Randell R, Mitchell N, Dowding D, Cullum N, Thompson C. (2007) Effects of computerized decision support systems on nursing performance and patient outcomes. Journal of Health Services Research and Policy 12(4), pp.242-251

Effects of Computerised Decision Support Systems on Nursing Performance and Patient Outcomes: A Systematic Review

Abstract

Objective To examine the effect of computerised decision support systems (CDSS) on nursing performance and patient outcomes.

Data sources 15 databases including Medline and CINAHL were searched up to May 2006, together with reference lists of included studies and relevant reviews.

Review methods Randomised controlled trials, controlled clinical trials, controlled before and after studies and interrupted time series studies that assessed the effects of CDSS use by nurses in a clinical setting on measurable professional and/or patient outcomes were included.

Results 8 studies, 3 comparing nurses using CDSS with nurses not using CDSS and 5 comparing nurses using CDSS with other health professionals not using CDSS, were included. Risk of contamination was a concern in 4 studies. The effect of CDSS on nursing performance and patient outcomes was inconsistent.

Conclusion The introduction of CDSS may not necessarily lead to a positive outcome; further studies are needed in order to identify contexts in which CDSS use by nurses is most effective. CDSS are complex interventions and should be evaluated as such; future studies should explore the impact of the users and the protocol on which the CDSS is based, reporting details of both. Contamination is a significant issue when evaluating CDSS, so it is important that randomisation is at the practitioner or the unit level. Future systematic reviews should focus on particular uses of CDSS.

Introduction

In developed healthcare systems such as the United States, Canada, Australia, and the UK, nurses are taking on extended roles with greater decision making responsibility.[1-3] Examples include nurse led first contact care[4] and chronic disease management,[3] and independent nurse prescribing,[5] motivated by a desire to reduce costs and improve access to care.[3]

Computerised decision support systems (CDSS) are designed to aid clinical decision making, matching patient characteristics to a computerised knowledge base to generate patient-specific assessments or recommendations.[6] CDSS are being used by nurses in a number of extended roles, including nurse led management of asthma,[7, 8] angina,[7] and diabetes,[9] and nurse led first contact care.[10, 11]

Evidence regarding the impact of CDSS on nurse performance and patient outcomes is uncertain. While previous systematic reviews have evaluated the effectiveness of CDSS in clinical settings,[6, 12, 13] they have focused on doctors as users. With increasing international interest in such systems, there is a need to assess the effects of CDSS on the processes and outcomes of nurse decision making, and to understand in what contexts CDSS can support nurse decision making.

Methods

Eligibility criteria

The review sought to identify randomised controlled trials (RCTs), controlled clinical trials (CCTs), controlled before and after (CBA) studies and interrupted time series (ITS) studies, that assessed the effects of CDSS use by nurses in a clinical setting on measurable professional and/or patient outcomes.

Searching

The following databases were searched: Medline, CINAHL, EMBASE, British Nursing Index (BNI), HMIC Health Management Information Consortium, the Cochrane Controlled Trials Register, ASSIA, Sociological Abstracts, PsycINFO, INSPEC, SIGLE, National Research Register, and Social Science Citations Index up to April 2005. Searches were not limited by language. Search terms referring to the technology, such as 'decision support systems', 'expert system' and 'reminder systems', were used. The search was rerun in May 2006 to identify recently published studies.

Reference lists of included studies and relevant reviews were also searched. Experts in the field were contacted to identify recently published work, conference publications and unpublished studies.

Selection

Two reviewers independently reviewed abstracts of identified references, rating each paper as "potentially relevant" or "not relevant" based on intervention and participants. The reviewers then reviewed the full texts of all potentially relevant papers and rated each paper based on intervention, participants, and methods to select the final set of included studies. Disagreements between reviewers were resolved by consensus or by a third reviewer.

Validity assessment

Two reviewers, using criteria from the Cochrane Effective Practice and Organisation of Care Group (EPOC) data collection checklist,[14] independently assessed the methodological quality of included studies. Details of the criteria for RCTs can be found in Table 1. Risk of

contamination was felt to be important as previous studies have shown that nurses incorporate CDSS knowledge, using that knowledge when the CDSS is not available;[15] such inadvertent application of aspects of the intervention to the control group can dilute the effects of the intervention.

Data abstraction

For included studies, two reviewers independently abstracted data on methods, setting, participants, intervention (including CDSS characteristics) and outcomes. The studies substantially differed in type and number of outcomes assessed and the majority of studies did not define a single outcome for statistical testing. Therefore, data was abstracted for all reported practitioner performance and patient outcomes. Disagreements between reviewers were resolved by consensus or by a third reviewer.

Quantitative data synthesis

The studies identified in the review varied in terms of the system being evaluated, clinical area and outcome measures. Therefore, meta-analysis was not appropriate. Following earlier systematic reviews,[16, 17] reference outcomes were identified for each study, derived by calculating the absolute risk difference for all dichotomous performance and patient outcomes and identifying the performance measure and/or the patient outcome demonstrating the median effect. To preserve the meanings of the outcomes, where there were an even number of outcomes the lower of the two outcomes that surrounds the theoretical median was used as the reference outcome. In describing the results of the studies, focus will be on the reference outcomes. Use of reference outcomes enables consistency of effects to be assessed across studies. Focusing on median rather than mean effects helps to eliminate skewing, based on one or two outliers with particularly large or small effect sizes.[16] Dichotomous outcomes were

focused upon because they were reported more frequently and continuous outcomes were rarely reported in enough detail for the standardised mean difference to be calculated. The hypothesised direction of effect differed between studies, so to standardise reporting in this review, a positive difference reflects improvement. Absolute risk differences were calculated using Comprehensive Meta-analysis Version 2 (Biostat, Englewood NJ).

A previous systematic review of CDSS used meta regression to identify features of CDSS that predict the impact on patient and performance outcomes.[13] Within the current review, meta-regression was not appropriate because of the small number of studies.

Results

Description of studies

Eight studies described in nine papers were included in the final review (Figure 1). Three studies compared nurses using CDSS with nurses not using CDSS (comparison 1). Five studies compared nurses using CDSS with other health professionals not using CDSS (comparison 2). Across the studies, more than 100 nurses and more than 24,000 patients acted as study participants. Four studies were concerned with anticoagulation management, three were concerned with telephone triage in first contact care, and one was concerned with glucose regulation in the intensive care unit (ICU). Five studies were conducted within a primary care context and six studies were conducted in the UK.

Methodological quality

Risk of contamination was a concern in 4 of the 7 RCTs.[18-21] One study involved only one nurse, who provided treatment to patients in both arms of the trial.[21] Details of which validity criteria were met are provided for each study in Tables 2, 4 and 6.

Comparison 1: nurses using CDSS compared with nurses not using CDSS (3 RCTs, 4846 participants)

Characteristics of the studies for comparison 1 are given in Table 2 and the results are reported in Table 3. Improved performance and patient outcomes were anticipated if the CDSS was effective. Targeted behaviours were anticoagulation management,[21] telephone triage of same day appointment requests,[22] and glucose regulation.[19]

The studies by Richards et al.[22] and Rood et al.[19] assessed the impact of CDSS in terms of performance measures. Richards et al. compared management of same day appointment requests by nurses using CDSS at NHS Direct (the telephone triage and advice service for England) with practice nurses using clinical protocols. In the intervention group, the likelihood of having a nurse as a final point of contact was significantly lower (risk difference -0.07, 95% CI -0.10 to -0.04, p = 0.00). This was perceived as a negative outcome by the authors, as it meant greater GP workload in the intervention group. Rood et al. compared glucose regulation in intensive care by nurses using CDSS with nurses using a paper-based guideline. CDSS use significantly improved the number of samples taken on time (risk difference 0.05, 95% CI 0.02 - 0.07, p = 0.00) and there was a significant difference in three of the four performance outcomes measured favouring the intervention group.

All three studies assessed the effect of CDSS in terms of patient outcomes. White and Mungall[21] compared anticoagulation management by a nurse-specialist using CDSS with anticoagulation management by a nurse-specialist without CDSS. When CDSS was used, there was no significant difference in the number of patients with final prothrombin time within 2 seconds of the target time (risk difference 0.07, 95% CI -0.35 – 0.22, p = 0.65). In

the study of triage of same day appointment requests, CDSS use had no effect on the number of practice based consultations, emergency department consultations, and out of hours consultations in the month following triage.[22] When CDSS was used for glucose regulation in ICU, there was no effect on the proportion of time blood glucose levels were within the target range (risk difference 0.01, 95% CI -0.13 – 0.15, p = 0.85).[19]

In summary, in one study CDSS use improved performance measures,[19] in another it was associated with poorer performance,[22] and no study found an impact of CDSS on patient outcomes. However, two studies had small sample sizes[19, 21] and were too small to identify clinically important effects as statistically significant, if they existed. Equally, the finding of no significant difference may be the result of contamination in two of the studies.[19, 21]

Comparison 2: nurses using CDSS compared with other health professionals not using CDSS (4 RCTs, 1 ITS, 19,744 participants)

In this comparison, equivalent performance and patient outcomes in both study groups were anticipated if the CDSS was effective, although only two studies were powered to detect equivalence.[18, 23] In three RCTs, the targeted behaviour was anticoagulation management.[18, 20, 24] Characteristics of these studies are given in Table 4 and the results are reported in Table 5. Two studies assessed telephone triage and advice in first contact care.[23, 25] Characteristics of these studies are given in Table 6 and the results are reported in Table 7.

Only one study of anticoagulation management assessed the impact of CDSS in terms of performance.[20] This study was not powered to detect equivalence. The study compared acceptance of CDSS advice by the nurse practitioner with the agreement between junior doctors and the CDSS. CDSS use led to a significant increase in acceptance of dose and

interval advice (risk difference 0.19, 95% CI 0.09 – 0.29, p = 0.00), although level of acceptance depended on the target INR (international normalised ratio) range of patients, with nurse practitioners having significantly increased acceptance of CDSS advice for patients with a target INR range of 2.0-3.0 but not for patients with a target INR range of 3.0-4.5. All three studies of anticoagulation management assessed the effect of CDSS in terms of patient outcomes. In the pilot study by Fitzmaurice et al.[24] there was no significant difference in mortality, although the study was not powered to detect equivalence (risk difference 0.16, 95% CI -0.14 – 0.46, p = 0.31). In the study by Vadher et al.[20] level of INR control varied depending on the target INR range of patients, with nurse practitioners using CDSS being significantly better at INR control than junior doctors for patients with a target INR range of 2.0-3.0 but not for patients with a target INR range of 3.0-4.5. In the second study by Fitzmaurice et al.[18] there was no significant difference in the rates of serious adverse events with CDSS (risk difference 0.02, 95% CI -0.02 – 0.05, p = 0.39) and all other patient outcomes showed a non-significant difference.

Both triage studies assessed the impact of CDSS in terms of performance measures and patient outcomes. In out-of-hours first contact care, CDSS use by practice nurses for telephone triage led to a significant reduction in the percentage of calls managed with telephone advice from a GP (risk difference 0.34, 95% CI 0.33 – 0.36, p = 0.00).[23] In triage of same day appointment requests, CDSS use led to a decrease in GP appointments (risk difference 0.23, 95% CI 0.20 – 0.26, p = 0.00).[25] In out-of-hours telephone triage, there was a reduction in adverse events in the intervention group, with a significant difference in two of the four measures.[23] The upper 95% confidence interval for the number of deaths within 7 days of contact with the service in the intervention arm was well within the limits of equivalence (risk difference 0.00, 95% CI 0.00 – 0.00, p=0.48). In triage of same day

appointment requests, there was a significant difference in all three patient outcome measures (number of out of hours consultations, number of accident and emergency visits, and number of return consultations), all favouring the control group.[25]

In summary, three RCTs comparing nurses using CDSS with doctors for anticoagulation management found no significant difference in terms of patient outcomes, suggesting that CDSS may help nurses to manage anticoagulation as effectively as doctors. However, these studies were underpowered to detect important adverse consequences of poor anticoagulation management such as death. The two studies of triage for first contact care suggest CDSS to be beneficial in terms of performance, with significantly decreased GP workload when nurses used CDSS. One study suggests CDSS to be detrimental to patient outcomes,[25] while one study suggests CDSS to be beneficial in terms of some patient outcomes.[23]

Discussion

The expanding role of nurses in developed healthcare systems has been accompanied by investment in CDSS, underpinned by the assumption that use of such systems improves nursing performance. The purpose of this review was to evaluate the evidence for this, examining the effect CDSS use has on both nursing performance and patient outcomes. 8 studies were identified that have considered the impact of CDSS use on nursing performance and/or patient outcomes. The studies were limited to three areas of practice: anticoagulation management, telephone triage in first contact care, and glucose regulation in intensive care.

The assumption that CDSS use improves nursing performance is not strongly supported by current evidence. Three studies compared nurses using CDSS with nurses not using CDSS; while one study found CDSS use improved performance measures, in another it was

associated with poorer performance. This is in contrast to previous systematic reviews that found that CDSS use improved clinical practice in over 60% of trials.[12, 13] None of the studies in this comparison group demonstrated an improvement in patient outcomes.

The assumption that CDSS use enables nurses to provide care equivalent to that provided by other health professionals is not strongly supported by current evidence. Five studies compared nurses using CDSS with other health professionals not using CDSS, two of which showed a significant difference favouring the control group for some patient outcomes. There is some evidence to suggest anticoagulation management by nurses using CDSS is an effective alternative to standard management. However, none of the studies were powered to detect either difference or equivalence in adverse events; a much larger study would be needed to determine whether it is a safe alternative to standard management. While there is some evidence to suggest CDSS use for telephone triage in first contact care can be beneficial in terms of performance, the benefits in terms of patient outcomes are uncertain.

Present enthusiasm for supporting healthcare practice through introduction of new technologies means that CDSS have been introduced without adequate evaluation. CDSS are being used to support nurse-led first contact care in walk-in centres and accident and emergency departments.[11] Current evidence on the benefit of such systems for telephone triage is equivocal and no clinical trials to date have evaluated their use in face-to-face consultations. Evaluation is also needed of CDSS for nurse-led chronic disease management; while such systems have been evaluated in studies involving nurses, the studies fail to distinguish between different practitioners when reporting results.[7-9] The remainder of this section discusses what is required for adequate evaluation of CDSS.

CDSS are complex interventions, comprising a number of components: the system itself, the protocol on which it is based, its users, and the processes that surround its use.[26] Although all studies included in this review are concerned with CDSS, there is heterogeneity in the way the interventions work, the protocols they are based on, and the decision tasks they support. Differences in results across the studies suggest that future studies should seek to explore the significance of each component for nursing performance and patient outcomes. A previous systematic review of CDSS found the following features to be important in improving clinical practice: automatic provision of decision support; provision of recommendations rather than just assessments; and provision of decision support at the time and location of decision making.[13] When all these features were present, practice was significantly improved in 94% of trials. However, the system descriptions suggest that these features were present in the trials included in this review yet the results were still inconsistent. We need to look further to understand differences in the results.

While failure to apply CDSS recommendations has been cited as a reason for CDSS not having the expected impact,[27] for a number of studies in this review, the results suggest that the failure lies with the protocols on which the CDSS is based. In the study of CDSS for glucose regulation in ICU, adherence to the recommendation was high yet the difference in time spent in normal range was too small to be clinically important, leading the authors to suggest that it is the protocols that need to be improved.[19] In triage of same day appointment requests by practice nurses using CDSS, compared with standard care, CDSS use led to a significant reduction in GP appointments but was also associated with increased use of out of hours and accident and emergency services.[25] The authors suggest that this could be because patients' needs were not adequately met by the triage system. Again, this points to the need to look at the protocols on which the CDSS is based.

Perhaps the most complex study to interpret of those presented in this review is the study of management of same day appointment requests, comparing NHS Direct nurses using CDSS with practice nurses using clinical protocols.[22] Patients triaged by the NHS Direct nurses were less likely to have a consultation with a nurse as their final point of contact and more likely to have a consultation with a general practitioner, interpreted as a negative outcome because of the increase in GP workload. The authors speculate that the difference in performance could be because the practice nurses are the same nurses who subsequently see patients face-to-face and therefore they have a greater sense of what a practice nurse can manage. There is a need to compare the protocols used in the two arms of the trial. The CDSS currently used throughout NHS Direct does not have 'nurse consultation' as option, instead having the following options: A&E, immediate or routine contact with a GP, advice on self-care at home, and information giving.[28] Creation of complex protocols such as those used for triage requires a prioritisation of certain performance measures above others; while the aim of the protocols used in the control arm of the trial may be to reduce unnecessary GP appointments, the software used by NHS Direct nurses seeks to minimise malpractice risks.[28]

The results of these studies suggest that it is first necessary to adequately evaluate the protocol before development of a CDSS even begins. Then the CDSS should be evaluated against its paper-based counterpart,[27] following the phases outlined in the MRC framework for evaluation of complex interventions.[26] As well as enabling evaluators to distinguish between the impact of the protocol and the impact of the technology, evaluating the CDSS against its paper-based counterpart would identify contexts in which a paper-based solution is as effective, preventing unnecessary expenditure on computer-based interventions. In order to distinguish between impact of the CDSS and impact of the practitioner, data should be

collected on levels of use and adherence to recommendations. If adherence is greater in one arm of the trial, reasons for this can then be explored; collection of qualitative data could be useful for this, as demonstrated by qualitative studies of CDSS use in first contact care.[28, 29] As discussed above, contamination is a significant issue facing RCTs in this area as inadvertent application of the intervention, or aspects of the intervention, to the control group can dilute the effects of the intervention. Therefore, randomisation should be at the practitioner or unit level. There is enormous unexplained variation between health professionals using CDSS and this must be considered in study designs; it is important that more than one nurse is included in the trial and actual numbers of nurses included in the trial should be reported.

Conclusions

With the current emphasis on the introduction of technology to support healthcare practice, adequate evaluation of CDSS is not being undertaken before they are introduced into practice. The results of this review suggest there is currently an inadequate evidence base upon which to support wholesale introduction of CDSS to assist nursing practice. In order to ensure the technology that is introduced has the potential to improve both nursing practice and patient outcomes, future developments should focus on first evaluating the protocol on which the CDSS is to be based. Only if the protocol is shown to be effective should development of a CDSS begin. Such systems then need to be evaluated against their paper-based counterparts by adequately designed and powered studies which collect data on both nursing performance and patient outcomes. The results of this review suggest that CDSS is a very different beast when applied in different contexts; future systematic reviews should focus on particular uses of CDSS and not repeat the general approach taken here.

Acknowledgements

[Removed to mask identity of authors]

Reference List

1. Bryant-Lukosius D, DiCenso A, Browne G, Pinelli J. Advanced practice nursing roles: development, implementation and evaluation. J Adv Nurs. 2004; 48: 519-29

2. Furlong E, Smith R. Advanced nursing practice: policy, education and role development. J Clin Nurs. 2005; 14: 1059-66

3. Horrocks S, Anderson E, Salisbury C. Systematic review of whether nurse practitioners working in primary care can provide equivalent care to doctors. BMJ. 2002; 324: 819-23

4. Rosen R, Mountford L. Developing and supporting extended nursing roles: the challenges of NHS walk-in centres. J Adv Nurs. 2002; 39: 241-8

5. Jones M, editor. Nurse Prescribing: Politics to Practice. London: Harcourt Publishers, 1999

6. Hunt D, Haynes R, Hanna S. Effects of computer-based clinical decision support systems on physician performance and patient outcomes. JAMA. 1998; 280: 1339-46

7. Eccles M, McColl E, Steen N, et al. Effect of computerised evidence based guidelines on management of asthma and angina in adults in primary care: cluster randomised controlled trial. BMJ. 2002; 325: 941

8. McCowan C, Neville RG, Ricketts IW, Warner FC, Hoskins G, Thomas GE. Lessons from a randomized controlled trial designed to evaluate computer decision support software to improve the management of asthma. Med Inform Internet Med. 2001; 26: 191-201

9. Eccles M, Whitty P, Speed C, et al. A cluster randomised controlled trial of a Diabetes REcall And Management system: The DREAM Trial. BMJ. In press:

10. Dunt D, Day S, Kelaher M, Montalto M. Impact of standalone and embedded telephone triage systems on after hours primary medical care service utilisation and mix in Australia. Aust New Zealand Health Policy. 2005; 2: 30

11. Salisbury C, Chalder M, Scott TM, Pope C, Moore L. What is the role of walk-in centres in the NHS? BMJ. 2002; 324: 399-402

12. Garg AX, Adhikari NKJ, McDonald H, et al. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: A systematic review. JAMA. 2005; 293: 1223-38

13. Kawamoto K, Houlihan CA, Balas EA, Lobach DF. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. BMJ. 2005; 330: 765-72

14. Cochrane Effective Practice and Organisation of Care Group (EPOC). Data Collection Checklist; 2002

15. O'Cathain A, Sampson FC, Munro JF, Thomas KJ, Nicholl JP. Nurses' views of using computerized decision support software in NHS Direct. Journal of Advanced Nursing. 2004; 45: 280-6

16. Grimshaw JM, Thomas RE, MacLennan G, et al. Effectiveness and efficiency of guideline dissemination and implementation strategies. Health Technol Assess. 2004; 8:

17. Shojania KG, Ranji SR, Shaw LK, et al. Diabetes Mellitus Care. Closing the Quality Gap: A Critical Analysis of Quality Improvement Strategies. 2004; 2:

18. Fitzmaurice DA, Hobbs FDR, Murray ET, Holder RL, Allan TF, Rose PE. Oral anticoagulation management in primary care with the use of computerized decision support and near-patient testing: A randomized, controlled trial. Arch Intern Med. 2000; 160: 2343-8

19. Rood E, Bosman RJ, van der Spoel JI, Taylor P, Zandstra DF. Use of a computerized guideline for glucose regulation in the intensive care unit improved both guideline adherence and glucose regulation. J Am Med Inform Assoc. 2005; 12: 172-80

20. Vadher BD, Patterson DL, Leaning M. Comparison of oral anticoagulant control by a nurse-practitioner using a computer decision-support system with that by clinicians. Clin Lab Haematol. 1997; 19: 203-7

21. White RH, Mungall D. Outpatient management of warfarin therapy: Comparison of computer-predicted dosage adjustment to skilled professional care. Ther Drug Monit. 1991; 13: 46-50

22. Richards DA, Godfrey L, Tawfik J, et al. NHS Direct versus general practice based triage for same day appointments in primary care: Cluster randomised controlled trial. BMJ. 2004; 329: 774

23. Lattimer V, George S, Thompson F, et al. Safety and effectiveness of nurse telephone consultation in out of hours primary care: Randomised controlled trial. BMJ. 1998; 317: 1054-9

24. Fitzmaurice DA, Hobbs FDR, Murray ET, Bradley CP, Holder R. Evaluation of computerized decision support for oral anticoagulation management based in primary care. Br J Gen Pract. 1996; 46: 533-5

25. Richards DA, Meakins J, Tawfik J, et al. Nurse telephone triage for same day appointments in general practice: Multiple interrupted time series trial of effect on workload and costs. BMJ. 2002; 325: 1214-7

26. Medical Research Council. A framework for development and evaluation of RCTs for complex interventions to improve health. London: Medical Research Council; 2000

27. Liu J, Wyatt J, Altman DG. Decision tools in health care: Focus on the problem, not the solution. BMC Med Inform Decis Mak. 2006; 6:

28. Hanlon G, Strangleman T, Goode J, Luff D, O'Cathain A, Greatbatch D. Knowledge, technology and nursing: The case of NHS Direct. Hum Relat. 2005; 58: 147-71

29. Greatbatch D, Hanlon G, Goode J, O'Cathain A, Strangleman T, Luff D. Telephone triage, expert systems and clinical expertise. Sociol Health Illn. 2005; 27: 802-30