Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success
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CRD summary
This review identified four features associated with the success of decision support systems in clinical practice: computer-based; provided as part of clinician workflow; delivered at the time and place of decision-making; actionable recommendations provided. These features were supported by the evidence presented, but potential biases in the study selection process meant that relevant studies may have been missed.

Authors' objectives
To identify features of clinical decision support systems deemed essential for improving clinical practice.

Searching
MEDLINE (from 1966 to 2003), CINAHL (from 1982 to 2003) and the Cochrane Controlled Trials Register (2003) were searched; the search terms were reported. Reference lists were also checked for additional relevant studies. Non-English language articles were excluded.

Study selection
Study designs of evaluations included in the review
Randomised controlled trials (RCTs) were eligible for inclusion. Those with less than 7 units of randomisation per study arm were excluded.

Specific interventions included in the review
Studies of any electronic or non-electronic decision support system (where patient-specific assessments or recommendations were given to clinicians) in a real clinical setting were eligible for inclusion. Included in the review were a variety of interventions based upon reminder or prompt, feedback, or decision support systems. The majority were computer-based with printed patient-specific advice (34%); others included non-electronic systems with chart-based, patient-specific advice (26%) and decision support within computerised order entry systems (16%). Those where mandatory compliance with the system was required were excluded. Studies where either the intervention content or clinician interaction with the system were not described were also excluded.

Participants included in the review
Studies where systems were used by clinicians (physicians, physician assistants, or nurse practitioners) who were directly involved in the care of patients were eligible for inclusion. Over half of the included studies included predominantly residents and fellows; other studies included mid-level clinicians (23% were physician assistants and nurse practitioners) and patients (11% were paediatric patients).

Outcomes assessed in the review
Studies that assessed improvements in clinical practice using patient outcomes or process measures were eligible for inclusion. Both clinical and statistical improvements were assessed in the included studies. The reported outcomes included patient and clinician compliance during delivery of the decision support system.

How were decisions on the relevance of primary studies made?
Two reviewers independently identified potentially relevant studies (from titles, index terms, abstracts and full papers) using a screening algorithm based on study type, design, participants, setting and intervention. Two reviewers independently determined the final set of included studies once the full set of inclusion and exclusion criteria had been applied. Any disagreements were resolved by discussion and inter-rater agreement (Cohen's unweighted kappa statistic) was reported.
Assessment of study quality
Studies with less than 5 points on a 10-point scale assessing five potential sources of study bias were excluded at the study selection stage. Although a reference was given (see Other Publications of Related Interest), no further details on the validity criteria were supplied. There was no separate report of how validity was assessed. However, given that the validity criteria were applied as part of the study selection process, it is assumed that this was done using the same process as when determining the relevance of primary studies.

Data extraction
Two reviewers independently extracted data on statistical and clinical improvements in clinical practice arising from decision support systems. Details of the setting and clinical specialty were reported, along with percentage success rates, rate differences (RDs) and 95% confidence intervals (CIs). Adjusted odds ratios (ORs) were then calculated in a meta-regression analysis. Data on the presence (or absence) of system features contributing to the success or failure of the systems were also collected. A list of 15 potentially relevant features that could be reliably abstracted (and subsequently used as a template for data extraction) was derived.

Methods of synthesis
How were the studies combined?
A univariate analysis was performed to determine the significance of the 15 system features on an individual study basis. A multiple regression analysis (pooling the results of all studies) was then conducted to assess independent predictors of success whilst taking account of other system features present. The results were supplemented by a narrative synthesis of direct experimental evidence, and the results of this were structured in terms of the relevance of specific system features.

How were differences between studies investigated?
A secondary regression analysis produced subgroup results to separate the effects of computer-based and non-electronic systems. In all analyses, steps were taken to identify the role of potentially confounding factors arising from the decision support context (acute care versus non-acute care) and study environment (academic versus non-academic; out-patient versus in-patient).

Results of the review
Seventy studies (from 88 papers) were included in the review. There were 82 relevant comparisons in which 71 compared a decision support system with a control group and 11 provided a direct comparison of systems. Amongst the studies, there were approximately 6,000 clinicians caring for 130,000 patients.

Decision support systems improved clinical practice in 68% of the studies. In the univariate analysis, 6 system features were relevant to intervention success. Differences in the success rates were reported for studies of interventions with and without the specific feature. For those reaching statistical significance (P=0.05), 75% of interventions were successful when decision support was provided as part of routine clinical practice (RD 75%, 95% CI: 37, 84) and 73% were successful when integrated with charting or order entry systems (RD 37%, 95% CI: 6, 61). Seventy-six per cent of the interventions were successful when a recommendation (rather than assessment alone) was provided (RD 35%, 95% CI: 8, 58). All interventions were successful when reasons for non-compliance with recommendations were requested from the clinician (RD 41%, 95% CI: 19, 54). Seventy-six per cent of the interventions were also successful when computer-based systems were included (RD 26%, 95% CI: 2, 49). A further feature (although marginally short of the significance level) was the provision of support at the time and location of decision-making (RD 26%, 95% CI: 2, 49). A further feature (although marginally short of the significance level) was the provision of support at the time and location of decision-making (RD 48%, 95% CI: 0, 70).

In the multivariate regression analysis, four of the above features were confirmed as independent predictors of successful interventions. Of the 32 systems including all 4 features, 30 (94%) were noted to improve clinical practice. These were the provision of support as part of the clinical workflow (adjusted OR 112.1, 95% CI: 12.9, infinity, P=0.00001); the provision of decision support at the time and location of decision making (adjusted OR 15.4, 95% CI: 1.3, 300.6, P=0.0263); the provision of a recommendation rather than assessment alone (adjusted OR 7.1, 95% CI: 1.3, 45.6, P=0.0187); and the use of computer-based systems (adjusted OR 6.3, 95% CI: 1.2, 45.0, P=0.0294). The subgroup analysis of computer-based versus non-electronic systems was consistent with these findings.
The survey of direct experimental evidence confirmed the importance of providing decision support at the time and location of decision-making and the requesting of documented reasons for non-compliance. In addition, success was enhanced when clinicians were provided with periodic feedback about their compliance with recommendations, and when decision support results were conveyed to both clinicians and patients.

The analysis of inter-rater agreement showed favourable results for the study selection (range: 66 to 96%) and data extraction (91 and 94%).

Authors' conclusions
Four features were significantly correlated with the success of decision support systems in terms of improved clinical practice: the automatic inclusion of decision support systems within the clinical workflow; the provision of recommendations rather than assessments alone; the provision of decision support at the time and location of decision-making; and the provision of computer-based systems. Direct experimental evidence showed that periodic performance feedback, conveying recommendations to patients, and the follow-up of reasons for non-compliance with recommendations represented additional important predictors of success.

CRD commentary
The question and inclusion criteria for this review were clear. These were followed by a search strategy that sought the retrieval of RCTs published in English. The restrictive nature of this search meant that relevant studies might have been missed. A validity assessment was implied as part of the study selection criteria, but the absence of reporting on specific criteria (and subsequent results of the assessment) potentially limits the reliability of the findings. Other aspects of the review process included some appropriate measures to eliminate bias.

The statistical methods used to synthesise the data appeared to have been relevant to the objective of the study, and the parallel reporting of results from experimental research added strength to the review's findings. Variation and potential confounding were appropriately addressed in subgroup analyses, although the regression sample size was reportedly small. The authors' conclusions appear to have been reliably based on the evidence presented in the review. However, the authors acknowledged the possibility that the results might have been biased towards significant findings for those process outcomes for which data could be reliably abstracted. This means that potentially relevant findings in relation to ineffective interventions, patient and other less tangible outcomes might have been overlooked.

Implications of the review for practice and research
Practice: The authors stated that future clinical decision support systems should be designed with ease of use in mind. The system should ideally be computer-based as part of the normal clinical workflow, and delivered (with actionable recommendations provided) at the time and location of decision-making. Research: The authors stated that future research should be experimental, with focus upon the explicit description of interventions and the provision of details regarding clinician-system interaction.

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