications associated with them. Single-hospital studies found, for example, prescribing errors in 0.4–15.4% of prescriptions written in the US[7,8] and in 7.4–18.7% of those written in the UK.[9,10]

There have been previous attempts to synthesize data systematically from studies of prescribing errors.[11-14] However, they were either limited in scope (such as focusing on a particular patient group[11,12] or speciality[13]), concerned predominately with research methodology[14] or have incorporated all types of medication error.[15] None have focused on the prevalence or incidence of prescribing errors more generally. The aim of this systematic review was, for the first time, to identify all informative, published evidence concerning the prevalence, incidence and nature of prescribing errors in specialist and non-specialist hospitals, and collate, analyse and synthesize conclusions from it.

1. Literature Search Methodology

1.1 Search Strategy

The following electronic databases were searched: MEDLINE and MEDLINE In-process and other Non-Indexed Citations, EMBASE, CINAHL and International Pharmaceutical Abstracts, all from 1985 to October 2007. The search strategy was developed by two authors (PJL and DMA). Search terms included: 'error(s)';

'medication error(s)'; 'near miss(es)'; 'preventable adverse event(s)'; 'prescription(s)'; 'prescribe'; 'medication order(s)'; 'incident report(s)'; 'incidence'; 'rate(s)'; 'prevalence'; 'epidemiology'; 'inpatient(s)'; 'hospital(s)'; and 'hospitalization'. (Further details of the search strategy are available from the corresponding author). The reference lists of all included studies were searched for additional studies.

1.2 Inclusion and Exclusion Criteria

Studies published in English between 1985 and 2007 that reported on the detection and rate of prescribing errors in prescriptions handwritten for adult and/or child hospital inpatients were included. Systematic reviews, randomized controlled trials, non-randomized comparative studies and observational studies were all included. Abstracts were included if they provided sufficient data to calculate prescribing error rates (prevalence or incidence). Studies that only provided data on electronic prescriptions via computerized physician order entry (CPOE) were excluded. In addition, studies that evaluated errors for only one disease or drug class or for one route of administration or one type of prescribing error were excluded.

1.3 Data Abstraction and Validity Assessment

A data-extraction form was designed 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); definitions used; the error rate (including the nature of the denominator) [for studies investigating the impact of CPOE, only error rates for prescriptions that were handwritten were extracted from the study]; and any other relevant information captured by the study, such as severity of errors, type of error and medications commonly associated with errors. Two reviewers extracted relevant data from each publication independently and resolved any differences by discussion. If they could not achieve consensus, a third reviewer arbitrated.

1.4 Quantitative Data Analysis

The studies retrieved by the search were extremely heterogeneous but it was possible to group them by the type of denominator used and calculate median error rates and interquartile ranges (IQRs) across studies. Studies reporting medication errors were only included if it was possible to separate out the rate of prescribing errors. To be included, studies had to report the rate of erroneous orders, errors per admission or errors per patient day. Studies with an estimated denominator were excluded from the analysis of median rates. To facilitate comparison across studies, the latter rates were converted to common denominators: rates per 100 admissions and per 1000 patient days. When publications gave data from two or more studies where the methodology was similar, the results were aggregated into a median rate. We also explored differences between studies of adults and children and examined error rates in relation to methods of detection. The classification scheme of Thomsen and colleagues[16] provided a framework for extracting and reporting the types of medications involved and the types of errors.

2. Literature Search Results

The electronic search identified 595 publications. After initial screening of the abstracts, 493 publications did not meet the inclusion criteria. The remaining 102 publications were obtained in full text and assessed for suitability, as shown in figure 1. Searching of the reference lists of the included publications identified a further 12 eligible studies. In all, 63 publications were included, reporting 65 unique studies. The main reasons for exclusion were absent or insufficient data to calculate prevalence rates (n = 36); data included administration errors, outpatient prescriptions, and/or verbal and electronic prescriptions (n = 7); reported rates were of interventions or violations of policy not deemed errors (n = 5); and duplication of previously published data (n = 3).

2.1 Study Characteristics

2.1.1 Country and Date

Most studies were conducted in the US (25/65)[8,17-40] or the UK (22/65).[9,10,41-58] Other

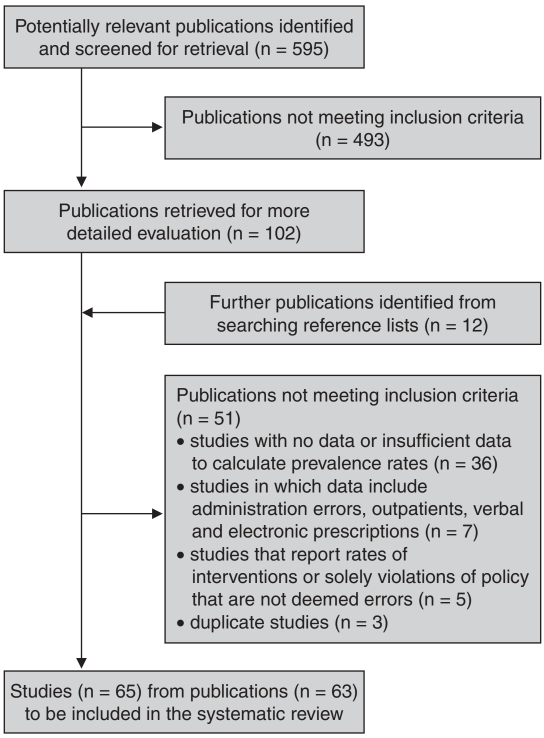

Fig. 1. Flow diagram of the screening process.

countries included Canada (n = 3),[59-61] the Netherlands (n = 3),[62-64] India (n = 2),[65,66] Australia (n = 2),[67,68] Israel (n = 2),[69,70] Croatia (n = 1),[71] Belgium (n = 1),[72] France (n = 1),[73] Denmark (n = 1),[74] Thailand (n = 1)[75] and Spain (n = 1).[76] Over two-thirds of studies were published after 2000 (46/65).

2.1.2 Types of Hospitals

Fifty-four percent of studies (35/65) were conducted in university-affiliated hospitals, 17% (11/65) took place in general hospitals and 6% (4/65) were carried out in both types of hospital. Six studies (9%) were conducted in paediatric hospitals. Two studies (4%) did not state the type of hospital.[25,67] The rest (11%, 7/65) were conducted in specialist hospitals such as mental health facilities.

2.1.3 Numbers of Hospitals

Eighty-four percent of studies (55/65) were carried out on single hospital sites, 11% (seven studies) were carried out in two hospital sites, 3% (two studies) in nine sites[21,56] and 2% (one study) in 24 sites.[54] However, studies carried out in more than two hospitals were conducted in one speciality only (paediatric intensive care unit [ICU],[21] ICU[54] and mental health[56]).

2.1.4 Specialties

Thirty-eight percent (25/65) of studies were carried out only in adult specialities or wards, 22% (14/65) included only children's specialties or were conducted exclusively in paediatric hospitals (including one study conducted purely in neonates[76]), 23% (15/65) included both adults and children, and the remaining 17% (11/65) did not state the age range of patients.

2.1.5 Study Design

Most studies (89%, 58/65) were prospective in design; 11% (7/65) were retrospective. The shortest period of data collection was 4 days[51] and the longest was 9 years.[32] Twenty-three (35%) of the studies were before-and-after studies, in which case-only data from the baseline or control arm were used. Eleven of these assessed the impact of CPOE on the number of prescribing errors[9,20,30,33,41,44,45,49,64,70,72] and the remainder assessed a variety of other interventions, such as the participation of clinical pharmacists on ward rounds[31,40] or the effect of educational interventions.[10]

Eighty-three percent (54/65) of studies were process-based, meaning they reported the findings of healthcare professionals reviewing prescriptions, usually as part of routine work.[14] This type of study does not intend to measure harm as the error is detected and reported to the prescriber before reaching the patient. Outcome-based studies only measuring actual patient harm by reporting ADEs[14] made up only 3% of included studies.[18,31] A small proportion (14%) of studies were both process- and outcome-based in that they investigated both incident reports (some of which included actual ADEs) and prescribing errors detected on prescriptions.

2.1.6 Methods of Error Detection

Data collectors were most commonly pharmacists (54/65, 83%). The most frequent method of detecting errors (25/65, 38%) was the screening of prescriptions. Eighteen percent (12/65) of studies also included prescription or prescription chart review, which was not necessarily part of routine work and which was sometimes carried out by healthcare professionals other than pharmacists. Four studies (6%)[26,31,41,71] detected prescribing errors by review of patients' medical records and five studies (8%)[30,58,65,68,75] used incident reporting. Almost one-third of studies (27%) used a combination of the above methods and some even included additional methods such as stimulated self report,[59] medication reconciliation[61] and interviews with other healthcare professionals.[42] Two studies did not state how prescribing errors were identified.[22,62]

2.1.7 Validation Review of Errors

Seventy-four percent (48/65) of studies employed a process to check the validity of part of or all the prescribing error data collected. The validation approach varied between studies, some (14%, 9/65) using consensus to rate the severity of errors. Fewer than half the studies (42%, 27/65) included review of the errors themselves, such as determination by a panel of clinicians as to whether reported errors fell within the study definitions and classification of those that did. Only 28% of studies (18/65) checked reported errors with the prescribing doctor to validate the claim that a prescribing error had occurred. Twenty-three percent of studies (15/65) did not report any process of review.

2.2 Definitions of Prescribing Errors

The definition of a prescribing error was extremely varied, with 42% of studies (27/65) developing their own definitions or modifying ones used in previous studies. Eleven studies (17%) used a definition of prescribing errors developed by Dean et al.[77] The 12 studies (18%) recording medication errors or ADEs provided definitions accordingly. Of these, two[24,74] used the American Society of Health-System Pharmacists criteria and two[26,76] used the National Coordinating Council for Medication Error Reporting and Prevention (NCCMERP) criteria. Nearly one-quarter of studies (23%) did not state any definition.

2.3 Prevalence and Incidence of Prescribing Errors

Five studies[52,62,67,71,76] either explicitly used prescription charts (with potentially multiple medication orders) or did not clearly state their denominator (whether order or chart). Four studies provided an estimated denominator[47-49,51] and were therefore excluded from the analysis. Studies reporting error rates per medication order, per patient and per patient day and that are included in the analysis are presented in table I of the supplementary material (see the supplementary material ['ArticlePlus'] at http://drugsafety.adisonline.com).

Many studies (51%, 33/65) reported the percentage of erroneous medication orders, the median of which was 7% (IQR 2–14%). Six studies did not make it clear whether orders were reported as having more than one error and could not, therefore, be included in the calculation.[17,22,33,39,60,69] Nineteen studies provided a rate of errors per admission, the median of which was 52 (IQR 8–227) errors per 100 admissions. This wide range in rates could partly be explained by different means of error detection, the lowest rate (0.4 errors per 100 admissions) being derived from incident reporting[75] and the highest rate (323 errors per 100 admissions) resulting from a combination of three methods of error detection.[46] Eleven studies provided an incidence of errors per patient days, the median of which was 24 (IQR 6–212) errors per 1000 patient days. The only two outcome-based studies included in this review reported incidences of errors per patient days,[18,31] the median of which was nine errors per 1000 patient days. A subgroup analysis of the remaining nine process-based studies gave a median incidence of 116 errors per 1000 patient days. The lowest incidence of errors was given by a study that used incident reports to detect errors[30] and the highest rate was given by a process-based, prospective study of error in an ICU.[72]

Subgroup analysis of studies reporting percentage of erroneous orders suggested that errors were more prevalent in adults than in children (median 18% [ten studies, IQR 7–25%] vs median 4% [six studies, IQR 2–17%]).

2.4 Medications Involved in Prescribing Errors

Twenty-two studies (34%) detailed the medications most commonly associated with prescribing errors, and those providing quantitative data are summarized in table II of the supplementary material. Four studies gave information about the classes of medication associated with medication error; however, class-specific prevalence rates could not be determined.[18,29,38,59] Antimicrobials, with a median error prevalence of 32% of orders, were the class most commonly associated with error, particularly in children where all five studies found antimicrobials to be most commonly associated. Other common associations were with drugs acting on the cardiovascular system (median prevalence, 17%), CNS (median prevalence, 8%) and gastrointestinal medications (median prevalence, 8%). Errors involving fluids, electrolytes and parenteral nutrition had a median prevalence of 9%.

2.5 Types of Prescribing Errors Detected

Sixty-five percent of studies (42/65) reported on the types of errors, of which 33, shown in table III (see supplementary material), provided percentages for error types. Five studies focused specifically on admission or discharge and were therefore excluded from the table as it was likely the types of error would be quite specific (i.e. errors of omission). Dosage errors were the most commonly reported error (18/33 studies), the remainder being accounted for by incomplete prescription orders, omission of therapy, illegibility, errors in dosage interval, incorrect formulation, drug-drug interactions and transcription errors. Seven studies[23,25,33,35,58,65,75] listed the most frequent types of prescribing errors in paediatric practice. Five of the seven (71%)[23,35,58,65,75] found dosage errors to be the most common, and the remaining two studies found errors of omission to be the most common.[25,33]

2.6 Severity of Detected Prescribing Errors

Many studies (74%, 48/65) attempted to classify the severity of errors; however, some (8/48) did not distinguish prescribing errors from errors in administration and dispensing. Two studies, which stated they recorded severity, did not report severity data. Of those that reported severity, three studies[20,63,64] rated severity according to their own modification of the NCCMERP index for categorizing medication errors,[78] one study[43] used criteria set out by the UK National Patient Safety Agency[79] to rate severity and two studies[19,34] based their criteria on the work of others such as Folli et al.[23] Remaining studies provided their own classification of prescribing-error severity. This disparity made it impossible to compare severity across studies.

3. Discussion

This is the first systematic review of the prevalence, incidence and nature of prescribing errors in hospital inpatients. It shows that a high rate of prescribing errors is an international problem. The median rates of prescribing errors using three different denominators were 7% (IQR 2–14%) of medication orders, 52 (IQR 8–227) errors per 100 admissions and 24 (IQR 6–212) errors per 1000 patient days. A key strength of our review was the range of databases searched. It is possible that studies reporting error prevalence or incidence were published in journals not indexed by the databases. To reduce that risk, we conducted a search of the reference lists of the included studies. However, only studies published in English were included and there may have been studies written in other languages that were not detected.

The reported rates of prescribing errors vary remarkably, as demonstrated by the wide IQRs. This variability can be partly explained by differences in study methods; for example, outcome-based studies inevitably yielded much lower error rates than process-based studies as actual patient harm is not an inevitable outcome of a prescribing error. However, that does not explain all the variability because most studies were process-based.

The method used to detect errors may have been a more important source of variability; for example, studies relying on incident reports often had very low error rates, probably as a result of under-reporting.[80] Review of patient records identified more errors but still only those noted in the records and therefore this approach remains vulnerable to incomplete documentation.[81] Furthermore, the retrospective nature of record review gave little opportunity for follow-up. Studies that identified errors during prescription review were likely to be the most comprehensive[14] and accurate, yet there was still great variation between rates derived from that method of error detection. Furthermore, the use of more than one means of error detection introduced yet further variability, although the higher rates that resulted from more comprehensive ascertainment may have been closer to the actual prevalence.

Another important consideration was inconsistency in the definition of prescribing errors, with most studies using their own bespoke definitions. Even when definitions were given, some were subjective. For example, a prescribing error is 'a prescription not appropriate for the patient'[9] or 'any omitting or incorrect ordering of a medication that was critical for the overall care of the patient in the judgement of one of the investigators'.[8] However, others were very specific in their definition: 'a prescribing error is an incorrect drug selection (based on indications, contraindications, known allergies, existing drug therapy and other factors), dose, dosage form, quantity, route, concentration, rate of administration, or instructions for use of a drug product ordered or authorized by a physician (or other legitimate prescriber); illegible prescriptions or medications or orders that lead to errors that reach the patient; or use of non-standard nomenclature or abbreviations'.[21] Reviews in paediatric[12,19] and mental[13] healthcare have also found large variations in how prescribing errors were defined. This source of variability has resulted in the formulation of a practitioner-led definition of a prescribing error.[77] That definition was the one most commonly used, albeit in only 17% of studies.

Whilst the evidence base as a whole was characterized by variability, there were specific limitations in individual studies, such as poor classification of errors. Fewer than half of studies reported any system of error validation. Most did not state whether there was any discussion of errors with the original prescriber. The finding in one study that 13% of errors detected by a pharmacist were not accepted by the prescriber[69] suggests a discrepancy between observers' and the prescribers' perceptions of error. Classification of errors by the data collector without the input of others could result in bias. Furthermore, one study showed variability in error detection and classification between data collectors despite training.[50] Few studies commented self-critically upon this source of potential bias.

Other limitations of the included studies were the short duration of data collection and the use of estimated denominators in some studies. Although not a limitation *per se*, the location and type of study site may also have affected the reported rates and types of prescribing errors. Some studies were conducted in specific contexts such as psychiatric hospitals[51] or ICUs,[54] whereas others focused on a particular stage of the patient's stay in hospital such as admission[25,42,43] or discharge.[8,28,34] These studies showed higher numbers of particular types of error such as duplication or omission. Furthermore, most studies were on single sites and there were no studies of larger numbers of errors in non-specialist hospitals. With this in mind, future studies could usefully apply the same methods to record prescribing errors across numerous non-specialist sites.

The severity of detected prescribing errors is important information because, without it, we cannot evaluate the potential harm that could result from them. For example, our results have shown that antimicrobials are associated with the most errors, yet studies have shown that it is cardiovascular medications that are associated with the most preventable ADEs.[16] However, the lack of standardization between severity scales made it impossible to compare results directly.

We found errors of dosage to be the most commonly reported type of prescribing error, as was also reported from a systematic review of medication errors in children.[12] Winterstein et al.[6] also found dosage errors to be the most common type of medication error and that most medication errors were initiated during prescribing. Furthermore, clinical negligence claims are most often associated with errors in dose, strength or frequency.[5] So, there is an obvious target for preventive measures, some of which are already being put into place by means of CPOE systems. Previous research in the US has shown that a computer-assisted antimicrobial management programme can reduce ADEs and costs,[82] a finding that might be extended to other healthcare settings. Interestingly, some studies we reviewed were designed to determine the effect of CPOE on error rates[44,49] and they found improvements in dosage errors and errors of omission. However, they also reported errors unseen with paper-based prescriptions, such as double prescriptions.[72] Work in this area has also highlighted that there can be many unintended consequences of CPOE including both positive and negative effects.[83] As well as improvements in systems, education has been highlighted as an area for improvement.[6] A survey of junior doctors in the UK found that doctors themselves would welcome more teaching in clinical pharmacology, particularly covering drug dosing.[84]

What was also apparent in this review was the importance of healthcare professionals in the process of error detection. Pharmacists were particularly well placed to collect data on errors and were commonly recruited for that purpose. Furthermore, a study by Phansalkar et al.[85] found that pharmacists were the most thorough when conducting chart reviews. Despite this, some errors may remain undetected.

4. Conclusions

Prescribing errors are common, affecting a median of 7% of medication orders, 2% of patient days and 50% of hospital admissions. The majority of included studies were process-based and used pharmacists to collect data. Antimicrobials and drug dosages were most frequently associated with errors. However, the ranges around these findings are very broad and, to some degree, are conditional upon each study's purpose, setting and methods. The lack of standardization between different studies, especially around definitions and data-collection methods, was a barrier to understanding the extent of prescribing errors and is an obvious area of development for future research. If standardization could be achieved, the results of individual studies could more confidently be combined, providing a clearer picture of the prevalence, incidence and nature of prescribing errors. Despite the difficulty of aggregating error data, our findings highlight that this is an important area for future research, in both methodology and intervention, to ensure patient safety.

Acknowledgements

The authors would like to thank Kathryn Bell for her assistance with data extraction.

This systematic review was commissioned by the UK General Medical Council to contribute to the evidence base informing policy developments. The authors have no conflicts of interest that are directly relevant to the content of this review.

The protocol was designed by all authors. The searches were designed by Penny J. Lewis and Darren M. Ashcroft and conducted by Penny J. Lewis. All authors were involved in extracting data from the publications. Penny J. Lewis and Darren M. Ashcroft analysed the results and Penny J. Lewis prepared the first draft of the review. All authors commented on subsequent drafts.

References

1. Brennan TA, Leape LL, Laird NM, et al. Incidence of adverse events and negligence in hospitalized patients: results of the Harvard Medical Practice Study I. N Engl J Med 1991 Feb; 324 (6): 370-6
2. 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 Jan; 277 (4): 301-6
3. Phillips DP, Christenfeld N, Glynn LM. Increase in US medication-error deaths between 1983 and 1993. Lancet 1998 Feb; 351 (9103): 643-4
4. Bates DW, Spell N, Cullen DJ, et al. The costs of adverse drug events in hospitalized patients. Adverse Drug Events Prevention Study Group. JAMA 1997 Jan; 277 (4): 307-11
5. National Patient Safety Agency. Safety in doses: medication safety incidents in the NHS report [online]. Available from URL: http://www.npsa.nhs.uk/nrls/alerts-and-directives/directives-guidance/safety-in-doses/ [Accessed 2009 Mar 5]
6. Winterstein AG, Johns TE, Rosenberg EI, et al. Nature and causes of clinically significant medication errors in a

tertiary care hospital. Am J Health Syst Pharm 2004 Sep; 61 (18): 1908-16

7. Lesar TS, Briceland L, Stein DS. Factors related to errors in medication prescribing. JAMA 1997 Jan; 277 (4): 312-7
8. Morrill GB, Barreuther C. Screening discharge prescriptions. Am J Hosp Pharm 1988 Sep; 45 (9): 1904-5
9. Fowlie F, Benniw M, Jardine G, et al. Evaluation of an electronic prescribing and administration system in a British hospital [abstract]. Pharm J 2000 Sep; 265 (7114): R16
10. Gethins B. Wise up to medication errors. Pharm Pract 1996 Oct; 6: 323-8
11. Wong IC, Ghaleb MA, Franklin BD, et al. Incidence and nature of dosing errors in paediatric medications: a systematic review. Drug Saf 2004; 27 (9): 661-70
12. Ghaleb MA, Barber N, Franklin BD, et al. Systematic review of medication errors in pediatric patients. Ann Pharmacother 2006 Oct; 40 (10): 1766-76
13. Maidment ID, Lelliott P, Paton C. Medication errors in mental healthcare: a systematic review. Qual Saf Health Care 2006 Dec; 15 (6): 409-13
14. Franklin BD, 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
15. Allan EL, Barker KN. Fundamentals of medication error research. Am J Hosp Pharm 1990 Mar; 47 (3): 555-71
16. Thomsen LA, Winterstein AG, Sondergaard B, et al. Systematic review of the incidence and characteristics of preventable adverse drug events in ambulatory care. Ann Pharmacother 2007 Sep; 41 (9): 1411-26
17. Anderson JG, Jay SJ, Anderson M, et al. Evaluating the potential effectiveness of using computerized information systems to prevent adverse drug events. Proc AMIA Annu Fall Symp 1997; 228-32
18. Bates DW, Cullen DJ, Laird N, et al. Incidence of adverse drug events and potential adverse drug events: implications for prevention. JAMA 1995; 274 (1): 29-34
19. Blum KV, Abel SR, Urbanski CJ, et al. Medication error prevention by pharmacists. Am J Hosp Pharm 1988 Sep; 45: 1902-3
20. Bobb A, Gleason K, Husch M, et al. The epidemiology of prescribing errors: the potential impact of computerized prescriber order entry. Arch Intern Med 2004 Apr; 164 (7): 785-92
21. Cimino MA, Kirschbaum MS, Brodsky L, et al. Assessing medication prescribing errors in pediatric intensive care units. Pediatr Crit Care Med 2004 Mar; 5 (2): 124-32
22. Edwards KL, Todd MW, Hogan TT. Evaluation of prescribing errors in a teaching hospital [abstract]. ASHP Midyear Clinical Meeting 1996 Dec; 31: 61E
23. Folli HL, Poole RL, Benitz WE, et al. Medication error prevention by clinical pharmacists in two children's hospitals. Pediatrics 1987 May; 79 (5): 718-22
24. Fox GD, Restino MS, Byerly WG, et al. Identification of prescribing error patterns in a teaching hospital [abstract]. ASHP Midyear Clinical Meeting 1997 Dec; 32: 139E
25. Granberry HE, Wright CC, Oldag KL, et al. Admission medication order reconciliation for pediatric patients [abstract]. ASHP Midyear Clinical Meeting 2005; 40: 95D
26. Grasso BC, Genest R, Jordan CW, et al. Use of chart and record reviews to detect medication errors in a state psychiatric hospital. Psychiatr Serv 2003 May; 54 (5): 677-81
27. Hendey GW, Barth BE, Soliz T. Overnight and postcall errors in medication orders. Acad Emerg Med 2005 Jul; 12 (7): 629-34
28. Johnson KB, Butta JK, Donohue PK, et al. Discharging patients with prescriptions instead of medications: sequelae in a teaching hospital. Pediatrics 1996 Apr; 97 (4): 481-5
29. Kaushal R, Bates DW, Landrigan C, et al. Medication errors and adverse drug events in pediatric inpatients. JAMA 2001 Apr; 285 (16): 2114-20
30. King WJ, Paice N, Rangrej J, et al. The effect of computerized physician order entry on medication errors and adverse drug events in pediatric inpatients. Pediatrics 2003; 112 (3): 506-9
31. Leape LL, Cullen DJ, Clapp MD, et al. Pharmacist participation on physician rounds and adverse drug events in the intensive care unit. JAMA 1999 Jul; 282 (3): 267-70
32. Lesar TS, Lomaestro BM, Pohl H. Medication-prescribing errors in a teaching hospital: a 9-year experience. Arch Intern Med 1997 Jul; 157 (14): 1569-76
33. Potts AL, Barr FE, Gregory DF, et al. Computerized physician order entry and medication errors in a pediatric critical care unit. Pediatrics 2004 Jan; 113 (1): 59-63
34. Schumock GT, Guenette AJ, Keys TV, et al. Prescribing errors for patients about to be discharged from a university teaching hospital [letter]. Am J Hosp Pharm 1994 Sep; 51: 15
35. StClair AT, Ofosu JR. Tracking potential prescribing errors in a pediatric teaching hospital [abstract]. ASHP Midyear Clinical Meeting 1995 Dec; 30: P202
36. Terceros Y, Chahine-Chakhtoura C, Malinowski JE, et al. Impact of a pharmacy resident on hospital length of stay and drug-related costs. Ann Pharmacother 2007; 41 (5): 742-8
37. Togashi CT, Akahoshi PC, Lamp CD, et al. Pharmacist intervention of medication prescribing errors in a university teaching hospital [abstract]. ASHP Midyear Clinical Meeting 1991 Dec; 26: P327E
38. Wang JK, Herzog NS, Kaushal R, et al. Prevention of pediatric medication errors by hospital pharmacists and the potential benefit of computerized physician order entry. Pediatrics 2007 Jan; 119 (1): E77-85
39. West DW, Levine S, Magram G, et al. Pediatric medication order error rates related to the mode of order transmission. Arch Pediatr Adolesc Med 1994 Dec; 148 (12): 1322-6
40. Scarsi KK, Fotis MA, Noskin GA. Pharmacist participation in medical rounds reduces medication errors. Am J Health Syst Pharm 2002 Nov; 59 (21): 2089-92
41. Barber N, Franklin BD, Cornford T, et al. Safer, faster, better? Evaluating electronic prescribing: report to the Patient Safety Research Programme 2006 [online]. Available from URL: http://www.pcpoh.bham.ac.uk/publichealth/psrp/documents/PS019_Final_Report_Barber.pdf [Accessed 2008 Jul 2]
42. McFadzean E, Isles C, Moffat J, et al. Is there a role for a prescribing pharmacist in preventing prescribing errors in a medical admission unit? Pharm J 2003 Jun; 270: 896-9

43. Rees S, Thomas P, Shetty A, et al. Drug history errors in the acute medical assessment unit quantified by use of the NPSA classification. Pharm J 2007 Oct; 279: 469-71
44. Shulman R, Singer M, Goldstone J, et al. Medication errors: a prospective cohort study of hand-written and computerised physician order entry in the intensive care unit. Crit Care 2005 Oct; 9 (5): R516-21
45. Tully MP, Parker D, Buchan I, et al. Patient safety research programme. Medication errors 2: pilot study. Report prepared for the Department of Health, 2006 [online]. Available from URL: http://www.pcpoh.bham.ac.uk/publichealth/psrp/documents/PS020_Final_Report_Cantril.pdf [Accessed 2008 Jul 2]
46. Dale A, Copeland R, Barton R. Prescribing errors on medical wards and the impact of clinical pharmacists. Int J Pharm Pract 2003; 11 (1): 19-24
47. Dean B, Schachter M, Vincent C, et al. Prescribing errors in hospital inpatients: their incidence and clinical significance. Qual Saf Health Care 2002 Dec; 11 (4): 340-4
48. Dobrzanski S, Hammond I, Khan G, et al. The nature of hospital prescribing errors. Br J Clin Gov 2002; 7 (3): 187-93
49. Franklin BD, O'Grady K, Donyai P, et al. The impact of a closed-loop electronic prescribing and administration system on prescribing errors, administration errors and staff time: a before-and-after study. Qual Saf Health Care 2007; 16 (4): 279-84
50. Franklin BD, O'Grady K, Paschalides C, et al. Providing feedback to hospital doctors about prescribing errors: a pilot study. Pharm World Sci 2007 Jun; 29 (3): 213-20
51. Haw C, Stubbs J. Prescribing errors at a psychiatric hospital. Pharm Pract 2003; 13 (2): 64-6
52. Mandal K, Fraser SG. The incidence of prescribing errors in an eye hospital. BMC Ophthalmology 2005 Mar 22; 5 (1): 4
53. Olsen S, Neale G, Schwab K, et al. Hospital staff should use more than one method to detect adverse events and potential adverse events: incident reporting, pharmacist surveillance and local real-time record review may all have a place. Qual Saf Health Care 2007 Feb; 16 (1): 40-4
54. Ridley SA, Booth SA, Thompson CM. Prescription errors in UK critical care units. Intensive Care Society's Working Group on Adverse Incidents. Anaesthesia 2004 Dec; 59 (12): 1193-200
55. Sagripanti M, Dean B, Barber N. An evaluation of the process-related medication risks for elective surgery patients from pre-operative assessment to discharge. Int J Pharm Pract 2002; 10 (3): 161-70
56. Stubbs J, Haw C, Taylor D. Prescription errors in psychiatry-a multi-centre study. J Psychopharmacol 2006; 4: 553-61
57. Webbe D, Dhillon S, Roberts CM. Improving junior doctor prescribing: the positive impact of a pharmacist intervention. Pharm J 2007 Feb; 278 (7437): 136-8
58. Wilson DG, McArtney RG, Newcombe RG, et al. Medication errors in paediatric practice: insights from a continuous quality improvement approach. Eur J Pediatr 1998 Sep; 157 (9): 769-74
59. Forster AJ, Halil RB, Tierney MG. Pharmacist surveillance of adverse drug events. Am J Health Syst Pharm 2004; 61 (14): 1466-72
60. Ho L, Brown GR, Millin B. Characterization of errors detected during central order review. C J Hosp Pharm 1992; 45 (5): 193-7
61. Vira T, Colquhoun M, Etchells E. Reconcilable differences: correcting medication errors at hospital admission and discharge. Qual Saf Health Care 2006; 15 (2): 122-6
62. Fijn R, Van den Bemt PM, Chow M, et al. Hospital prescribing errors: epidemiological assessment of predictors. Br J Clin Pharmacol 2002 Mar; 53 (3): 326-31
63. Van den Bemt PMLA, Postma MJ, Van Roon EN, et al. Cost-benefit analysis of the detection of prescribing errors by hospital pharmacy staff. Drug Saf 2002; 25 (2): 135-43
64. Van Gijssel-Wiersma DG, Van den Bemt PM, Walenbergh-van Veen MC. Influence of computerised medication charts on medication errors in a hospital. Drug Saf 2005; 28 (12): 1119-29
65. Aneja S, Bajaj G, Mehandiratta SK. Errors in medication in a pediatric ward. Indian Pediatr 1992 Jun; 29 (6): 727-30
66. Pote S, Tiwari P, D'Cruz S. Medication prescribing errors in a public teaching hospital in India: a prospective study. Pharm Pract 2007; 5 (1): 17-20
67. Dawson KP, Penna AC, Drummond D, et al. Prescription errors in a children's ward: audit and intervention. Aust J Hosp Pharm 1993; 23 (5): 326-8
68. Parke J. Risk analysis of errors in prescribing, dispensing and administering medications within a district hospital. J Pharm Pract Res 2006; 36 (1): 21-4
69. Lustig A. Medication error prevention by pharmacists: an Israeli solution. Pharm World Sci 2000 Feb; 22 (1): 21-5
70. Oliven A, Michalake I, Zalman D, et al. Prevention of prescription errors by computerized, on-line surveillance of drug order entry. Int J Med Inf 2005 Jun; 74 (5): 377-86
71. Baci VV, Beirevi-Laan M, Bozikov V, et al. Prescribing medication errors in hospitalised patients: a prospective study. Acta Pharmaceutica 2005 Jun; 55 (2): 157-67
72. 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 Feb; 10 (1): R21
73. Lepaux DJ, Schmitt E, Dufay E. Fighting medication errors: results of a study and reflections on causes and ways for prevention. Int J Risk Saf Med 2002; 15 (4/3): 203-11
74. Lisby M, Nielsen LP, Mainz J. Errors in the medication process: frequency, type, and potential clinical consequences. Int J Qual Health Care 2005; 17 (1): 15-22
75. Sangtawesin V, Kanjanapattanakul W, Srisan P, et al. Medication errors at Queen Sirikit National Institute of Child Health. J Med Assoc Thai 2003 Aug; 86 Suppl. 3: S570-5
76. Villegas AC, Lopez Herrara M, Lopez De Heredia I, et al. Medication errors in a neonatal intensive care unit (NICU) [abstract]. Patient Safety Research – Shaping the European Agenda Conference; 2007 Sep 24-26; Porto
77. Dean B, Barber N, Schachter M. What is a prescribing error? Qual Saf Health Care 2000 Dec; 9 (4): 232-7

78. NCC MERP Index for catorgorizing medication errors [online]. Available from URL: http://www.nccmerp.org/pdf/indexBW2001-06-12.pdf [Accessed 2008 Jul 5]
79. NPSA risk assessment tool for assessing the level of investigation required, and the external reporting requirements to the NPSA, following adverse incidents involving patients [online]. Available from URL: http://www.npsa.nhs.uk/site/media/documents/537_annex%20f%20npsa%20risk%20assessment%20tool.doc [Accessed 2008 Jul 2]
80. Nuckols TK, Bell DS, Liu H, et al. Rates and types of events reported to established incident reporting systems in two US hospitals. Qual Saf Health Care 2007 Jun; 16 (3): 164-8
81. Thomas EJ, Petersen LA. Measuring errors and adverse events in health care. J Gen Intern Med 2003 Jan; 18 (1): 61-7
82. Evans RS, Pestotnik SL, Classen DC, et al. A computer-assisted management program for antibiotics and other antiinfective agents. N Engl J Med 1998 Jan; 338 (4): 232-8
83. Ash JS, Sittig DF, Poon EG, et al. The extent and importance of unintended consequences related to computerized provider order entry. J Am Med Inform Assoc 2007 Jul; 14 (4): 415-23
84. 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 Sep; 64 (3): 363-72
85. Phansalkar S, Hoffman JM, Nebeker JR, et al. Pharmacists versus non-pharmacists in adverse drug event detection: a meta-analysis and systematic review. Am J Health Syst Pharm 2007 Apr; 64 (8): 842-9

Correspondence: Dr *Penny J. Lewis*, School of Pharmacy and Pharmaceutical Sciences, University of Manchester, Stopford Building, Oxford Rd, Manchester, M13 9PT, UK.
E-mail: penny.lewis@manchester.ac.uk

