

SYSTEMATIC REVIEW

Strategies to reduce medication errors with reference to older adults

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Abstract

Background In Australia, around 59% of the general population uses prescription medication with this number increasing to about 86% in those aged 65 and over and 83% of the population over 85 using two or more medications simultaneously. A recent report suggests that between 2% and 3% of all hospital admissions in Australia may be medication related with older Australians at higher risk because of higher levels of medicine intake and increased likelihood of being admitted to hospital. The most common medication errors encountered in hospitals in Australia are prescription/medication ordering errors, dispensing, administration and medication recording errors. Contributing factors to these errors have largely not been reported in the hospital environment. In the community, inappropriate drugs, prescribing errors, administration errors, and inappropriate dose errors are most common.

Objectives To present the best available evidence for strategies to prevent or reduce the incidence of medication errors associated with the prescribing, dispensing and administration of medicines in the older persons in the acute, subacute and residential care settings, with specific attention to persons aged 65 years and over.

Search strategy Bibliographic databases PubMed, Embase, Current contents, The Cochrane Library and others were searched from 1986 to present along with existing health technology websites. The reference lists of included studies and reviews were searched for any additional literature.

Selection criteria Systematic reviews, randomised controlled trials and other research methods such as non-randomised controlled trials, longitudinal studies, cohort or case-control studies, or descriptive studies that evaluate strategies to identify and manage medication incidents. Those people who are involved in the prescribing, dispensing or administering of medication to the older persons (aged 65 years and older) in the acute, subacute or residential care settings were included. Where these studies were limited, evidence available on the general patient population was used.

Data collection and analysis Study design and quality were tabulated and relative risks, odds ratios, mean differences and associated 95% confidence intervals were calcu-

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lated from individual comparative studies containing count data where possible. All other data were presented in a narrative summary.

Results Strategies that have some evidence for reducing medication incidents are:

- computerised physician ordering entry systems combined with clinical decision support systems;
- individual medication supply systems when compared with other dispensing systems such as ward stock approaches;
- use of clinical pharmacists in the inpatient setting;
- checking of medication orders by two nurses before dispensing medication;
- a Medication Administration Review and Safety committee; and
- providing bedside glucose monitors and educating nurses on importance of timely insulin administration.

In general, the evidence for the effectiveness of intervention strategies to reduce the incidence of medication errors is weak and high-quality controlled trials are needed in all areas of medication prescription and delivery.

Key words: intervention studies, medication errors, nursing, prevention.

Introduction

Background

In Australia, around 59% of the general population uses prescription medication with this number increasing to about 86% in those aged 65 and over, and with 83% of the population over 85 using two or more medications simultaneously.¹

A recent report suggests that between 2% and 3% of all hospital admissions in Australia may be medication related.² The Harvard Medical Practice study in the USA found that in hospital patients disabled by some form of medical treatment, 19% of recorded adverse events were related to medications.³

Older Australians have higher rates of medication incidents because of higher levels of medicine intake and increased likelihood of being admitted to hospital (hospital statistics being the main source of medication incident reporting).⁴

In the community setting, it has been estimated that up to 400 000 adverse drug events may be managed in general practices each year in Australia.⁴

The financial burden is staggering with one estimate putting the cost of preventable medication errors in the USA alone between \$17 and \$29 billion per year.⁵ In Australia, the cost has been estimated at over \$350 million annually.²

What are the types and causes of medication errors?

Studies examining the types and causes of medication errors occurring in older adults (≥ 65 years) are limited. However, evidence is available on the general population and is taken

to be representative of those issues that would arise in the geriatric setting. Where specific reference to older adults is found, it is highlighted in this report.

In a recent review by the Australian Council for Safety and Quality in Health Care, the types of medication errors most frequently encountered in an Australian healthcare setting and their likely causes were presented.⁴ The results of this report present the best data with a particular focus on Australia that is presently available and are summarised as follows.

Errors in hospital. The most common errors related to medication that are encountered in hospitals in Australia are:

- prescription/medication ordering errors;
- dispensing errors;
- errors in administration of medicines; and
- errors in the medication record.

Table 1 Types of medication errors in general medical practice

Type of incident	Rate per 100 incidents
Inappropriate drug	30
Prescribing error	22
Administration error	18
Inappropriate dose	15
Side-effect	13
Allergic reaction	11
Dispensing error	10
Overdose	8
System inadequacies	7
Drug omitted or withheld	6

Source: Australian Council for Safety and Quality in Health Care (2002, p. 33).⁴

Data from the Australian Incident Monitoring System showed that most medication incidents occurring in hospital were categorised as omissions (>25%), overdoses (20%), wrong medicines (10%), drug of addiction discrepancy (<5%), incorrect labelling (<5%) or an adverse drug reaction (<5%). However, little is known as to why medication errors occur in Australian hospitals. Failure to read, or misreading the chart, and a lack of robust systems for prescribing and ordering were suggested as the reasons for most of these errors.⁴

Errors can occur at any step in the medication process. A recent Australian review has attempted to describe the types of medication errors at each stage in the process, which is summarised as follows.⁴

Prescription/medication ordering errors. Medication errors occur during the prescribing or interpretation/trans-lation of orders from one document to another.

Based on limited Australian data on prescription errors, approximately 2% of all prescriptions have the potential to cause an adverse event with the most common causes being the wrong or ambiguous dose, missing dose, or the directions for use were unclear or absent. This can be compared with other countries in which the medication error rates have been reported to be between 2% and 7%.⁶

Dispensing errors. Dispensing errors occurring within the hospital pharmacy have not been comprehensively studied. Error rates have been reported to range from 0.08% to 0.8% of all items dispensed. However, the causes and the potential for adverse events have not been reported.⁴

Errors in administration of medicines. These errors occur when different patient medication supply systems are used.

When patients are given medicines from a common ward supply, error rates are between 15% and 20% compared with error rates of between 5% and 8% when individual patient medicine supplies are provided.⁴

Timing errors as high as 8% of administered doses have been shown to occur as a result of a patient being provided with a medicine at least 1 h before or 1 h after the scheduled time. These errors occur most likely because of time constraints and are unlikely to cause harm in the majority of cases.⁴

Errors in the medication record. A common error is the lack of documentation of previous adverse drug reactions and allergies. Australian studies have found that previously known adverse drug reactions were not recorded in 75–77% of cases evaluated. In another study 8% of cases had omissions of known allergic reactions in patient records. The causes and potential for adverse drug events were not described.⁴

Table 2 Factors contributing to incidents in general practice

Contributing factor	Rate per 100 incidents
Poor communication between patient and health professionals	23
Action of others (not general practitioner or patient)	23
Error of judgement	22
Poor communication between health professionals	19
Patient consulted other medical officer	15
Failure to recognise signs and symptoms	15
Patient's history not adequately reviewed	13
Omission of checking procedure	10
General practitioner tired, rushed or running late	10
Patient misunderstood their problem and/or treatment	10
Inadequate patient assessment	10

No correlation between these contributing factors and the resulting incident (Table 1) was made.

Source: Australian Council for Safety and Quality in Health Care (2002, p. 33).⁴

Errors in the community setting. The review described medication incidents in general practice and community pharmacies.⁴ General practitioners (GPs) and pharmacists were asked to provide explanation as to why the medication incidents occurred.

General practice. The types of medication incidents most commonly reported are described in Table 1. The factors contributing to these errors are summarised in Table 2.

Pharmacies. The most common types of dispensing errors reported by pharmacists are the selection of the incorrect strength, incorrect product or misinterpretation of a prescription. The major reason for selecting the incorrect strength or product has been described as the result of 'look alike' or 'sound alike' error.

The report⁴ describes an Australian survey of 209 community pharmacists where the major factors cited for contributing to dispensing errors were cited as:

- high prescription volume;
- overwork;
- fatigue;
- interruptions to dispensing; and
- 'look alike, sound alike' drug names.

Other factors that contribute to medication errors. The review also described other possible factors that could contribute to medication error.⁴

Inadequate continuity of care. Medication histories upon admission or discharge from hospital are often incomplete. Studies reviewing discharge prescriptions for patients found that 15% of medications intended to be continued were

omitted at discharge, or that at least one medicine on average was omitted from the discharge prescription. At admission one study found that on average one medicine was not documented on the medication history for every two patients.

In one survey of 106 GPs regarding the type of information they received from hospital about their patients, no notification was provided to the GPs in over 50% of cases. Because of a change in patient medications by the hospital in 87% of cases, the patient's medicine at discharge was different from what the GP understood before admission in 72% of cases.

Finally, in a regional hospital in Queensland, of the referral medical records of 100 oncology patients, 72% had the potential for one or more errors in the patient's medication. The most common reasons for these errors were described as:

- insufficient documentation to allow dosages to be confirmed;
- handwritten or illegible medication orders; and
- lack of instruction about the length of time between cycles of chemotherapy.

Multiple healthcare providers. In one study of 204 people, 48% had medicines prescribed by more than one doctor and 28% had medicines dispensed by more than one pharmacist. The effect on medication error and adverse drug events has not been studied.

Keeping unnecessary medications. This involves keeping medications that are no longer in use or have passed their expiry date. In one small study where pharmacists made home visits to assist in medication management, 21% of people were keeping medicines that were no longer in use and 20% were keeping expired medications. The effect on medication error and adverse drug events has not been studied.

Generic names/trade names. One study found that 29% of consumers did not understand the difference between the generic and trade name of a medication. Again, the effect on medication error and adverse drug events has not been studied.

Understanding the label. In a single survey 84% 'older consumers' incorrectly interpreted the instruction to 'take one tablet every 6 h, 1 h before food'. The effect on medication error and adverse drug events has not been studied.

As medication errors can occur at all stages in the medication process, from prescription by physicians to delivery of medication to the patient by nurses, and in any site in the health system, it is essential that interventions be targeted at all aspects of medication delivery.⁴

Therefore, it is vital that healthcare providers be aware of the current evidence in relation to effective interventions for reducing the incidence of medication errors. This review attempts to summarise the best available evidence on these research interventions highlighting where possible, prevention in the aged care arena.

Objectives

To present the best available evidence for strategies to prevent or reduce the incidence of medication errors associated with the prescribing, dispensing and administration of medicines in the older persons in the acute, subacute and residential care settings.

The specific review question to be addressed is: what strategies/interventions are most effective in reducing the incidence of medication incidents (errors) in the acute, subacute and residential care settings?

Review method

An expert panel of 13 clinicians, nurses, pharmacists and other allied health professionals was established to guide the systematic review process by defining the criteria for study inclusion, identification of key search terms and relevant databases, and evaluating the clinical importance of the resulting evidence (Appendix 1).

Criteria for considering studies for this review

Types of studies

This review considered any systematic reviews or randomised controlled trials (RCTs) that evaluate strategies to reduce or prevent medication incidents (Appendices II and III). However, in the absence of any RCTs, other research methods such as non-RCTs, longitudinal studies, cohort or case-control studies, or descriptive studies were used. Qualitative studies, grounded theory and ethnographic studies were included in a narrative summary. Only studies written in the English language were included in the review. For the purposes of the review, medication referred to medication that has been prescribed by a medical practitioner, not over-the-counter or herbal or vitamin preparations.

Types of participants

Those people who are involved in the prescribing, dispensing or administering of medication to the older persons (aged 65 years and older) in the acute, subacute or residential care settings were included in the review, namely:

- registered nurses;
- enrolled nurses (or equivalent, e.g. licensed practical nurses);

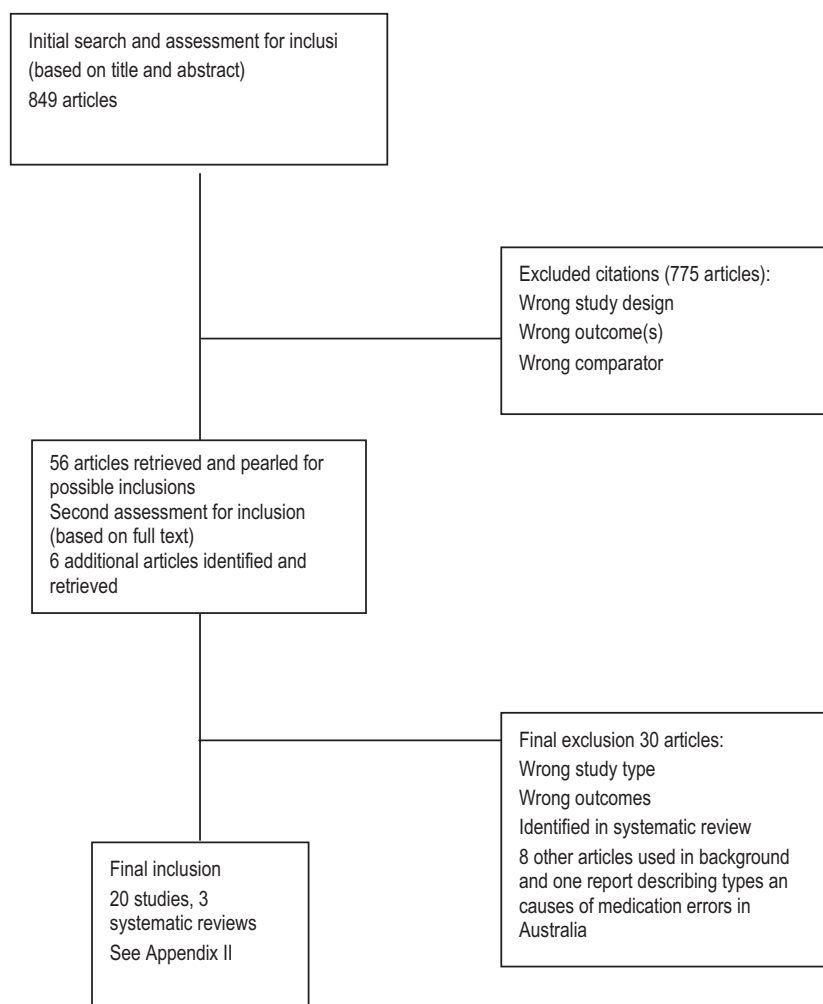


Figure 1 Schema of the stages of searching and inclusion/exclusion of references for the review.

- pharmacists;
- physicians/medical practitioners (or equivalents); and
- personal care attendants/ancillary staff (or equivalent).

In the absence of articles relating the older persons specifically to medication incidents (errors) in the acute, sub-acute or residential care settings, articles were reviewed that did not specify the age of the client/patient, using the same criteria as described previously.

Types of intervention

All studies reviewing strategies to prevent medication incidents (errors) in the acute, subacute and residential settings were considered.

Types of outcomes

The main outcome measure of interest to be considered was the number of medication errors or adverse drug events

Table 3 PubMed search strategy management of medication errors in older adults

Search category	Search terms
MeSH	Medication errors, aged, prescriptions, drug
Title or abstract terms	Medication errors, adverse event, aged, elderly, adults, drugs, medication

after intervention (and before in studies without parallel control groups). In the absence of primary outcome measures, studies with surrogate measures such as test scores and number of distractions were also considered.

Search strategy

The search terms in Table 3 were identified for a PubMed search (Appendix IV). Similar terms and strategies were used for the different bibliographic databases, with the same text

words being used along with the relevant alternatives to MeSH (i.e. EmTree headings in EMBASE).

Bibliographic databases

- PubMed (NLM): 1986–February 2005
- Embase: 1986–February 2005
- CINAHL (SilverPlatter): 1986–February 2005
- Current Contents: 1993–February 2005
- Cochrane Library: 1986–February 2005
 - Cochrane Database of Systematic Reviews (CDSR)
 - Database of Abstracts of Reviews of Effectiveness (DARE)
 - The Cochrane Controlled Trials Register (CCTR)
 - The Health Technology Assessment Database (HTA)
 - NHS Economic Evaluation Database (NHS EED)
- Science Citation Index Expanded
- ProceedingsFirst: 1993–February 2005
- Social Science Index
- International Pharmaceuticals Abstracts

Health Technology Assessment (HTA) websites were also searched for relevant systematic reviews and studies (see Appendix V).

Search phases

The initial search was through the aforementioned electronic databases. Articles for inclusion were first assessed from titles and abstracts only. Articles identified as potential inclusions were collected and assessed for inclusion based on the full text. The reference lists of all studies determined to match the inclusion criteria for effectiveness or safety were then perused for any possible inclusions (Figure 1).

Methodological quality

The evidence presented in the selected studies was assessed and classified using the dimensions of evidence defined by the National Health and Medical Research Council.⁷

These dimensions (Table 4) consider important aspects of the evidence supporting a particular intervention and

include three main domains: strength of the evidence, size of the effect and relevance of the evidence. The first domain is derived directly from the literature identified as informing a particular intervention. The last two require expert clinical input as part of their determination.

The three subdomains (level, quality and statistical precision) are collectively a measure of the strength of the evidence.

Level of evidence

Levels of evidence differ in terms of the hierarchy, depending on the type of research question being asked. Studies assessing the effectiveness of interventions were assessed using the National Health and Medical Research Council levels of evidence (Table 5).

Quality of evidence

The appraisal of systematic reviews was performed using a checklist developed by the National Health Service Centre for Reviews and Dissemination.⁸ This is a generic checklist that allows for the appraisal of systematic reviews that incorporate study designs other than RCTs (Appendix VI). A 'quality score' will be approximated from this checklist by attaching a point to each criterion that is met by the systematic review.

The appraisal of intervention studies was undertaken using a checklist developed by the Joanna Briggs Institute for Evidence Based Nursing and Midwifery.

A checklist of the quality of observational studies developed by the Joanna Briggs Institute for Evidence Based Nursing and Midwifery was also used where appropriate (Appendix VI).

Data collection and analysis

Study design and quality were tabulated and relative risks, odds ratios, mean differences and associated 95% confidence intervals were calculated from individual comparative

Table 4 Evidence dimensions

Type of evidence	Definition
Strength of the evidence	
Level	The study design used, as an indicator of the degree to which bias has been eliminated by design
Quality	The methods used by investigators to minimise bias within a study design
Statistical precision	The <i>P</i> value or, alternatively, the precision of the estimate of the effect. It reflects the degree of certainty about the existence of a true effect
Size of effect	The distance of the study estimate from the 'null' value and the inclusion of only clinically important effects in the confidence interval
Relevance of evidence	The usefulness of the evidence in clinical practice, particularly the appropriateness of the outcome measures used

Table 5 Designations of levels of evidence for assessing intervention studies

Level of evidence	Study design
I	Evidence obtained from a systematic review of all relevant randomised controlled trials
II	Evidence obtained from at least one properly designed randomised controlled trial
III-1	Evidence obtained from well-designed pseudo-randomised controlled trials (alternate allocation or some other methods)
III-2	Evidence obtained from comparative studies (including systematic reviews of such studies) with concurrent controls and allocation not randomised, cohort studies, case-control studies or interrupted time series with a control group
III-3	Evidence obtained from comparative studies with historical control, two or more single-arm studies, or interrupted time series without a parallel control group
IV	Evidence obtained from case series, either post-test or pre-test/post-test

Modified from National Health and Medical Research Council (2000).⁷

studies containing count data where possible. All other data were presented in a narrative summary.

Size of effect and relevance of evidence

For intervention studies, rank scoring methods were used to determine the clinically important benefit of the effect size, as well as the clinical relevance of the outcome being assessed.⁷ A clinically important benefit will be set as a 20% difference between the confidence limit closest to the measure of no effect and the no effect line (Appendix VI).

Results

Are interventions effective at reducing medication errors in older persons?

Are interventions that are designed to reduce medication errors during the ordering, transcribing, dispensing and administering of prescription drugs to patients 65 years and over effective?

Three systematic reviews,^{6,8-10} one review⁴ and 20 studies¹¹⁻³⁰ were identified that attempted to answer this question. One systematic review provided very general information on the results of trials and therefore any studies not identified in the other reviews that addressed interventions to reduce medication errors were individually identified and assessed¹⁰ and are included in the count of the number of studies in the beginning of the paragraph.

Before the discussion of the results of included studies, several points should be highlighted. First, the majority of studies did not direct interventions to patients in the older persons category (≥ 65 years) but rather to patients within their unit or hospital in general. Because of the paucity of research specifically addressing the older persons, studies that involved general patients were included. Second, the

definition of a medication error varied and the severity of medication errors (i.e. life threatening vs. minor) was not always reported.

Computerised systems

Analyses of medication errors have revealed that targeting error prevention strategies at procedures and not individuals is likely to be more effective.⁶ The following discussion addresses the use of computer-based interventions at some phase of the prescribing to administration pathway to reduce medication errors.

Computerised physician ordering entry and clinical decision support systems. Systems such as computerised physician ordering entry (CPOE) and clinical decision support systems (CDSS) were designed to target stages of ordering, and administration and dispensing stages, respectively.

CPOE is described as a computer-based system whereby the physician writes all orders online. Within this system the physician is provided with a menu of medications available from the formulary displayed with the default doses and a list of the potential range of doses. The system attempts to improve legibility, completeness and safety of orders.

CDSS provides computerised advice on drug doses, routes and frequencies. CDSS can also perform drug allergy and drug-drug interaction checks as well as prompt for corollary orders (such as glucose levels after insulin has been ordered).

A systematic review of studies evaluating CPOE and CDSS in the reduction of adverse drug events and medication errors was identified.⁹ Included study designs consisted of RCTs, non-RCTs and observational studies with controls. No patient group was specified. Definitions of medication errors and adverse drug events as defined in the systematic review are provided in the following box.

Medication error: errors in the process of ordering, prescribing, dispensing, administering or monitoring medications.

Potential adverse drug events: medication errors with significant potential to harm a patient that may or may not actually reach a patient.

Results were not combined in a meta-analysis but provided as narrative summaries and are summarised as follows.

Medication errors and adverse events. In two studies^{31,32} significant reductions in non-intercepted serious medication errors (medication errors that either have the potential to or actually cause harm to a patient) of 55% and 86% were identified, with one study showing a 17% decrease in adverse drug events; however, this was not significant.

Other outcomes. The remaining studies evaluated more specific outcomes. A single study reported a significant improvement in the rate corollary orders using computerised reminders³³ whereas another demonstrated an improvement in five prescribing practices³⁴ and a third study identified a 13% and 24% decrease in inappropriate dose and frequency, respectively, of nephrotoxic drugs in patients with renal insufficiency.³⁵

Three studies examined the effectiveness of computerised advice for antibiotic dosing on adverse drug events, rates of toxic drug levels or pathogen susceptibility.^{36–38} In a prospective before and after trial, use of CDSS was associated with a 70% decrease in adverse drug events compared with control, whereas an RCT found a 17% greater pathogen susceptibility to the antibiotic drug regimen suggested by CDSS.

In two RCTs evaluating CDSS guidance of theophylline dosing, results between studies were contradictory.^{39,40} In the larger of the two studies, the treatment group displayed significantly lower rates of theophylline toxicity than the control group. The smaller study found no such difference and is likely underpowered.

Finally, two studies examining CDSS guidance of anticoagulant dosing^{41,42} found no significant differences in bleeding outcomes; however, given the small sample sizes, it is likely that these studies are underpowered.

In a recent controlled trial, the effect of CPOE on medication errors was evaluated in a university hospital setting.³⁰ After 8- and 11-month pre-intervention periods, two general medicine units were provided with a CPOE system for a further 7 and 4 months, respectively. During both pre- and post-intervention periods, the number of reported medication errors was recorded. Other hospital units that continued

to use handwritten physician orders were also monitored for medication errors and acted as control units.

Medication error was defined as an error in the process of ordering, dispensing or administering a medication regardless of whether the potential for injury was present.

Medication errors and potential errors were voluntarily reported on a form by nurses, pharmacists and physicians to the University's Centre for Medication Safety. Each error was investigated and the severity of the error was rated by medication safety team member on a scale from 0 to 6 (no actual incident occurred; potential error to incident resulted in death).

Results showed that individually, the units receiving CPOE systems showed no significant change in the number of reported medication errors before and after the implementation of CPOE (Table 6). Pooled results of both units showed an increase in the number of reported errors per discharge. During the same period, control units displayed a reduction in reported errors per discharge. Examination of the stage at which errors occurred showed an increase in reported error rates involving entry into the pharmacy computer system (pharmacy order processing category) on units using CPOE, but at no other stage.

Anecdotal evidence suggests that implementation of the CPOE system in two US hospitals has reduced medication errors by 37% and more than 50% since inception.⁴³

Automated dispensing. A systematic review identified five studies that examined the effectiveness of automated dispensing systems on reducing medication error rates.⁶ This review concluded that the available evidence was generally poor and did not support the suggestion that automated dispensing systems improved outcomes.

Not included in the Shojania review was a single study that evaluated an automated point-of-use dose system (Medstation Rx) in a 26-bed adult general medicine unit.²⁸

The system involves the location of controlled and secure medicine storage units at nursing stations with patient medication profiles downloaded in the Pharmacy and transferred to the appropriate nursing unit.

To dispense the desired medication the nurse selects the patient of interest using the computer.

Nurse selects desired medication and the storage unit releases the specific drawer and pocket containing the medication.

Drug inventory required in each storage unit determined through historical usage data.

Measurement of the incidence of dispensing error was determined by comparing the technician error rate for filling

Table 6 Effect of computerised physician ordering entry (CPOE) on the number of medication errors

Study	Level of evidence	Quality	Population	Measure	Results		
					Before	After	<i>P</i>
Spencer <i>et al.</i> , 2005 ³⁰	III-3 Before and after study	QS 7/11 Clinical importance not estimable <i>R</i> not estimable	General medicine units	<i>Unit monitored</i>			
				Unit 1 with CPOE	0.079	0.092	NS
				Unit 2 with CPOE	0.06	0.083	NS
				Pooled CPOE	0.068	0.088	0.011
				Control units	0.133	0.079	<0.001
				<i>Point of error</i> [†]			
				Prescribing	0.014	0.008	NS
				Unit order processing	0.014	0.018	NS
				Pharmacy order processing	0.027	0.053	<0.01
				Dispensing	0.003	0.001	NS
				Delivery	0.005	0.002	NS
Administration	0.019	0.025	NS				
Clinical monitoring	0.001	0.001	NS				

[†]CPOE units only.

NS, not significant; *P*, probability; QS, quality score; *R*, relevance.

Table 7 Effectiveness of an automated point-of-use dose system

Study	Level of evidence	Quality	Population	Outcomes	Results
					% of doses dispensed
Ray <i>et al.</i> , 1995 ²⁸	III-3 Before and after study	QS 6/11 Clinical importance 2/4 <i>R</i> 3/5	Patients on a 26-bed medical unit	Technician error rate for filling	0.89% before implementation 0.61% after implementation <i>P</i> = 0.04 Relative difference (95% CI): 28.7% (3.6–53.8%)

CI, confidence interval; *P*, probability; QS, quality score; *R*, relevance.

Table 8 Effectiveness of a bedside terminal system (BTS)

Study	Level of evidence	Quality	Population	Outcomes	Results
Brown <i>et al.</i> , 1995 ¹⁴	III-3 Before and after study	QS 7/11 Clinical importance not estimable <i>R</i> not estimable	Patients on a 35-bed surgical unit	Medical error rate [†] (40-h observation)	0.7/1000 before BTS 0.7/1000 after BTS

[†]Total number of medical errors/1000 doses dispensed.

QS, quality score; *R*, relevance.

storage units 6 weeks before and 6 weeks after the introduction of the Medstation Rx system.

Results are described in Table 7. The use of an automated point-of-use dose system significantly reduced the rate of error in filling of dosage carts by technicians.

Bedside terminal system. One study examined the effectiveness of a portable bedside terminal documentation system on nursing practice and medication error rate.¹⁴ A medication error was defined as a variation from standard practice and was to be recorded on an incidence report.

Bedside terminal systems involve the use of touch screen handheld portable terminals to enter and access data on individual patients. These portable computers communicate via radio frequency to a terminal server located on the unit.

Results are summarised in Table 8. The use of a bedside terminal system had no effect on the reported medication error rate.

In a 6-month study in three US hospitals in which full-function clinical information systems were moved from nurs-

ing stations to the patient bedside, the authors claim a reduction in medication errors of 34%.¹⁵

Computer-generated medication administration records. One before and after study (Level III-3) in a 584-bed hospital converted their handwritten 14-day medical administration records (MAR) to a 24-h computer-generated MAR in an attempt to increase the accuracy of medication administration, avoid discrepancies between the pharmacy and the nursing staff and providing neat, legible documentation.¹¹

The MAR is initially generated by order entry in the pharmacy. The computer-generated MAR is then reconciled by the 11 PM to 7 AM shift nurses. If a discrepancy exists, a variance report is filled out and any corrections are made by the pharmacy.

The definition of a medication error was not defined in this report.

The authors claim that a decrease in medication errors of 18% was obtained after the first year of the new protocol.

Computer alert system. Five studies were identified in a systematic review that examined the use of computer alerts to prevent adverse drug events.⁶ However, the evidence for the effectiveness of such systems is weak. Only one study demonstrated significant decreases in adverse drug events using the alert system in a before and after study. One other study found no significant benefit of an alert system on the incidence of adverse drug events and three others only saw improvements in the response times to obtaining laboratory values. A final study demonstrated a significant change in physician behaviour and their modification of patient therapy based on the alerts and subsequent recommended actions.

One other uncontrolled trial evaluated the incorporation of 37 adverse drug event alerts into the existing computerised hospital information system of a 650-bed teaching hospital.²⁷

An example of an adverse drug event alert was the following:

Primary prevention alert

Cardiac

Arrhythmia-digoxin – patient receiving digoxin and has a serum potassium level <3.2 mmol/L, a serum magnesium level <0.75 mmol/L or a digoxin level >2.5 nmol/L. Recommendation: electrolyte replacement or digoxin dose reduction.

Based on the patient information entered into the system, a prescription could generate an adverse drug event alert that is printed out and evaluated within the pharmacy. If necessary, the alert is discussed with the appropriate nurse regarding the patient's clinical condition. The pharmacist may contact the attending physician when the recommendations made by the alert seem appropriate.

The study collected data on consecutive alerts for 6 months after inception of the program. A total of 9306 non-obstetrical patients flowed through the system with 1116 alerts recorded. Of these, 596 alerts (53%) were deemed to be true positives requiring action. In 44% of these true positives (265/596), the physician stated they were unaware that a potentially dangerous clinical situation existed.

Bar codes. A systematic review found one observational study in which a hospital used hand-held scanners to identify the patient, nurse and the medication being administered.⁶ The study found that the medication error rate in the hospital decreased from 0.17% before the system was instituted to 0.05% after (*P* value not reported). Although this result was encouraging, the use of the bar coding device was 'easily and frequently circumvented', bringing into question the real contribution of the device to the overall error rate decrease.

In a recent ethnographic study nurse, physician and pharmacist interaction with a newly instituted computerised system of bar code medication administration (BCMA) was observed in three veterans hospitals in the USA.²⁶ The aim of incorporating this technology was to reduce the incidence of adverse drug events.

One observer, trained in ethnographic field observations, conducted all observations before and after the implementation of BCMA. Observations occurred during all parts of day, evening and night shifts for a duration of between 1 and 7 h.

BCMA involved the incorporation of software installed on a laptop permanently attached to the wheeled medication chart.

Physicians were observed performing computerised order entry followed by verification by the inpatient pharmacists.

Nurses scanned bar coded wristbands on individual patients and 'DUE' medications would be indicated for that patient. The medication bar code was then scanned and if it matched the displayed information then the system recorded the medication as given and recorded the time. If there was any discrepancy, a pop-up alert was displayed.

Five negative themes (side-effects) were identified in this study:

- 1 nurse confusion over automated removal of medications by the BCMA;
- 2 degraded coordination between the nursing staff and the physicians;
- 3 nurses dropped activities to reduce workload during busy periods;
- 4 increased prioritisation of monitored activities during busy periods; and
- 5 decreased ability to deviate from routine sequences.

It was suggested that these observed side-effects might 'create new paths to adverse drug events'.

Therefore, the study authors recommended that the software undergo design revisions and the hospitals institute best practice training.

General conclusions: computerised systems

Some evidence suggests that:

CPOE combined with CDSS may be effective in reducing medication errors in a general hospital population.

Lower-level evidence for the effectiveness of:

Computer-generated MAR.

Computer adverse drug event detection and alerts.

No evidence to suggest that:

Automated dosing systems reduce medication error incidence.

Only reduce errors in filling of drawers by technicians.

The use of bedside terminal systems reduces medication error incidence.

Bar coding patients or medications reduce medication error incidence.

General conclusions: individual patient medication supply
Individual medication supply systems have been shown to reduce medication error rates compared with other dispensing systems such as ward stock approaches.

Education and training

One study examined the effect of a compulsory medication examination on the rate of medication error in a 376-bed community medical centre.²⁴

Unit dosages for each patient prepared in the pharmacy and administered by registered nurses only.

During Phase I nurses were required to pass an annual written medication examination consisting of 22 multiple-choice and 12 matching questions and 5 dosage calculation questions.

Phase II was instituted after policy was changed to eliminate the annual examination as a requirement.

The study followed the number of reported medication errors over a 6-month period for each phase.

Individual patient medication supply

Individual patient medication supply refers to the practice of dispensing medications in a package that is ready to administer to the patient. One systematic review⁶ and two Australian studies^{44,45} were identified.

In the Australian studies,^{44,45} the use of individual patient supply was found to significantly reduce the medication error rate compared with a ward stock system of medication supply with studies showing a decrease in the medication error rate from 15.4% (76/494) to 4.8% (24/502)⁴⁵ or missed medications from 5.7% (223/3931 doses) to 4.1% (136/3287 doses), respectively.⁴⁴

In the systematic review,⁶ results suggested that there is a positive impact of error reduction using an individual patient supply system. Five studies met the review inclusion criteria (four cross-sectional studies and one before and after study). The majority of these studies reported reductions in medication errors using this system compared with alternative dispensing methods such as the ward stock approach, primarily in errors of omission and commission (erring in a task).

A medication error was defined as administering:

- the wrong medication;
- an extra dose;
- a medication to the wrong patient;
- a medication via the wrong route;
- a medication >30 min before or after the scheduled time;
- a medication from an expired order;
- an intravenous fluid at the wrong rate by >10%;
- or by omitting a medication.

Results showed no difference in the incidence of medication errors between the two time periods (Table 9).

One RCT evaluated the effectiveness of a 3-h educational intervention compared with control (no education) on the ability of nurses to calculate appropriate drug dosages.¹² Errors in calculating medication dosages and flow rates were assumed to be a surrogate outcome for medication errors.

Sixty-seven registered nurses were randomised into one of four groups (three intervention, one control). Before intervention, all participants completed a medication calculation test.

Medication calculation test included:

Table 9 Effectiveness of medication examination

Study	Level of evidence	Quality	Population	Outcomes	Results
Ludwig Beymer <i>et al.</i> , 1990 ²⁴	III-3 Before and after study	QS 5/11 Clinical importance not estimable R not estimable	Community medical centre patients	Incidence of medication errors over a period of 6 months	With testing: 142 errors/6 months Without testing: 137 errors/6 months

QS, quality score; R, relevance.

- 10 items on calculating oral dosages
- 4 items on intramuscular and subcutaneous dosages
- 6 items involving calculation of intravenous medication dosages and flow rates

Intervention groups then underwent 3-h training via one of:

- 1 self-study workbook
- 2 computer-assisted instruction
- 3 group classroom instruction

Nurses re-tested 4–5 months after intervention.

Results showed an increase in post-test scores for all groups (Table 10). However, analysis of covariance revealed no significant difference in post-test medication calculation test scores between any of the experimental groups and controls (not shown).

General conclusions: education and training

There is no evidence to suggest that education addressing medication calculation, or a yearly medication examination is effective in reducing medication errors.

Pharmacists

A systematic review summarised the results of one systematic review and one RCT evaluating the role of clinical pharmacists in preventing adverse drug events in outpatients, and one systematic review and three other studies of hospitalised patients.⁶ In the inpatient setting, this review identified one prospective before and after study that demonstrated a statistically significant 66% decrease in preventable adverse drug events caused by medication ordering. In a retrospective before and after study, the use of a clinical pharmacist to check on new orders entering the pharmacy resulted in a 40–50% overall reduction in medication errors. In a meta-analysis of primarily controlled observational studies and non-randomised trials, the use of a pharmacist to follow up with patients resulted in patients being more likely to have a therapeutic peak and trough and less likely to have a toxic peak and trough. In the outpatient setting, a system-

atic review of over 16 000 outpatients determined that the use of a pharmacist for consultation, patient education and follow-up resulted in improvements in outcomes for patients with hypertension, hypercholesterolaemia, chronic heart failure and diabetes. Other outpatient studies determined that the use of pharmacist at discharge of geriatric patients resulted in significantly fewer medication errors. Finally, in an RCT of 181 patients with heart failure, patients in the intervention group received clinical pharmacist evaluation, which included medication evaluation, therapeutic recommendations to the attending physician, patient education and follow-up telemonitoring. The control group received usual care. This study found all-cause mortality and heart failure events were significantly lower in the intervention group compared with the control group (4 vs. 16; $P = 0.005$).

The involvement of a pharmacist at the point of prescription (ordering) of a drug by the physician was evaluated by three further studies.^{17,22,46} In two studies the pharmacist either made rounds with the medical team to provide immediate consultation²² or made rounds to each designated unit every half hour to check on the accuracy of orders and to provide consultation to the medical staff.⁴⁶ The results of these studies are summarised in Table 11.

Both studies displayed a decrease in the number of medication errors per 1000 patient days with the improved availability of a pharmacist for consultation. When the number of errors per number of patients in each study group was examined, the use of a pharmacist with the rounding team showed significant improvement compared with the rounding team only.²²

In a single study the process of reactive pharmacy intervention was evaluated in a single-arm study.¹⁷ The objective was, within the pharmacy, to identify prescriptions that may have defects to prevent a possible impact on the patient (i.e. an adverse event).

Table 10 Effectiveness of 3-h education interventions

Study	Level of evidence	Quality	Population	Outcomes	Results			
					Pre-score		Post-score	
					Mean	SD	Mean	SD
Bayne and Bindler, 1997 ¹²	II	QS 7/11 Clinical importance 3/4 R not estimable	67 registered nurses	Medication test calculation scores				
				Group				
				Control ($n = 18$)	74.7	15.6	81.1	13.0
				Workbook ($n = 18$)	80.0	15.2	78.3	16.7
			CAI ($n = 14$)	78.2	9.7	82.1	11.9	
			Classroom ($n = 17$)	70.3	17.5	78.8	17.1	

CAI, computer-assisted instruction; QS, quality score; R, relevance; SD, standard deviation.

Prescription considered by pharmacists

If prescription considered defective, the pharmacist recorded the following:

- relevant drug details
- summary and categorisation of the problem
- coding of outcomes
- total time taken to initiate a response and resolve the problem
- grade of the prescribing doctor

The potential for medical harm graded separately by a single physician.

The study found that approximately 3% of prescriptions written over the period of 28 days were flagged as faulty (Table 12). A high proportion of interventions were considered justified (83%) during review, with 75% of interventions resulting in altered prescriptions.

General conclusions: pharmacists

There is some evidence to suggest a role for clinical pharmacists in preventing adverse drug events in the inpatient setting.

Table 11 Effect of pharmacist intervention on a number of medication errors

Study	Level of evidence	Quality	Population	Outcomes	Results	OR (95% CI)
Kucukarslan <i>et al.</i> , 2003 ²²	III-2 Control study	QS 8/11 Clinical importance 1/4 R 2/5	<i>Experimental group:</i> 86 patients from general medical unit Mean age: 54 ± 19 years. <i>Control:</i> 79 patients from general medical unit Mean age: 56 ± 20 years	Preventable ADE [†]	Rounding team plus pharmacist <i>No. of errors/1000 patient days</i> 5.7 <i>No. of errors per population of study group (%)</i> 2/86 (2.5)	Rounding team only 26.5 9/79 (10) 0.19 (0.02, 0.94)
Shah <i>et al.</i> , 1994 ⁴⁶	III-3 Before and after study	QS 6/11 Clinical importance not estimable R not estimable	303-bed acute care facility	Reported medication incidents (per 1000 patient days)	Year before intervention 3.03	Year after intervention 1.12 NA

[†]Preventable adverse drug event (ADE) defined as undesired reaction to medication that may have been prevented by appropriate drug selection or management. CI, confidence interval; NA, not applicable; OR, odds ratio; QS, quality score; R, relevance.

Table 12 Effect of reactive pharmacy intervention on improvement in prescription quality

Study	Level of evidence	Quality	Population	Outcomes	Results
Hawkey <i>et al.</i> , 1990 ¹⁷	IV Prospective uncontrolled study	NA	All inpatients and outpatients in acute care, mental illness, or elderly	Interventions in prescribing process over a 28-day period, alterations to prescription, quality of the prescription	Intervention in 769 (2.9%) of all prescriptions over 28 days. 639 (83%) cases warranted intervention. 575 (75%) of intervention resulted in altered prescriptions most notably because of: <ul style="list-style-type: none"> • 280 wrong dosage • 50 dosage not stated • 48 over prolonged prescription. In 246 interventions (32%), alteration resulted in an appreciable improvement in the quality of the prescription

NA, not applicable.

Table 13 Effectiveness of dedicated medication nurses

Study	Level of evidence	Quality	Population	Outcomes	Results		P
					Medication nurses	General nurses	
Greengold <i>et al.</i> , 2003 ¹⁶	II RCT	QS 8/11	16 nurses ≥1 year of acute care nursing. Inpatients in 4 units each of 1 academic community hospital and 1 university teaching hospital	Total error rates [†]	912/5792 (15.7)	545/3661 (14.9)	<0.84
		Clinical importance not estimable		Medication error rates [‡]	651/5792 (11.2)	253/3661 (6.9)	<0.15
		R 2/5		Process variation error rates [§]	281/5792 (4.9)	306/3661 (8.4)	<0.06

[†]Total error rates = medication error rates + process variation error rates.

[‡]Medication error = wrong drug, dose, route, form, rate, dose preparation, administration technique or omission of drug.

[§]Process variation error = not checking patient wristband, borrowing medication, dosing from unlabelled dispenser (e.g. unlabelled syringe).

P, probability; QS, quality score; R, relevance; RCT, randomised controlled trial.

Nursing care models

Dedicated nurses. Three studies examined the effectiveness of using dedicated nurses to dispense medication to patients.^{14,16,25}

In one RCT, 16 nurses from four nursing units of two hospitals were designated to be either medication nurses, administering medications to assigned patients, or general nurses providing care in the 'usual manner'.¹⁶

Medication nurses participated in a medication safety program (1 day, 8 h).

Nurses were observed during medication administration 5 days a week (medication nurses for 2 days) for a period of 12 weeks.

The results of the study are presented in Table 13. This study suggests that the use of dedicated medication nurses does not reduce the incidence of total, medication and process-variation error rates.

In a pilot project of before and after design (Level III-3) involving four units in a 950-bed hospital, licensed practical nurses were used as designated medication nurses.¹³

Licensed practical nurses used as designated medication nurses from Monday to Friday on the day and evening shifts.

Regular nursing staff provided medications on night shifts and weekends.

The number of reported medication errors was evaluated before trial and 3 months after inception.

The authors report that at the end of the trial the number of reported medication errors was reduced to less than 50%

of pre-trial levels in three of the units whereas a fourth showed a 300% increase (4 reports to 12). The cause of this apparent aberration was explained as low reporting pre-trial and high staff turnover on this unit.

In a recent study, distractions during medication administration were used as a surrogate measure for the potential for medication errors.²⁵ The study of registered nurses in a medical surgical unit during medication administration 'cycles' evaluated the use of two different interventions compared with customary medication administration procedures to reduce the number of distractions.

Medication administration cycle: encompasses commencement of administration of all assigned patient medications through to completion of documentation of all administered medications.

Control: 8 cycles where nurses used customary medication administration procedures (i.e. no designated nurse to deliver medications).

Focused protocol: 8 cycles where a 'special nurse' designated and staff asked not to interrupt or distract unless the interruption is related to medications being administered.

Medsafe protocol: 8 cycles. Nurse required to wear a special vest that identified nurse as performing medication administration cycle and 'Do Not Disturb'. Staff asked to intercept all phone calls or other distractions during the cycle.

Distractions were measured using a medication administration distraction observation sheet that was validated for this study. The number of distractions per cycle was measured.

Results of this study suggest that the use of a designated nurse for medication administration can lead to a reduction in the number of distractions that a nurse may encounter during a medication administration cycle (Table 14).

Table 14 Effect of designated nurses on the number of distractions during medication cycles

Study	Level of evidence	Quality	Population	Study group	Number of distraction during cycle			
					Mean (of 8 cycles)	SD	Mean difference (95% CI)	P
Pape, 2003 ²⁵	III-2 Control study	QS 7/11 Clinical importance not estimable R 2/5	Registered nurses	Control	60.5	12.9		
				Focused protocol	22.5	8.5	38 (26.3, 49.7) [†]	<0.001
				Medsafe protocol	8.0	4.5	52.5 (42.1, 62.9) [†] 14.5 (7.2, 21.8) [‡]	<0.001 0.001

[†]Result compared with control.

[‡]Result comparing Medsafe protocol with focused protocol.

CI, confidence interval; P, probability; QS, quality score; R, relevance; SD, standard deviation.

Table 15 Effect of one or two nurses for medication administration

Study	Level of evidence	Quality	Population	Outcomes	Results		OR (95% CI)
					2 nurses	1 nurse	
Kruse <i>et al.</i> , 1992 ²¹	III-1 Cross-over controlled trial	QS 8/11 Clinical importance 2/5 R 2/5	Geriatric patients	Errors/opportunities	92/43 428	120/40 275	0.7 (0.5, 0.9)

CI, confidence interval; OR, odds ratio; QS, quality score; R, relevance.

General conclusions: dedicated nurses

There is no evidence to suggest that providing designated nurses to dispense medication significantly reduces the incidence of medication errors.

Use of the focused or Medsafe protocols in which nurses are identified as 'not to be disturbed' can reduce distractions to nurses during medication administration.

Checking (single vs. double). Two Australian studies evaluated the effectiveness of single versus double checking of medication by nurses for the reduction of medication errors.^{20,21}

In a single cross-over controlled trial in three wards of a geriatric assessment and rehabilitation unit, the effectiveness of two nurses versus one for reducing medication errors was evaluated.²¹

Ward A selected for two-nurse medication administration for 23 weeks.

Ward B selected for one-nurse medication administration for 23 weeks.

Cross-over and:

Ward A selected for one-nurse medication administration for 23 weeks.

Ward B selected for two-nurse medication administration for 23 weeks.

Ward C selected for two-nurse medication administration for whole period of study (control).

A medication error was defined as administering:

- a medication to the wrong patient;
- the wrong medication;
- an extra dose;
- a medication to patient with a known allergy to that medication;
- a medication from an expired order;
- or by omitting a medication;
- or the medication chart not signed.

The results are summarised in Table 15. The point estimate illustrates that the use of two nurses to administer medications results in 30% lower odds of a medication error being made compared with using one nurse.

In a lower-quality study (Level of evidence III-3), the impact on nursing practice and the number of reported medication errors were evaluated when standard practice of double checking of medications before administration was replaced with a single-checking protocol.²⁰

Medication errors were identified by those reported on the medication incident records over a period of 7 months for each arm of the study (i.e. double and single checking).

Only five reported medication incidents were identified over the 7-month period of standard practice (double checking) compared with four reported incidents during 7 months of the single-checking protocol. This difference was not significant and was suggestive that single checking was as safe as double checking in this institution.

General conclusions: nurse double checking

There is some evidence to suggest that having two nurses check medication orders before dispensing medication significantly reduces the incidence of medication errors.

Partners in patient care. This nursing practice model aims to extend nurse time by introducing the use of nursing partners. A single study that met inclusion criteria has examined the 'partner in patient care' (PIPC) model on nursing units of a Florida hospital.¹⁹ A description of the model is provided in a previous paper.²³

The PIPC nursing practice model involves five major components:

- 1 Participation in decision-making by staff (staff involved in the design of the practice model).
- 2 Use of a multiskilled technician in partnership with the nurse as a patient care extender (nurse extender).
- 3 Education provided on the change process (three formal classes).
- 4 Education on proper delegation of tasks to the nurse extender (one class).
- 5 Bedside computers installed as a point of care system (in each care room and at the central nursing station)

Pilot and control nursing units in a single hospital were randomly selected:

Control units used a total patient care nursing model.
Pilot units implemented the new PIPC model.
 Medication errors were derived from official incident reports.
 Data were sampled at three time points, before the intervention, 6 months into the implementation and at 1 year after implementation.

A medication error was determined by a single researcher as any incident that deviated from standard procedure and was clearly the responsibility of nursing.

Medication error rates ranged from 1/1000 to 4/1000 patient days; however, the comparison data from each study group (control and pilot) were not provided. The study found a significant difference in the medication error ratio (errors/patient day, $P = 0.008$).

General conclusions: PIPC

There is limited evidence to suggest that introducing the PIPC model significantly reduces the incidence of medication errors.

Medication Administration Review and Safety. A before and after study examined the effect of developing an interdisciplinary Medication Administration Review and Safety (MARS) committee to reduce the number of medication

administration documentation errors reported in a general hospital.²⁹

Control period before implementation involved present practice. The hospital utilised a clinical information computer system alongside an automated medication administration system.

MARS involved the introduction of an interdisciplinary committee of staff nurses, nurse managers, pharmacists, information systems analysts, a risk manager and a nursing educator. This committee reviewed all reported errors and then attempted to identify potential causes of the errors. If necessary, medication administration policies were revised. This information was then shared with staff through a publication called a 'Hot Spots' brief.

A concurrent chart review analysed medication administration documentation. Ten patients from each of every nursing unit were audited for 7 days.

A medication error was defined as mistake made during the transcription, preparation, dispensation or distribution phases of drug administration. Specifically, physician orders were reviewed for accuracy of transcription and timeliness of implementation. Documented medications were reviewed for accuracy of right patient, medication, dose, route and time. Timely administration of Stat, prn (as needed) and routine medications was also evaluated.

Before the introduction of the MARS committee, medication administration documentation errors were reported a frequency of 0.193 per patient day. One year after introduction of the MARS committee, the rate of errors had dropped 36.3% to 0.123 per patient day.

General conclusions: MARS

There is limited evidence to suggest that introducing MARS committee can significantly reduce the incidence of medication administration documentation errors.

Process change. One before and after study looked at the effect a process change and education would have on the ability of nurses to deliver insulin doses within a 60-min time frame from point of blood glucose testing.¹⁸ Before implementation, the procedure for ordering and administering insulin was not clearly defined or consistently followed. Three nursing units were evaluated (a cardiac, thoracic and neurosurgical ward, an orthopaedic ward and a cardiac progressive ward), for a period of 1 month before intervention and 6 months after implementation of the changes.

Control: standard practice. This involved a physician filling out a pre-printed insulin order form. A computerised MAR was generated by the pharmacist each evening to be used to record the times of administration of insulin to each patient the following

Table 16 Number of cases receiving insulin within 1 h of blood glucose testing

Study	Level of evidence	Quality	Population	Unit	Insulin delivered ≤60 min (%)		OR (95% CI)
					Control	Treatment	
Heatlie, 2003 ¹⁸	III-3 Before and after study	QS 6/11 Clinical importance 1/4 R 2/5	Nurses on 3 units	1	86/176 (48.9)	132/185 (71.4)	2.6 (1.7, 4.0)
				2	142/190 (74.7)	163/192 (84.9)	1.9 (1.1, 3.2)
				3	113/131 (86.3)	110/120 (91.7)	1.8 (0.8, 4.0)
				Pooled	361/497 (72.6)	405/497 (81.5)	2.2 (1.6, 3.0)

CI, confidence interval; OR, odds ratio; QS, quality score; R, relevance; Unit 1, cardiac progressive; Unit 2, cardiac, thoracic and neurosurgical; Unit 3, orthopaedic.

Table 17 Time interval between blood glucose determination and insulin administration (min)

Study	Level of evidence	Quality	Population	Unit	Time from blood glucose test to insulin delivery (min)				P	
					Control		Treatment			
					n	Mean ± SD	n	Mean ± SD		
Heatlie, 2003 ¹⁸	III-2 Control study	QS 7/11 Clinical importance 1/4 R 2/5	Nurses on 3 units	1	Breakfast	26	125.5 ± 49.5	41	46.1 ± 23.0	0.00
					Lunch	50	53.4 ± 28.4	50	56.9 ± 34.0	0.58
					Dinner	50	70.0 ± 46.8	50	50.0 ± 31.9	0.01
					Bedtime	50	60.7 ± 41.6	44	38.1 ± 32.6	0.01
				2	Breakfast	40	52.4 ± 24.8	47	38.1 ± 20.8	0.01
					Lunch	50	57.1 ± 29.0	50	46.7 ± 36.1	0.12
					Dinner	50	55.6 ± 28.2	49	57.4 ± 37.7	0.79
					Bedtime	50	37.2 ± 31.7	49	31.7 ± 23.8	0.33
				3	Breakfast	24	56.4 ± 43.4	30	43.2 ± 37.8	0.24
					Lunch	32	38.8 ± 21.5	30	27.1 ± 22.4	0.04
					Dinner	49	45.1 ± 31.5	31	39.8 ± 25.8	0.44
					Bedtime	26	30.6 ± 35.9	30	22.6 ± 33.7	0.39

P, probability (bold indicates significance); QS, quality score; R, relevance; SD, standard deviation; Unit 1, cardiac progressive; Unit 2, cardiac, thoracic and neurosurgical; Unit 3, orthopaedic.

day. The dose of insulin to be delivered was determined according to a sliding scale based on a result from the patients blood glucose test. No single method of blood glucose determination was used by staff.

Treatment involved three changes to standard practice:

- 1 A nursing education program discussing the prevention of insulin administration errors and the importance of the timing between determination of a blood glucose and the subsequent administration of insulin to a patient.
- 2 Introduction of bedside blood glucose monitors to all units.
- 3 The computerised MAR was changed so that time and dose of insulin were not recorded and therefore had to be recorded by the nurse at time of administration.

All MAR records from 1 month were examined for the month before the change and at 6 months after the implementation of the quality improvement plan. Insulin dose was compared with time of blood glucose time entered.

Data were analysed to determine the number of occasions where insulin was administered within 60 min of blood glucose determination, and the mean time between blood

glucose determination and insulin delivery for four times (breakfast, lunch, dinner and bedtime) for each unit. The results for each unit and pooled results are shown in Tables 16 and 17.

Overall, the number of cases that received insulin within 60 min of a blood glucose test improved significantly (Table 16). However, individually this improvement was only seen on Units 1 and 2. Examination of time periods in which a significant reduction in time interval between time of blood glucose test and insulin administration was seen at breakfast, dinner and bedtime in Unit 1 but only at breakfast in Unit 2 and lunch in Unit 3 (Table 17).

General conclusions: process change for insulin administration

There is limited evidence to suggest that providing education on diabetes management to nurses and the provision of bedside blood glucose monitors can significantly reduce the time between blood glucose measurement and insulin administration.

Quality of medication instruction to patients in the community
During the finalisation of this review, a single prospective cohort study was identified concerning the quality of instructions given to older adults taking warfarin, digoxin and phenytoin when filling a prescription in the community.⁴⁷ Patients receiving these drugs were selected because of the narrow therapeutic window of these medications and the resulting higher risk of severe adverse events. This report discusses only the baseline survey data from telephone interviews of over 4955 persons on the receipt of information and quality of that information concerning their prescription drugs at time of filling. The survey results suggested that almost one-third of responders reported not receiving any instruction on the use of these medications.

Discussion

The original goal of this systematic review was to evaluate interventions to improve medication error incidence rates in geriatric settings. However, it soon became apparent that little research had been performed in strictly this environment. Persons aged 55 years and over account for a large proportion of admitted patients and 49.6% of separations.⁴⁸ Therefore, it was considered appropriate to include studies from all clinical environments.

Types and causes of medication errors

Studies examining the types and causes of medication errors occurring in older adults (≥ 65 years) are limited. However, evidence is available on the general population and is taken to be representative of those issues that would arise in the geriatric setting.

Medication errors in the hospital setting have been studied extensively and the most common types of errors have been identified generally as prescription/medication ordering errors, dispensing errors, errors in administration of medicines and errors in the medication record. Specifically these errors can most often be categorised as omissions ($>25\%$), overdoses (20%), wrong medicines (10%), drug of addiction discrepancy ($<5\%$), incorrect labelling ($<5\%$) or an adverse drug reaction ($<5\%$). However, little is known as to why medication errors occur in Australian hospitals. Failure to read, or misreading the chart, and a lack of robust systems for prescribing and ordering were suggested as the reasons for most of these errors.⁴

Based on limited Australian data on prescription errors, approximately 2% of all prescriptions have the potential to cause an adverse event with the most common causes being the wrong or ambiguous dose, missing dose, or the direc-

tions for use were unclear or absent. This can be compared with other countries in which the medication error rates have been reported to be between 2% and 7%.⁶

Among the most common errors and their causes related to medication that are encountered in community practice (i.e. community pharmacies and general practices) are inappropriate drugs, prescribing errors, administration errors, and inappropriate dose errors.⁴ The factors contributing to these errors were forwarded by the doctors surveyed and not from empirical evidence. Most commonly cited reasons for medication errors in a community setting are poor communication between patient and health professionals, action of others (not GP or patient), error of judgement, poor communication between health professionals, patient consulted another medical officer and failure to recognise signs and symptoms.

The most common types of dispensing errors reported by pharmacists are the selection of the incorrect strength, incorrect product or misinterpretation of a prescription. The major reason for selecting the incorrect strength or product has been described as the result of 'look alike' or 'sound alike' error.

In an Australian survey of 209 community pharmacists, the major factors cited for contributing to dispensing errors were high prescription volume, overwork, fatigue, interruptions to dispensing, 'look alike, sound alike' drug names.

Other factors that have been suggested as contributing to medication errors are inadequate continuity of care between the hospital and the community after discharge of a patient, multiple healthcare providers where medicines can be prescribed by more than one doctor, keeping unnecessary medications, generic names/trade names and misunderstanding the label instructions. However, the effect of these factors on medication error and adverse drug events has not been studied.

Effectiveness

Numerous interventions to reduce the incidence of medication errors were identified that evaluated all steps in the pathway of delivery of medication to the patient. Included in this review are evaluations of computerised ordering by physicians, drug order checking by pharmacists, supply and delivery of drugs to the respective medical units, and administration of drugs to the patients by nursing staff. Within each step of the process, different types of interventions were evaluated, such as the use of single versus double checking by nurses before administration of a drug, or the use of a dedicated nurse with a distinctive 'jacket' to identify them as performing drug administration and not to be

disturbed. Overall, however, for a number of the interventions discussed in this review, the level of evidence was low (small sample sizes, before and after studies) or the results were poorly reported or inconclusive.

It was stressed in many of the researches reviewed here that medication errors do not necessarily translate into adverse drug events that could result in harm to patients. It was apparent from this literature that once a definition of a medication error was created the ease of determination of an error was dependent primarily on the level of reporting (i.e. the ease and willingness of clinicians to report an error). However, the resulting effect of a medication error, if any, on the patient was much harder to establish and therefore many studies did not extend their outcomes to include this eventuality.

In a number of studies, the number of reported medication errors was actually seen to increase after implementation of an intervention. This may have been the result of increased vigilance and improved reporting systems rather than an increase in the incidence of errors. Therefore, in some studies it was impossible to accurately determine the effectiveness of the specified intervention.

Computerised systems

Computerised systems consisted of a variety of interventions including CPOE, automated dispensing, bedside terminals, computer-generated MAR, alert systems and bar coding.

In summary, there was good evidence that CPOE system combined with CDSS is effective in reducing medication errors in a general hospital population.⁶ However, there was lower-level evidence for the effectiveness of computer-generated MAR, computer adverse drug event detection and alerts. Finally, there was no evidence to suggest the use of bedside terminal systems, or bar coding patients or medications reduces medication error incidence, or that automated dosing systems reduce medication error incidence but only reduce errors in filling of drawers by technicians.

The majority of the research was in the use of CPOE to reduce medication errors and ultimately adverse drug events. Although CPOE was shown to significantly decrease the incidence of medication errors, it was noted that there was little evidence for CPOE and/or CDSS reducing adverse drug events and actual patient harm.⁶

A single report on the introduction of a computerised MAR reported only that medication errors decreased from one year to the next by 18%.¹¹ It was assumed from the report that medication errors were defined as a discrepancy between the MAR and the pharmacy order, but this was not

implicitly stated. A positive of the new MAR was its readability over handwritten documents.

The use of a computer alert system in one study showed that in 44% of cases where the system alerted the physician to a potential risk of an adverse drug event-related injury, the physician was unaware of the risk.²⁷ This suggests that the system may be able to prevent a significant number of potentially harmful medical errors. However, the system consisted of only 37 drug-specific adverse drug events and therefore would need to be expanded and updated to encompass a greater variety of risk.

Providing bedside terminal systems in one community hospital was evaluated for its effect on registered nurse time spent in direct care activities, overtime, attitudes towards the technology and unit medication error rate.¹⁴ No difference in unit error rates was noted. However, the study duration for pre- and post-intervention observation was short at 40 h each and the errors were counted from reports on incident forms.

Identification of a single study in one systematic review⁶ found that nurse use of bar codes in a point of care information system decreased the medication error rate in the hospital from 0.17% before the system was instituted to 0.05% after (*P* value not reported). Although this result was encouraging, the use of the bar coding device was 'easily and frequently circumvented', bringing into question the real contribution of the device to the overall error rate decrease. The reasons for this were not described.

However, a recent ethnographic study of nurse, physician and pharmacist interaction with a newly instituted computerised system of BCMA identified five negative themes (side-effects) that may elucidate the reason for the under-use of the bar coding system reported in the review:²⁶

- 1 nurse confusion over automated removal of medications by the BCMA;
- 2 degraded coordination between the nursing staff and the physicians;
- 3 nurses dropped activities to reduce workload during busy periods;
- 4 increased prioritisation of monitored activities during busy periods; and
- 5 decreased ability to deviate from routine sequences.

The available evidence from a systematic review for the use of automated dispensing was found to be generally poor and did not support the suggestion that automated dispensing systems improved outcomes.⁶ In a single study the use of an automated point-of-use dose system significantly reduced the rate of error in filling of dosage carts by technicians only.²⁸

Individual patient medication supply

Individual medication supply systems have been shown to reduce medication error rates compared with other dispensing systems such as ward stock approaches. However, one systematic review suggested that the use of these systems shifts the chances for error from the nursing ward into the pharmacy, where distractions are also common and errors will occur.⁶

Education and training

Few studies were identified that examined the effectiveness of nursing education or training programs on the prevention of adverse drug events. From the two studies that were included, there is no evidence to suggest that education addressing medication calculation, or a yearly medication examination is effective in reducing medication errors.^{12,24} Looked at another way, neither written medication examinations nor education on medication calculation could improve nurse competence to prevent errors beyond the skills they had already accrued.

Pharmacists

There is good evidence to suggest a role for clinical pharmacists in preventing adverse drug events in the inpatient setting. From a systematic review, pharmacist intervention in one study resulted in a 66% decrease in preventable adverse drug events because of medical ordering and a study of geriatric patients at the time of discharge found statistically significant decreases in medication errors.⁶ The value of the presence of a pharmacist during medication rounds was also determined in two other studies.^{22,46} Both studies displayed a decrease in the number of medication errors per 1000 patient days with the improved availability of a pharmacist for consultation.

Evidence for the effectiveness of pharmacists in reducing adverse drug events in the outpatient setting is less compelling.

Nursing care models

The strongest evidence suggests that having two nurses check medication orders before dispensing medication significantly reduces the incidence of medication errors.²¹ However, the authors question the clinical advantage of this policy and do not recommend it. Weaker evidence suggested that single checking could be as safe as double checking, but was reliant on the number of medication errors reported in the medication incident records and might be a conservative estimate of the actual number of medication errors that actually occurred.²⁰ It has been demon-

strated that actual error rate could be 33% higher than reported rates.⁴⁹

There is no evidence to suggest that providing designated nurses to dispense medication significantly reduces the incidence of medication errors.^{14,16,25} However, the use of the focused or Medsafe protocols in which nurses are identified as 'not to be disturbed' can reduce distractions to nurses during medication administration.²⁵ Distractions were used as a surrogate measure of the potential for a medication error. Although these strategies did not eliminate distractions during the medication 'cycle', these interventions were shown to reduce them by as much as 87% compared with customary medication rounds. The weakness of this study may lie in the method of collection of distractions using a previously unvalidated collection tool and the unavoidable use of an unblinded observer.

Employment of a MARS committee was shown to have a positive effect on reducing the number of medication administration documentation errors over a period of 1 year.²⁹ This is likely due to the heightened awareness of medication error prevention and reporting.

There is limited evidence from one study to suggest that introducing the PIPC model significantly reduces the incidence of medication errors.²³ This model was instituted in an attempt to reduce the workload on registered nurses by delegating less clinical tasks to a multiskilled technician. Despite the claim that the PIPC model was effective at significantly reducing the medication error ratio (errors/patient day, $P = 0.008$), the data for before the institution of the PIPC model and after were not presented and therefore could not be verified.

As an example of the implementation of process change to improve the delivery of a specific drug and reduce the likelihood of an adverse event, diabetes education to nurses and the installation of blood glucose testing units in all wards were assessed.¹⁸ Overall, the number of cases that received insulin within 60 min of a blood glucose test improved significantly. However, when individual units were evaluated this improvement was not universal. Examination of time periods in which a significant reduction in time interval between time of blood glucose test and insulin administration was seen at three time periods (breakfast, dinner and bedtime) for one unit but at only one time period (breakfast or lunch) in the other two units. The unit showing greatest improvement showed consistently higher mean time intervals between blood glucose testing and insulin delivery during the control phase of the study at all measurement periods (means of 53–125 min) whereas the mean times of the other units were all below 60 min.

Recommendations

Implications for practice

Computerised systems

- CPOE should be considered as this strategy may reduce the risk of misreading medication orders.

Individual patient medication supply

- Individual patient medical supply should be considered for use wherever possible.

Pharmacists

- Where possible, pharmacists should be made available for double checking medication orders and for consultation.

Nursing care models

- Double checking of medication orders by nurses before administration of medicines can reduce the number of medication errors.
- Identifying a dedicated nurse for medication administration may reduce the number of medication errors through the reduction of distractions.
- The use of a MARS committee may have a positive effect on reducing medication errors, likely because of the heightened awareness of medication error prevention and reporting.

Implications for research

More research is needed to determine:

- the effectiveness of MAR, bedside terminals, computer alert systems and bar codes to reduce medication errors;
- the effectiveness of educational interventions to reduce medication errors;
- whether the use of multiskilled technicians partnering with nurses to reduce their workload (PIPC model) can reduce the incidence of medication errors; and
- whether the use of dedicated nurses or double checking can reduce the incidence of medication errors.

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Appendix I

Supporting committee for medication management

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Dr Michael Murray	(Geriatrician) St George's Health Service
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Professor Kenn Raymond	(Professor of Pharmacology) La Trobe University Bendigo
Mr Dipak Sanghvi	(Pharmacist) The Pharmacy Guild of Australia
Dr Michael Whishaw	(Geriatrician) Melbourne Extended Care and Rehabilitation Service

ACEBAC, Australian Centre for Evidence Based Aged Care.

Appendix II

Studies included in the review

Systematic reviews

Study	Level of evidence	Appraisal score	Location	Databases searched	Inclusion criteria	Method	Outcomes assessed	Length of follow-up
Kaushal <i>et al.</i> , 2003 ^a	I	<p><i>Review objective:</i> Review the cumulative evidence on the effects of CPOE and CDSS on medication safety.</p> <p><i>Sources used:</i> See 'Databases searched' column.</p> <p><i>Inclusion criteria:</i> Studies evaluating CPOE observational studies or above, surrogate clinical outcomes or better.</p> <p><i>Quality assessed by:</i> Hierarchy of study design and outcome measures.</p> <p><i>Data extraction:</i> Bibliographic details, study description, design, outcomes and results.</p> <p><i>Data synthesis:</i> Narrative summaries</p>	Boston, MA, USA	<ul style="list-style-type: none"> MEDLINE Cochrane Library 	<ul style="list-style-type: none"> Studies evaluating CPOE with CDSS, or CDSS alone. Observational studies with controls, controlled trials, and randomised controlled trials. Surrogate clinical outcomes, clinical outcomes 	<p>Database search and retrieval. Two-person determination of study quality using prospectively determined elements of quality.</p> <p>Studies grouped into two categories: CPOE with CDSS, or CDSS alone</p>	<p>Medication errors. Defined as errors in the process of ordering, transcribing, dispensing, administering or monitoring medications</p>	NA

Study	Level of evidence	Appraisal score	Location	Databases searched	Inclusion criteria	Method	Outcomes assessed	Length of follow-up
Shojania et al., Mortality 2001 ⁶	I	<p><i>Review objective:</i> Identification and evaluation of patient safety practices.</p> <p><i>Sources used:</i> See 'Databases searched' column.</p> <p><i>Inclusion criteria:</i> Observational study designs or higher. Surrogate or clinical outcomes.</p> <p><i>Quality assessed by:</i> Hierarchy of study design and outcome measures.</p> <p><i>Data extraction:</i> 10 extraction elements</p> <ol style="list-style-type: none"> 1. Bibliographic information 2. Level of study design 3. Description of intervention 4. Study population 5. Outcome 6. And level of outcome 7. Main results 8. Adverse events 9. Costs 10. Information on implementation. <p><i>Data synthesis:</i> Narrative summaries</p>	San Francisco, CA, USA	<ul style="list-style-type: none"> • MEDLINE • Cochrane Library • CINAHL • PsycINFO • INSPEC • ABI/INFORM • Institute for Scientific Information's Science Citation Index • Social Sciences Citation Index 	<ul style="list-style-type: none"> • Any practice that can be applied to the hospital setting or to the inpatient/outpatient interface AND can be applied to a broad range of healthcare conditions or procedures. • Study design of at least observational study with controls or above. • Outcome measure must be at least surrogate or clinical 	<p>Morbidity</p> <p>Mortality</p> <p>Adverse events</p> <p>Observed errors</p>	NA	

CDSS, clinical decision support system; CPOE, computerised physician ordering entry; NA, not applicable.

Randomised control trials

Study	Level of evidence	Appraisal score	Location	Study design	Study population	Intervention	Outcomes assessed	Length of follow-up
Greengold <i>et al.</i> , 2003 ¹⁶	II	QS 8/11 Clinical importance not estimable R 2/5	Two university hospitals in the USA: California and Ohio	Multicentre randomised controlled trial	RNs with at least 1 year of acute care nursing experience and a minimum of 6-month full-time employment at respective hospitals	Nurses randomised to a role as either a medication nurse or a general nurse. <i>Medication nurses:</i> received a 1-day 8-h medication safety program. Nurses assigned between 15 and 18 patients each. Administered all scheduled medications to their assigned patients unless unable to administer time critical medications such as insulin, in which case asked for assistance from staff nurses on the unit. Did not administer Stat medicines, total parental nutrition, hydration or bolus medications. These handled by unmonitored staff nurses. <i>General nurses:</i> provided nursing care in the usual manner, covering 6 patients each. Observed only when providing medication. Study conducted simultaneously at the 2 hospitals in two 6-week blocks, 5 days per week excluding the weekends	Medication error rates (errors/opportunities). Calculated for wrong: <ul style="list-style-type: none"> • Medication • Dose • Dose form • Route • Rate • Dose preparation • Administration technique • And drug omission 	12 weeks
Bayne and Bindler 1997 ¹²	II	QS 7/11 Clinical importance 3/4 R not estimable	Three healthcare facilities in the USA: <ul style="list-style-type: none"> • Teaching hospital • Tertiary care hospital • Home healthcare agency 	Randomised controlled trial	69 RNs	Nurses randomly assigned to 1 of 4 intervention groups: <p><i>Control:</i> ($n = 18$), nurses were instructed not to update their calculation skills in any manner other than normally necessary for their work situation.</p> <p><i>Computer-assisted instruction:</i> ($n = 14$), nurses instructed to use a program (NURS PROCALC, Professional Development Software, Chapel Hill, NC, USA) for at least 3 h.</p> <p><i>Self-study workbook:</i> ($n = 18$), nurses instructed to work on the workbook for a minimum of 3 h.</p> <p><i>Classroom instruction:</i> ($n = 17$), nurses provided with a 3-h class concerning medication calculation taught by a nurse educator.</p> <p>No other descriptions of the intervention were given</p>	Pre- and post-instruction test scores Mean % \pm SD	Post-test given 4–5 months after pre-test

Study	Level of evidence	Appraisal score	Location	Study design	Study population	Intervention	Outcomes assessed	Length of follow-up
Heinemann <i>et al.</i> , 1996 ¹⁹	III-1	QS 7/11 Clinical importance not estimable R not estimable	Nursing units of a private non-for-profit community medical centre, FL, USA	Pseudo-randomised (by ward)	Control group: 34-bed surgical trauma unit. Pilot treatment group: 36-bed orthopaedic trauma unit	Control group: use the total patient care model. Pilot treatment group: use the PIPC model. This protocol included the concurrent introduction of: <ul style="list-style-type: none"> Participative decision-making by staff throughout the development, design, implementation and testing. Use of a partner in patient care extender under the direction of an RN. Classes to educate staff to the dynamics of change in the practice environment. Classes in delegation to help the RNs to delegate appropriate tasks to their PIPC extender 	Medication errors. Defined as those incidents that deviated from standard procedure and were clearly the responsibility of nursing. Errors derived from official incident reports. Described by number of incidents per patient day	6-month observation period
Kruse <i>et al.</i> , 1992 ²¹	III-1	QS 8/11 Clinical importance 2/4 R 2/5	Three ward of a geriatric assessment and rehabilitation unit, NSW, Australia	Pseudo-randomised (by ward). Cross-over	RNs	Ward A: Control for first 23 weeks: 2 nurses administering medications. Trial for second 23 weeks: 1 nurse administering medications. Ward B: Trial for first 23 weeks: 1 nurse administering medications. Control for second 23 weeks: 2 nurses administering medications. Ward C: Control for first and second 23 weeks: 2 nurses administering medications. Audit of charts by an independent observer	Medication errors measured by errors per number of medications dispensed. Errors defined by: Wrong: Patient Medication Dosage Time Omitted medication Medication chart not signed	23 weeks for each segment. 46 weeks in total

PIPC, partner in patient care; QS, quality score; R, relevance; RN, registered nurse.

Controlled trials

Study	Level of evidence	Appraisal score	Location	Study design	Study population	Intervention	Outcomes(s) assessed	Length of follow-up
Kucukarslan <i>et al.</i> , 2003 ²²	III-2	QS 8/11 Clinical importance 1/4 R 2/5	General hospital, MI, USA	Controlled trial	Six clinical pharmacists and inpatients admitted to 1 of 2 internal medicine units. <i>Control group:</i> n = 79 Mean age: 56.5 ± 19.6 years 36 male, 43 female. <i>Study group:</i> n = 86 Mean age: 53.9 ± 19.8 years 36 male, 50 female	<i>Control:</i> patients in this group received standard care from pharmacists with a ratio of 1 pharmacist for every 30 patients. <i>Study:</i> 2 clinical pharmacists assigned to patient care at bedside including rounds, documentation of pharmacotherapy history and providing discharge counselling	Preventable drug events. Events/1000 patient days. Events/total patients	87 days, from 5 September to 30 November
Pape, 2003 ²⁵	III-2	QS 7/11 Clinical importance not estimable R 2/5	Medical surgical unit of acute care hospital, TX, USA	Controlled trial	Convenience sample of registered nurses on a medical surgical unit of 30 patients	<i>Control:</i> total of 8 cycles. Nurses used customary medication administration procedures. <i>Focused protocol:</i> total of 8 cycles. A 'special nurse' designated and staff asked to not interrupt or distract the special nurse unless related to medications being administered. <i>Medsafe protocol:</i> total of 8 cycles. Nurse administering medications asked to wear a special vest that identified them as in the process of administering medications. Vest labelled with a 'Medsafe Nurse, do not disturb'. Other nurses instructed to not interrupt Medsafe nurse and to intercept all phone calls or other distractions	<i>Number of distractions</i> measured by number per cycle and total distractions over measurement period. A cycle was defined as beginning when the nurse initiated administration of all assigned patient medications and end when documentation of administered medications is completed	24 total cycles. 8 cycles per intervention

QS, quality score; R, relevance.

Other experimental designs

Study	Level of evidence	Appraisal score	Location	Study design	Study population	Intervention	Outcomes(s) assessed	Length of follow-up
Cerne, 1989 ¹⁵	III-3	QS not estimable Clinical importance not estimable R not estimable	Three states in the USA: Nebraska, Georgia, Pennsylvania	Little information. Likely a before and after trial	Nursing staff in nursing units	Pre: standard care. Post: bedside computer terminals provided containing full clinical information of patients in unit	Medication errors as % of previous time period	Not stated
Ludwig Beymer <i>et al.</i> , 1990 ²⁴	III-3	QS 5/11 Clinical importance not estimable R not estimable	Community medical centre, USA	Before and after trial	All RNs in the medical center	Pre: all RNs required to pass a yearly medication examination. Number of medication errors reported on incident forms recorded for an 8-month period. Post: no medication examination errors reported on incident forms recorded for an 8-month period in the following year after requirement for medication examinations abolished	Medication error: total errors/8-month period. A medication error was defined as: wrong medication or extra dose; wrong patient, route or rate of intravenous fluid; omitting a medication; providing a medication from an expired order; or administering a medication ≥ 30 min before or after the scheduled time	8 months before and 8 months after change in policy
Shah <i>et al.</i> , 1994 ⁴⁶	III-3	QS 6/11 Clinical importance not estimable R not estimable	General hospital, NJ, USA	Before and after trial	All clinical staff	Pre: no roving pharmacist. Post: roving pharmacist employed between 8 AM and 4 PM. Carrying out rounds every 0.5 h on all designated units Performing medication order entry and providing a resource to nursing staff and physicians. Dealt with any ordering problems	Medication incidents reported. Errors/patient days	Data collected for 4 years before 3 years after intervention
Hawkey <i>et al.</i> , 1990 ¹⁷	IV	QS not estimable Clinical importance not estimable R not estimable	Six hospitals in the Nottingham area, UK	Observational trial	All hospital inpatients and outpatients	Recording of every important intervention made by pharmacists to all prescriptions and administration of medicines for a period of 28 days	Number of interventions. Number of warranted interventions. Number of cases where prescription was altered. Number of cases where appreciable changes were made	28 days

Schaubhut and Jones, 2000 ²⁹	III-3	QS 6/11 Clinical importance not estimable R not estimable	General hospital, LA, USA	Before and after trial	All inpatients	<p><i>Interdisciplinary committee</i> formed.</p> <p>Consists of: Staff nurses Nurse managers Pharmacists Information systems Analysts Risk manager Nursing educator. Committee to review all reported errors and then the potential causes of error identified. This information was then shared with staff with regular 'Hot Spots' briefs. All nursing units reviewed by selecting 10 patients per unit per month with each selected patients chart reviewed for 7 consecutive days of medication documentation</p>	No. of documentation errors per patient day	1-year period of follow-up after intervention
Heatlie, 2003 ¹⁸	III-3	QS 6/11 Clinical importance 1/4 R 2/5	Nursing units of a study hospital, MI, USA	Before and after trial	Diabetic patients on 3 nursing units: a cardiac, thoracic and neurosurgical unit, a cardio-progressive unit and an orthopaedic unit	<p><i>Control:</i> standard practice before the institution of the intervention. <i>Treatment:</i> nursing education program highlighting the importance of the timing of blood glucose determinations and the subsequent administration of insulin. Provision of capillary blood glucose monitors for all units to allow bedside testing. Time and dose notations removed from MAR forcing nurse administering the insulin to write in the time and dose when the procedure was performed</p>	Interval between blood glucose test and insulin administration (in min). Proportion of cases where insulin provided ≥ 60 min after blood glucose test (in %)	1-month pre intervention data collection period, followed by a 6-month changeover period and further 1-month data collection period

Study	Level of evidence	Appraisal score	Location	Study design	Study population	Intervention	Outcomes(s) assessed	Length of follow-up
Ray <i>et al.</i> , 1995 ²⁸	III-3	QS 7/11 Clinical importance 2/4 R 3/5	University hospital, San Diego, CA, USA	Before and after trial	General medical patients and medical cart filling technicians	<i>Control:</i> unit-dose cart fill system. Involves 24 medication cassette change. In anticipation of the following day medication administration for each patient. Unit doses are produced in the pharmacy and delivered to the unit every 24 h. <i>Medstation Rx:</i> an inventory is established for each Medstation cart based on the specific needs of the unit. The medication profile for each patient is established by the pharmacy and downloaded to the central terminal (in real time, i.e. it happens as quickly as it is processed, no lag time) and transferred to the appropriate console on the ward. The nurse can then select the patient's name and the prescribed medication. The medication is then released from the medication drawer on the cart	Technician error rate in filling	<i>Pre:</i> 6 weeks. <i>Post:</i> 6 weeks
Brown <i>et al.</i> , 1993 ¹³	III-3	QS 7/11 Clinical importance not estimable R not estimable	Four units of a 950-bed hospital, NC, USA	Before and after trial	Licensed practical nurses	<i>Pre:</i> nurses provide medication to assigned patients. <i>Post:</i> designated medication nurses provide medication to all patients on respective units from Monday to Friday, day and evening shifts. On weekend and night shifts nurses provide medication to assigned patients	Number of medication errors in each unit	3 months

Jarman <i>et al.</i> , 2002 ²⁰	III-3	QS 7/11 Clinical importance not estimable R not estimable	Adult inpatient units of hospital, Geelong, Australia	Before and after trial	Convenience sample of all RNs who were checked as competent for single checking of medications	Pre: standard practice of double checking of medications before administration. Post: single checking performed	Reported medication errors Derived from medication incident records	Pre: 7 months. Post: 7 months
Raschke <i>et al.</i> , 1998 ²⁷	IV	QS 7/11 Clinical importance not estimable R not estimable	Community hospital, AZ, USA	Prospective case series	Consecutive sample of 9306 non-obstetrical patients seen over a period of 6 months	A <i>computer alert system</i> was created that targeted 37 drug- specific adverse drug events. An alert was generated in clinical situations where there was increased risk of an adverse drug event-related injury	True-positive alerts Defined as a written order by a physician being consistent with the recommendations of the computer-generated alert	6 months
Brown <i>et al.</i> , 1995 ¹⁴	III-3	QS 7/11 Clinical importance not estimable R not estimable	Community hospital, NH, USA	Before and after trial	RNs working in a 35-bed surgical unit with a high concentration of orthopaedic patients. RNs working for an average of 10 years and at this hospital for an average of 9 years. 77% were full time	<i>Control</i> : regular care 40 h of observation on day and evening shifts of week days and 1 day on the weekend. <i>Intervention: bedside terminal system</i> . The bedside terminal system includes order entry, nursing care planning, laboratory and X-ray result reporting. One hand-held portable terminal installed in each patient room and 2 in the central nursing station. These terminals communicate with a terminal server located on each unit. 40 h of observation on day and evening shifts of week days and 1 day on the weekend	Medication error rate measured by medication errors per 1000 doses dispensed. Errors identified from reports on incident reporting forms. Errors defined as variation from standard practice	40 h before and after intervention
Adams, 1989 ¹¹	III-3	QS 5/11 Clinical importance not estimable R not estimable	Regional medical centre, SC, USA	Before and after trial	Clinical staff throughout hospital involved with drug delivery (physicians, pharmacists, nurses)	Pre: 14-day handwritten MAR. Required manual MAR. Required manual colours of ink. A separate MAR was required for chemotherapy, anticoagulants and insulin. Respiratory therapy drugs were not located on an MAR. No procedure to match the Patient Profile in the Pharmacy with the Nursing MAR. Post: 24-h computer-generated MAR. This MAR was generated directly in the pharmacy	Medication errors. Nurses on the 11 PM to 7 AM shift would check the order against the MAR. Discrepancies were considered errors	1 year

Study	Level of evidence	Appraisal score	Location	Study design	Study population	Intervention	Outcomes(s) assessed	Length of follow-up
Patterson <i>et al.</i> , 2002 ²⁶	Ethnography	QS 10/10	Three Veterans affairs hospitals (acute care, oncology and nursing home), USA	Ethnography. Observation of medication passes and human-computer interaction before and after introducing BCMA technology	RNs, physicians and pharmacists	<p><i>Pre: observation of standard medication passes</i> <i>Post: BCMA software accessed using a laptop fixed to a wheeled medication chart. This laptop linked to a central electronic database via a wireless network. Scanning a patient bar code on a wristband prompts the computer to list the medications that are due. The bar codes of these medications are then scanned to verify that the correct patient is getting the correct medication in the correct dose at the correct time. If the scanned information on the medication does not match, the nurse is alerted by a pop-up dialogue box.</i></p> <p>Observation of this interaction was performed for 1–7 h on day, evening and night shifts</p> <p>Interesting interaction sequences were analysed as mini-cases and then grouped by emerging themes</p> <p>Observer also watched computerised order entry by physicians and order verification by pharmacists</p>	Negative side-effects of instituting BCMA	21-h observation before intervention. 60 h after intervention

Spencer <i>et al.</i> , 2005 ³⁰	III-3	QS 7/11 Clinical importance not estimable R not estimable	Teaching hospitals, NC, USA	Before and after trial	Patients from general medical units and critical care step-down units	<i>Pre: standard ordering procedure.</i> Handwritten orders by the physician entered into the pharmacy computer system by the pharmacy staff. <i>Post: CPOE system</i>	Medication errors categorised by errors in the process of ordering, dispensing or administering a medication regardless of whether the potential for injury was present	15 months. <i>Pre:</i> 8 and 11 months on 2 units designated for CPOE and 8 months for all other units not designated for CPOE. <i>Post:</i> 2 units using CPOE followed for 7 and 4 months with all other units without CPOE followed for a further 7 months
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BCMA, bar code medication administration; CPOE, computerised physician ordering entry; QS, quality score; R, relevance; RN, registered nurse.

Appendix III

Studies excluded from the review

Study	Reason for exclusion
Alemagno <i>et al.</i> , 2004 ⁵⁰	Wrong outcome
Aufseeser Weiss and Ondeck, 2001 ⁵¹	Discussion paper
Ayuthya <i>et al.</i> , 2003 ⁵²	Wrong outcome
Bates <i>et al.</i> , 1998 ³¹	Described in systematic review ⁹
Bates <i>et al.</i> , 1999 ³²	Described in systematic review ⁹
Bolton <i>et al.</i> , 2004 ⁵³	Wrong outcome
Boyle <i>et al.</i> , 1998 ⁴⁴	Described in review ⁴
Briggs, 2002 ⁴³	Discussion paper
Burton <i>et al.</i> , 1991 ³⁷	Described in systematic review ⁹
Casner <i>et al.</i> , 1993 ⁴⁰	Described in systematic review ⁹
Chertow <i>et al.</i> , 2001 ³⁵	Described in systematic review ⁹
Dhalla <i>et al.</i> , 2002 ⁵⁴	No intervention
Dimant, 2001 ⁵⁵	No intervention
Evans <i>et al.</i> , 1994 ³⁸	Described in systematic review ⁹
Evans <i>et al.</i> , 1998 ³⁶	Described in systematic review ⁹
Hurley <i>et al.</i> , 1986 ³⁹	Described in systematic review ⁹
Larrabee <i>et al.</i> , 1991 ⁴⁹	No intervention
McNally <i>et al.</i> , 1997 ⁴⁵	Wrong outcome
Meredith <i>et al.</i> , 2001 ⁵⁶	Wrong outcome
Mungall <i>et al.</i> , 1994 ⁴²	Described in systematic review ⁹
Mutter, 2003 ⁵⁷	Wrong outcome
Nelson, 2004 ⁵⁸	Descriptive, no intervention
Overhage <i>et al.</i> , 1997 ³³	Described in systematic review ⁹
Papastrat and Wallace, 2003 ⁵⁹	Wrong outcome
Roark, 2004 ⁶⁰	Discussion paper
Strohecker, 2003 ⁵	Discussion paper
Teich <i>et al.</i> , 2000 ³⁴	Described in systematic review ⁹
Van den Bemt <i>et al.</i> , 2002 ⁶¹	Wrong outcome
Westwood <i>et al.</i> ¹⁰	References assessed separately
White <i>et al.</i> , 1987 ⁴¹	Described in systematic review ⁹
Whitman <i>et al.</i> , 2002 ⁶²	Wrong outcome

Appendix IV

Example search strategies

Search strategy for PubMed (contains MEDLINE and pre-MEDLINE)

Search number	Search	Number of citations
#1	Search 'medication errors'[MeSH Terms]	5 207
#2	Search 'aged'[MeSH Terms]	1 431 569
#3	Search 'prescriptions, drug'[MeSH Terms]	13 485
#4	Search 'medication errors'[Title/Abstract]	1 050
#5	Search 'aged'[Title/Abstract]	182 861
#6	Search 'elderly'[Title/Abstract]	99 191
#7	Search 'adults'[Title/Abstract]	154 948
#8	Search 'drug'[Title/Abstract]	429 370
#9	Search 'adverse event'[Title/Abstract]	3 891
#10	Search 'medication'[Title/Abstract]	61 164
#11	Search (((#1)) OR (#4)) OR (#9)	9 306
#12	Search (((#2)) OR (#5)) OR (#6)) OR (#7)	1 673 459
#13	Search (((#3)) OR (#8)) OR (#10)	486 510
#14	Search (((#11)) AND (#12)) AND (#13)	960

Appendix V

Health Technology Assessment (HTA) websites

Australia

- Australian Safety and Efficacy Register of New Interventional Procedures – Surgical (ASERNIP-S) <http://www.surgeons.org/open/asernip-s.htm>
- Centre for Clinical Effectiveness (Monash University, Australia) <http://www.med.monash.edu.au/healthservices/cce/evidence/>
- Health Economics Unit, Monash University <http://chpe.buseco.monash.edu.au>

Austria

- Institute of Technology Assessment/HTA unit <http://www.oeaw.ac.at/ita/e1-3.htm>

Canada

- Agence d'Evaluation des Technologies et des Modes d'Intervention en Santé (AETMIS) <http://www.aetmis.gouv.qc.ca/en/index.htm>
- Alberta Heritage Foundation for Medical Research (AHFMR) <http://www.ahfmr.ab.ca/publications.html>
- Canadian Coordinating Office for Health Technology Assessment (CCHOTA) <http://www.ccohta.ca/newweb/pubapp/pubs.asp>
- Canadian Health Economics Research Association (CHERA/ACRES) – Cabot database <http://www.mycabot.ca>
- Centre for Health Economics and Policy Analysis (CHEPA), McMaster University <http://www.chepa.org>
- Centre for Health Services and Policy Research (CHSPR), University of British Columbia <http://www.chspr.ubc.ca>
- Health Utilities Index (HUI) <http://www.fhs.mcmaster.ca/hug/index.htm>
- Institute for Clinical and Evaluative Studies (ICES) <http://www.ices.on.ca>

Denmark

- Danish Institute for Health Technology Assessment (DIHTA) http://www.dihta.dk/publikationer/index_uk.asp

Finland

- Finnish Office for Health Technology Assessment (FINOHTA) <http://www.stakes.fi/finohta/e/>

France

- L'Agence Nationale d'Accréditation et d'Evaluation en Santé (ANAES) <http://www.anaes.fr/>

Germany

- German Institute for Medical Documentation and Information (DIMDI)/HTA <http://www.dahta.dimdi.de/>
- German Scientific Working Group of Technology Assessment [http://www.epi.mh-hannover.de/\(eng\)/hta.html](http://www.epi.mh-hannover.de/(eng)/hta.html)

The Netherlands

- Health Council of the Netherlands Gezondheidsraad <http://www.gr.nl/engels/welcome/frameset.htm>

New Zealand

- New Zealand Health Technology Assessment (NZHTA) <http://nzhta.chmeds.ac.nz/>

Norway

- Norwegian Centre for Health Technology Assessment (SMM) <http://www.oslo.sintef.no/smm/Publications/Engsmdrag/FramesetPublications.htm>

Spain

- Agencia de Evaluación de Tecnologías Sanitarias, Instituto de Salud 'Carlos III'/Health Technology Assessment Agency (AETS) <http://www.isciii.es/aets/cdoc.htm>
- Catalan Agency for Health Technology Assessment (CAHTA) <http://www.aatm.es/cgi-bin/frame.pl/ang/pu.html>

Sweden

- Swedish Council on Technology Assessment in Health Care (SBU) <http://www.sbu.se/admin/index.asp>

Switzerland

- Swiss Network on Health Technology Assessment (SNHTA) <http://www.snhta.ch/>

United Kingdom

- Health Technology Board for Scotland <http://www.htbs.org.uk/>
- National Health Service Health Technology Assessment (UK)/National Coordinating Centre for Health Technology Assessment (NCCHTA) <http://www.hta.nhsweb.nhs.uk/>
- University of York NHS Centre for Reviews and Dissemination (NHS CRD) <http://www.york.ac.uk/Institute/crd/>
- National Institute for Clinical Excellence (NICE) <http://www.nice.org.uk/index.htm>

United States

- Agency for Healthcare Research and Quality (AHRQ) <http://www.ahrq.gov/clinic/techix.htm>

- Harvard Center for Risk Analysis – Cost-Utility Analysis Database Project (comprehensive league table) <http://www.hcra.harvard.edu/tablesdata.html>
- US Department of Veterans Affairs Technology Assessment Program (VATAP) http://www.va.gov/resdev/prt/pubs_individual.cfm?webpage=pubs_ta_reports.htm

Appendix VI**Critical appraisal checklists***Systematic review critical appraisal checklist*Source: Khan *et al.*, 2001⁸

Title of assessment:

Title of systematic review:

Author(s):

Year:

Comparators:

Score: /6

1. What is the review's objective?

What were the population/participants, interventions, outcomes and study designs?

2. What sources were searched to identify primary studies?

What sources (e.g. databases) were searched and were any restrictions by date, language and type of publication used? Were other strategies used to identify research?

3. What were the inclusion criteria and how were they applied?

4. What criteria were used to assess the quality of primary studies and how were they applied?

5. How were the data extracted from the primary studies?

6. How were the data synthesised?

How were differences between studies investigated?

How were the data combined? Was it reasonable to combine the studies?

What were the summary results of the review?

Do the conclusions flow from the evidence reviewed?

*Rank scoring for appraising the clinical importance of benefit/harm*Source: NHMRC, 2000⁷

Title of review:

Title of study:

Author(s):

Year:

Comparators:

Clinically important effect:

Rank Score: /4

Ranking	Clinical importance of benefit/harm
1	A clinically important benefit for the full range of plausible estimates. The confidence limit closest to the measure of no effect (the 'null') rules out a clinically unimportant effect of the intervention.
2	The point estimate of effect is clinically important BUT the confidence interval includes clinically unimportant effects.
3	The confidence interval does not include any clinically important effects.
4	The range of estimates defined by the confidence interval includes clinically important effects BUT the range of estimates defined by the confidence interval is also compatible with no effect, or a harmful effect.

*Rank scoring for classifying the relevance of evidence*Source: NHMRC, 2000⁷

Title of review:

Title of study:

Author(s):

Year:

Comparators:

Rank Score: /5

Ranking	Relevance of the evidence
1	Evidence of an effect on patient-relevant clinical outcomes, including benefits and harms, and quality of life and survival.
2	Evidence of an effect on a surrogate outcome that has been shown to be predictive of patient-relevant outcomes for the same intervention.
3	Evidence of an effect on proven surrogate outcomes but for a different intervention.
4	Evidence of an effect on proven surrogate outcomes but for a different intervention and population.
5	Evidence confined to unproven surrogate outcomes.

Checklist for appraising the quality of intervention studies

JBI Critical Appraisal Checklist for Experimental Studies

Reviewer _____ Date _____

Author _____ Year _____ Record Number _____

	Yes	No	Unclear
1. Was the assignment to treatment groups random?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Were participants blinded to treatment allocation?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Was allocation to treatment groups concealed from the allocator?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Were the outcomes of people who withdrew described and included in the analysis?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Were those assessing outcomes blind to the treatment allocation?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Were the control and treatment groups comparable at entry?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Were groups treated identically other than for the named interventions?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. Were outcomes measured in the same way for all groups?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Were outcomes measured in a reliable way?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. Was there adequate follow-up (>80%)?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. Was appropriate statistical analysis used?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Overall appraisal: Include Exclude Seek further info.

Comments (Including reasons for exclusion)

JBI QARI Critical Appraisal Checklist for Interpretive & Critical Research

Reviewer _____ Date _____
 Author _____ Year _____ Record Number _____

	Yes	No	Unclear
1. Is there congruity between the stated philosophical perspective and the research methodology?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Is there congruity between the research methodology and the research question or objectives?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Is there congruity between the research methodology and the methods used to collect data?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Is there congruity between the research methodology and the representation and analysis of data?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Is there congruity between the research methodology and the interpretation of results?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Is there a statement locating the researcher culturally or theoretically?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Is the influence of the researcher on the research, and vice versa, addressed?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. Are participants, and their voices, adequately represented?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Is the research ethical according to current criteria or, for recent studies, is there evidence of ethical approval by an appropriate body?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. Do the conclusions drawn in the research report flow from the analysis, or interpretation, of the data?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Overall appraisal: Include Exclude Seek further info.

Comments (Including reasons for exclusion)

JBI Data Extraction Form for Experimental/Observational Studies

Reviewer _____	Date _____
Author _____	Year _____
Journal _____	Record Number _____

Study Method RCT Quasi-RCT Longitudinal

Retrospective Observational Other _____

Participants

Setting _____

Population _____

Sample size _____

Intervention 1 _____ Intervention 2 _____ Intervention 3 _____

Interventions

Intervention 1 _____

Intervention 2 _____

Intervention 3 _____

Clinical outcome measures

Outcome Description	Scale/Measure