Authors' objectives
To assess the effects of computer-based clinical decision support systems (CDSSs) on physician performance and patient outcomes.

Searching
Studies from a previous review were included (see Other Publications of Related Interest). This previous review involved searching the US National Library of Medicine, MEDLINE, EMBASE, Inspec and SciSearch from 1974 to February 1992 for studies in any language. Conference proceedings and reference lists of relevant articles were reviewed and authors contacted. The search was updated using a similar strategy from February 1992 to March 1998. The MEDLINE search was conducted using the following terms: computer-assisted decision making; artificial intelligence; computer-assisted diagnosis; computer-assisted therapy; and hospital information systems. SCISEARCH was searched for references to the primary studies from previous reviews. The Cochrane library was searched for relevant citations. Reference lists from all relevant articles were examined and information on additional relevant published or unpublished studies sought from authors of relevant studies.

Study selection
Study designs of evaluations included in the review
Studies were included if they fulfilled the following criteria: participants and outcomes were as defined above; CDSS was evaluated in a clinical setting; and data was collected prospectively with a contemporaneous control group. Trials were excluded if they did not include sufficient results to determine the effects of using CDSS.

Specific interventions included in the review
CDSSs in clinical settings were studied with CDSSs defined as any software designed to directly aid in clinical decision making in which characteristics of individual patients were matched to a computerized knowledge base for the purpose of generating patient-specific assessments or recommendations that are then presented to clinicians for consideration. Topics studied included the following: drug dosing; diagnosis of pediatric patients, patients presenting with chest or abdominal pain, and identification of patients at high risk of developing respiratory complications; preventive care (including reminders of both single and multiple tests such as blood pressure assessment, vaccination or cancer screening); and other aspects of medical care (including disease specific and numerous medical problems).

Participants included in the review
Study participants were health professionals in clinical practice or post-graduate training.

Outcomes assessed in the review
Assessed outcomes included clinician performance (measuring the process of care) and patient outcomes (including any aspect of patient well-being).

How were decisions on the relevance of primary studies made?
All citations, and index terms and abstracts where available were reviewed and rated as "potentially relevant" or "not relevant". Inter-rater reliability was assessed. Full text articles were reviewed independently by either reviewer regarding inclusion criteria with disagreements being resolved by consensus.

Assessment of study quality
The following 5 potential sources of bias were assessed: allocation method (random vs quasi-random vs selected concurrent controls); unit of allocation (clinic vs physician vs patient); baseline differences between groups that were potentially linked to the study outcome (no baseline differences or appropriate statistical adjustment vs baseline).
differences present and no statistical adjustment vs unable to assess); type of outcome measure (objective or subjective outcome with blinded assessment vs subjective outcome with no blinding of assessors and no explicit criteria for each outcome); and completeness of follow-up (> 90% vs 80% to 90% vs < 80%). At least two authors assessed all primary studies independently for validity. A ten point rating scale was used and disagreements were resolved by consensus.

**Data extraction**
One of the authors extracted information concerning patients, setting, intervention and outcomes with this being verified by a second author. Measures of process of care and clinical outcomes were characterised for each study according to whether a statistically significant effect was reported.

**Methods of synthesis**
How were the studies combined?
The studies were combined in a narrative review.

How were differences between studies investigated?
Linear regression of the validity score of all trials against their year of publication was used to determine changes in validity over time.

**Results of the review**
A total of 68 studies were included (28 studies previously reviewed and 40 new studies).

Inter-rater reliability for coding of identified studies as potentially relevant or not Kappa = 58% (95%CI: 42%, 75%). Agreement on eligibility of studies Kappa = 86% (95%CI: 76%, 97%). Chance-corrected agreement between reviewers on validity Kappa = 82% (95%CI: 67%, 97%).

The majority of trials were randomised with 9 studies (13%) using quasi-random allocation or selected concurrent controls. The 28 studies in the original review had validity scores ranging from 2 to 9 (mean 6.4) with 7 (25%) scoring between 8 and 10. Validity scores for the new studies ranged from 4 to 10 (mean 7.7) with 21 (53%) scoring 8 to 10. Linear regression of validity vs year of publication estimated Beta = 0.14 (95%CI: 0.07, 0.20).

65 studies evaluating CDSSs on clinicians behaviour with 43 (66%) of these finding at least some benefit. These included 9 of 15 studies evaluating drug dosing; 1 of 5 studies evaluating diagnostic aids; 14 of 19 studies evaluating preventative care: and 19 of 26 studies evaluating other medical care.

14 studies evaluated the effect of CDSSs on patient outcomes with 6 (43%) documenting a benefit. 5 (62%) of trials finding no benefit had a power of less than 80% to detect a moderate or clinically important benefit.

Drug dosing: Benefit was found with the use of CDSSs in achieving or maintaining therapeutic theophylline (4 studies) or lidocaine hydrochloride levels (1 study) or improving anticoagulation control with heparin (1 study). 7 studies evaluating different outcomes in studies of warfarin control reported inconsistent results.

Diagnostic aids: the one study finding a benefit identified patients at high risk of developing respiratory complications postoperatively.

Prevention: all studies evaluated process of care with 14 (74%) of studies finding benefit for at least one care process. 1 study reported patient outcomes (blood pressure control) and noted no change.

Other medical care: inconsistent results were reported for hypertension care (2 studies: one reporting benefit); compliance with recommendations for diabetic care (4 studies: 2 reported improvement); compliance with recommendations for general medical problems (5 studies: all reported benefit). 7 studies reported patient outcomes with no improvement being reported for blood pressure (3 studies) and beneficial effects noted for changes in weight and quality of life (2 studies).
Authors' conclusions
Published studies of computer based clinical decision support systems (CDSSs) are increasing rapidly and their quality is improving. The CDSSs can enhance clinical performance for drug dosing, preventive care, and other aspects of medical care but not convincingly for diagnosis. The effect of CDSSs on patient outcomes have not been sufficiently studied.

CRD commentary
The aims and inclusion criteria were clearly stated. A thorough literature search was conducted. Validity was assessed using defined criteria. Methods by which studies were selected for inclusion and validity assessed were described. Given the differences in clinical problems, interventions, and outcome measures, a narrative review was appropriate. Relevant details of studies of drug dosing, preventative care and 'other medical care' were clearly presented.

Different outcomes were reported for some interventions but no discussion of potential causes of this heterogeneity was presented. Without some investigation of the heterogeneity among studies it is difficult to be certain of the aspect of the intervention that leads to benefit.

Implications of the review for practice and research
Practice: Ambulatory care services and clinics should consider opportunities to acquire preventative care reminder systems. Diagnostic aids systems should only be deployed in settings in which they are being properly evaluated.

Research: Larger confirmatory studies of CDSSs in drug dosing systems may be warranted. Health care centres should include some form of in-house evaluation when incorporating CDSSs.

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Bibliographic details

PubMedID
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Original Paper URL
http://jama.ama-assn.org/

Other publications of related interest

These additional published commentaries may also be of interest. Wyatt J. Computer-based clinical decision support systems can enhance physician performance but have been insufficiently studied with regard to patient outcomes. Evidenced-based Healthcare 1999;3:39.

Weekley J, Smith B. Review: computer-based clinical decision support systems can improve physician performance in some areas. ACP J Club 1999;130(3):79.

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