The effect of electronic prescribing on medication errors and adverse drug events: a systematic review
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CRD summary
The authors concluded that electronic prescribing can reduce medication errors and adverse drug events, but studies differed substantially in design, quality and findings. Although the direction of effect in the primary studies was generally consistent, the conclusions should be regarded with some caution due to the overall poor quality of the evidence.

Authors' objectives
To assess the effect of electronic prescribing on medication errors and adverse drug events (ADEs).

Searching
MEDLINE, EMBASE and Cochrane Database of Systematic Reviews were searched without language restriction. Search terms were reported. The Journal of the American Medical Informatics Association, the International Journal of Medical Informatics and Methods of Information in Medicine were handsearched. Search dates varied across sources and spanned 1966 to April 2006. The reference lists of studies retrieved were handsearched. The search was restricted to published studies.

Study selection
Studies of electronic prescribing systems (computer-based application systems for ordering drugs, used at the point of care) were eligible for inclusion. Studies could be conducted in any clinical setting and among any patient group, provided that physicians were the primary users. Studies were required to either compare electronic prescribing systems of differing sophistication or to compare electronic systems with handwritten prescribing. Eligible study designs were randomised controlled trials (RCTs) or non-randomised controlled trials (CTs), pre/post studies and time-series analyses. Studies were required to report medication errors, potential adverse drug events and/or adverse drug events as primary outcomes. Medication errors could include errors in ordering, transcribing, dispensing or monitoring medications, as defined in the primary study. Potential adverse drug events were defined as medication errors with significant potential to harm a patient. Adverse drug events were defined as patient injuries resulting from drug use. Studies using electronic prescribing systems for ordering diagnostic tests or therapeutic procedures were excluded, as were ongoing studies, laboratory studies and simulation studies.

Most of the included studies were conducted in the USA in inpatient adult and/or paediatric normal care or intensive care units. Some concerned specific drugs and/or patient groups; others had no restrictions. Eight studies were conducted at the same two sites using the same electronic systems. Home-grown (self-developed) electronic systems and commercial systems were each evaluated in about half of the studies. Half the electronic systems had advanced decision support and the rest had limited or no decision support. Many had been introduced only recently. The comparator in most studies was handwritten prescribing. There was wide variability in outcomes definition (for example, whether legibility was taken into account) and in methods of outcome ascertainment (for example, voluntary reporting and retrospective chart review). Study designs varied widely.

The authors stated neither how the papers were selected for the review nor how many reviewers performed the selection.

Assessment of study quality
Studies were evaluated using an established 16-item checklist, which included assessment of the quality of participant selection procedures, randomisation, sample comparability, blinding, outcomes measurement and statistical analysis. Two reviewers independently conducted the validity assessment. Disagreements were resolved by consensus.

Data extraction
Risk ratios (RRs) and 95% confidence intervals (CIs) were calculated from event rates in the two groups or from other available data. The number of orders was used as the unit of analysis, or (if not available) the number of patients or patient days. Electronic prescribing systems were classified as having no decision support, limited decision support or advanced decision support, according to the level of patient-specific recommendations or alerts included. Results for the longest duration of follow up were used in the review. Two reviewers extracted the data and reached consensus after discussion before a third reviewer checked the data independently. Disagreements were resolved by consensus. Study authors were contacted for further information if necessary.

Methods of synthesis
The studies were combined in forest plots, grouped by effect size. The data were not pooled statistically due to heterogeneity. Pre-specified subgroup analyses were conducted to examine the effect of the following clinical and methodological differences between the studies: clinical setting (inpatient, outpatient, intensive care); patient group; drug; system (home-grown, commercial); functionality (no, limited or advanced decision support); study design and method of error detection. These analyses were interpreted by scanning subgroups on the forest plots.

Results of the review
Twenty seven studies were included. The sample size ranged from 57 to 172,224 patients and from 67 to 204,681 orders (where stated). There were two randomised controlled trials, six time-series analyses, 14 pre/post studies, four cohort studies, and one pre/post study with untreated controls. Study quality was generally weak. Several studies were retrospective. Few had comparison groups recruited over the same period. Half conducted reliable outcomes measurement, but in most cases it was unblinded. Most studies used adequate hypothesis tests and reported measures of statistical variability, but few adjusted for confounding or clustering. Reporting quality was poor overall.

Electronic prescribing versus paper-based or less sophisticated electronic prescribing:

Medication errors (25 studies): Twenty three studies reported a statistically significant risk reduction in the intervention group, with relative risk reduction ranging from 13 per cent to 99 per cent. One study was inconclusive. One study reported a significant 26 per cent increase in errors in the intervention group, which was attributed to confounding and potential selection bias.

Potential adverse drug events (nine studies): Six studies reported a statistically significant risk reduction in the intervention group, with a relative risk reduction of 35 per cent to 98 per cent. Two studies were inconclusive. One reported a statistically significant 29 per cent increase in errors in the intervention group.

Adverse drug events: Four studies reported a significant risk reduction in the intervention group, with a relative risk reduction of 30 per cent to 84 per cent. Three studies (one with no events) found no statistically significant difference between the groups.

Subgroup analyses (seven studies): A greater reduction in medication errors was noted in studies using home-grown or more advanced electronic systems, and in those comparing electronic with handwritten prescribing. Effects differed depending on the method used for detecting errors.

Authors' conclusions
Electronic prescribing can reduce medication errors and adverse drug events, but studies differed substantially in design, quality and findings.

CRD commentary
The objectives and inclusion criteria of the review were clear. Relevant sources were searched for studies without language restriction. But, the restriction to published studies meant that the review was prone to publication bias. Steps were taken to minimise the risk of bias and error by having more than one reviewer independently undertake validity assessment and data extraction, but it was unclear whether this also applied to study selection. The decision not to combine data statistically appeared justified, given the heterogeneity between studies. Although comparison of subgroups by scanning forest plots did not appear statistically robust, these analyses were interpreted with appropriate caution. Potential biases related to poor design, inadequate reporting, poor control of confounders and heterogeneity...
among the primary studies were acknowledged in the review. More emphasis could have been given to study design in the interpretation of results, with priority given to the findings of randomised studies. Although the direction of effect in the primary studies was generally consistent, the authors’ conclusions should be regarded with some caution due to the overall poor quality of the evidence.

**Implications of the review for practice and research**

**Practice:** The authors stated that introduction of electronic prescribing systems should be carefully planned and that they should be integrated into general information systems, with carefully monitoring of medication errors and adverse drug events.

**Research:** The authors stated that there was a need for RCTs with long-term patient-relevant outcomes. Cost-effectiveness studies, studies in non-US and/or primary care settings, and studies using specific commercial systems were also needed. Qualitative research of the implementation of electronic prescribing systems and development of publication guidelines for evaluation studies were also suggested.

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