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The effects of on-screen, point of care computer reminders on processes and outcomes of care (Review)

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[Intervention Review]

The effects of on-screen, point of care computer reminders on processes and outcomes of care

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ABSTRACT

Background

The opportunity to improve care by delivering decision support to clinicians at the point of care represents one of the main incentives for implementing sophisticated clinical information systems. Previous reviews of computer reminder and decision support systems have reported mixed effects, possibly because they did not distinguish point of care computer reminders from e-mail alerts, computer-generated paper reminders, and other modes of delivering 'computer reminders'.

Objectives

To evaluate the effects on processes and outcomes of care attributable to on-screen computer reminders delivered to clinicians at the point of care.

Search methods

We searched the Cochrane EPOC Group Trials register, MEDLINE, EMBASE and CINAHL and CENTRAL to July 2008, and scanned bibliographies from key articles.

Selection criteria

Studies of a reminder delivered via a computer system routinely used by clinicians, with a randomised or quasi-randomised design and reporting at least one outcome involving a clinical endpoint or adherence to a recommended process of care.

Data collection and analysis

Two authors independently screened studies for eligibility and abstracted data. For each study, we calculated the median improvement in adherence to target processes of care and also identified the outcome with the largest such improvement. We then calculated the median absolute improvement in process adherence across all studies using both the median outcome from each study and the best outcome.

Main results

Twenty-eight studies (reporting a total of thirty-two comparisons) were included. Computer reminders achieved a median improvement in process adherence of 4.2% (interquartile range (IQR): 0.8% to 18.8%) across all reported process outcomes, 3.3% (IQR: 0.5% to 10.6%) for medication ordering, 3.8% (IQR: 0.5% to 6.6%) for vaccinations, and 3.8% (IQR: 0.4% to 16.3%) for test ordering. In a sensitivity analysis

using the best outcome from each study, the median improvement was 5.6% (IQR: 2.0% to 19.2%) across all process measures and 6.2% (IQR: 3.0% to 28.0%) across measures of medication ordering.

In the eight comparisons that reported dichotomous clinical endpoints, intervention patients experienced a median absolute improvement of 2.5% (IQR: 1.3% to 4.2%). Blood pressure was the most commonly reported clinical endpoint, with intervention patients experiencing a median reduction in their systolic blood pressure of 1.0 mmHg (IQR: 2.3 mmHg reduction to 2.0 mmHg increase).

Authors' conclusions

Point of care computer reminders generally achieve small to modest improvements in provider behaviour. A minority of interventions showed larger effects, but no specific reminder or contextual features were significantly associated with effect magnitude. Further research must identify design features and contextual factors consistently associated with larger improvements in provider behaviour if computer reminders are to succeed on more than a trial and error basis.

PLAIN LANGUAGE SUMMARY

On screen point of care computer reminders to improve care and health

It is known that doctors do not always provide the care that is recommended or according to the latest research. Many strategies have been tried in an attempt to reduce this gap between what is recommended and what is done. A potentially low cost way to do this could be to use computer systems that remind physicians about important information while they make decisions. For example, a doctor could be ordering antibiotics for a child with an ear infection. At that point, the computer the doctor is working on displays a pop up window with a reminder about the evidence for the best dose and length of time the antibiotics should be prescribed.

This review found 28 studies that evaluated the effects of different on-screen computer reminders. The studies tested reminders to prescribe specific medications, to warn about drug interactions, to provide vaccinations, or to order tests. The review found small to moderate benefits. The reminders improved physician practices by a median of 4%. In eight of the studies, patients' health improved by a median of 3%.

Although some studies showed larger benefits than these median effects, no specific reminders or features of how they worked were consistently associated with these larger benefits. More research is needed to identify what types of reminders work and when.

Summary of findings 1. Summary of findings

Point-of-care computerized decision support systems with or without co-intervention(s) compared with usual care or co-intervention(s)

Patient or population: Physicians (any specialty)

Settings: Point-of-care; the interventions were most commonly delivered in the outpatient setting, but were also delivered in the inpatient, long-term care, and other clinical settings. The majority of interventions occurred in the United States, but interventions also occurred in several other countries

Intervention: On-screen tools designed to aid clinical decision-making, with or without co-intervention(s), that were delivered within routinely-used clinical information systems (e.g. an electronic health record), accessible via physicians' usual workflow, and targeted the physician responsible for the clinical decision for which the on-screen tool was providing support

Comparison: Usual care or co-intervention(s)

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect: RR (95% CI)	Absolute effect: Median of median absolute improvements (IQR)	Absolute effect: Best of median absolute improvements (IQR)	No of Participants (Comparisons)	Quality of the evidence (GRADE)	Comments
	Assumed likelihood of outcome with comparison	Corresponding likelihood of outcome with intervention						
All process outcomes			1.29 (1.23 to 1.36)	2.71% (0.52% to 9.5%)		935 192 (114)	Low[1]	
Prescription of medications	405 per 1000	470 per 1000 (454 to 486)	1.16 (1.12 to 1.20)	2.41% (-0.08% to 6.76%)		276 410 (64)	Low[2]	
Prescription of recommended vaccines	255 per 1000	386 per 1000 (329 to 451)	1.51 (1.29 to 1.77)	4.8% (1.56% to 7.65%)		212 791 (30)	Moderate[3]	
Test ordering	412 per 1000	494 per 1000 (461 to 531)	1.20 (1.12 to 1.29)	1.96% (0.68% to 8.4%)		539 528 (25)	Low[4]	
Elements of recommended documentation	275 per 1000	481 per 1000 (407 to 569)	1.75 (1.48 to 2.07)	6.08% (1.14% to 20.5%)		66 725 (11)	Low[5]	

Other process outcomes	165 per 1000	269 per 1000 (243 to 299)	1.63 (1.47 to 1.81)	4.32% (1.03% to 10.4%)	300 114 (32)	Low[1]

RR: Risk Ratio; **CI:** Confidence interval; **IQR:** interquartile range

*The basis for the **assumed likelihood of outcome with comparison** was the median proportion of outcome recipients in the control group across studies, determined following application of the intervention to the intervention group.. The **corresponding likelihood of outcome with intervention** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **RR** of the intervention (and its 95% CI).

GRADE Working Group grades of evidence
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

[1]Quality of the evidence was downgraded by two levels. The evidence was downgraded by one level due to inconsistency; a notable minority of studies had anomalously large positive effect sizes, and quantitative measures of heterogeneity (I^2 value and χ^2 test) indicated the presence of inconsistency. The evidence was further downgraded by one level due to publication bias, as the funnel plot had substantial asymmetry in the direction of unduly favouring the intervention.
[2]Quality of the evidence was downgraded by two levels. Risk of bias downgraded the evidence by one level, as a substantial proportion of studies had a high risk of dissimilar baseline characteristics (24/64) and smaller but non-negligible proportions of studies had high risks of other biases. Inconsistency also downgraded the evidence by one level, due to some studies reporting anomalously large positive effect sizes and quantitative measures of heterogeneity (I^2 value and χ^2 test) indicating the presence of inconsistency.
[3]Quality of the evidence was downgraded by one level due to inconsistency, which was indicated by quantitative measures of heterogeneity (I^2 value and χ^2 test).
[4]Quality of the evidence was downgraded by two levels. The evidence was downgraded by one level due to inconsistency, which was indicated by quantitative measures of heterogeneity (I^2 value and χ^2 test). The evidence was further downgraded by one level due publication bias. The funnel plot displayed substantial asymmetry in the direction of unduly favouring the intervention.
[5]Quality of the evidence was downgraded by two levels. The evidence was downgraded by one level due to inconsistency. Inconsistency was indicated by variation in study effect sizes, with multiple studies reporting anomalously large positive effect sizes and one study reporting an abnormally large negative effect size. There was also a borderline lack of confidence interval overlap between studies, and the presence of inconsistency was corroborated by quantitative measures of heterogeneity (I^2 value and χ^2 test). The evidence was downgraded by one additional level due to publication bias, as the funnel plot displayed substantial asymmetry in the direction of unduly favouring the intervention.

BACKGROUND

Description of the condition

Gaps between recommended practice and routine care are widely known (McGlynn 2003; Quality of Health Care 2001; Schuster 1998). Interventions designed to close these gaps fall into a number of different categories: educational interventions (directed at clinicians or at patients), reminders (again, directed at clinicians or patients), audit and feedback of performance data, case management, and financial incentives to name a few (Shojania 2005). However, none of these categories of interventions confers large improvements in care, especially when evaluated rigorously. In fact, they often produce quite small benefits (Grimshaw 2004; Oxman 1995; Shojania 2006; Walsh 2006) and these benefits tend to involve process measures only, not patient outcomes.

Description of the intervention

Given the difficulty of changing the behaviour of healthcare providers and the resources required by many of the interventions that aim to do so, provider reminders offer a promising strategy, especially given their low marginal cost. Reminders delivered at the point of care prompt healthcare professionals to recall information that they may already know but could easily forget in the midst of performing other activities of care, or, in the case of decision support, provide information or guidance in an accessible format at a particularly relevant time. Paper-based reminders have existed for many years and have ranged from simple notes attached to the fronts of charts (for example reminding providers of the need to administer an influenza vaccine) to more sophisticated pre-printed order forms that include decision support (for example protocols for ordering and monitoring anti-coagulants). Computer-based reminders have the potential to address multiple topics and are automatic; therefore they represent a subset of reminders of great interest to those involved in quality improvement efforts.

How the intervention might work

A number of systematic reviews over the years have evaluated computerised reminders and decision support systems (Dexheimer 2008; Garg 2005; Hunt 1998; Kawamoto 2005). However, these reviews have tended to lump all forms of computerised reminders and decision support together, including, for instance, computer-generated paper reminders and e-mail alerts sent to providers, along with reminders generated at the point of care. It is this last category, computer reminders that prompt providers at the point of care, which represents the most promising form of computerised reminders. Such reminders, embedded into computerised provider order entry systems or electronic medical records, alert providers to important clinical information relevant to a targeted clinical task at the time the provider is engaged in performing the task.

Why it is important to do this review

While point of care computerised reminders have produced some well-known successes (Dexter 2001; Kucher 2005; Overhage 1997), other trials have shown no improvements in care (Ansari 2003; Eccles 2002a; Montgomery 2000), including studies from institutions with well-established computerised order entry systems (Dexter 2004; Sequist 2005; Tierney 2003). Therefore, we sought to quantify the expected magnitudes of improvements in processes and outcomes of care through the use of computerised reminders and decision support delivered at the point of care, and identify any features consistently associated with larger effects.

OBJECTIVES

In this review, we address the following questions:

1. Do on-screen computer reminders effectively improve processes or outcomes of care?
2. Do any readily identifiable elements of on-screen reminders influence their effectiveness (e.g. inclusion of patient-specific information as opposed to generic reminders for a given condition, requiring a response from users).
3. Do any readily identifiable elements of the targeted activity (e.g. chart documentation, test ordering, medication prescribing) influence the effectiveness of on-screen reminders?

METHODS

Criteria for considering studies for this review

Types of studies

We included randomised controlled trials (with randomisation at the level of the patient or the provider) and quasi-randomised trials, where allocation to intervention or control occurred on the basis of an arbitrary but not truly random process (for example even or odd patient identification numbers).

Types of participants

Any study in which the majority of participants (> 50%) consisted of physicians or physician trainees; we excluded studies that primarily targeted dentists, pharmacists, nurses, or other health professionals.

Types of interventions

The original protocol for this review defined 'on-screen computer reminders' as follows:

*Patient or encounter specific information that is provided via a computer console (either visually or audibly) and intended to prompt a healthcare professional to recall information usually encountered through their general medical education, in the medical records or through interaction with peers, and so remind them to perform or avoid some action to aid individual patient care (*Gordon 1998).

This original definition served primarily to distinguish computer reminders that were literally presented to users on a computer screen (hence 'on-screen reminders') from computer-generated reminders that were simply printed out and placed in a paper chart. While this distinction remains germane (i.e. some studies still involve 'computer reminders' that are really paper-based reminders that happen to have been generated by a computer), the use of computers in healthcare is now sufficiently widespread that the more important concept has become 'at the point of care', rather than merely 'on-screen'. A reminder that is ‘on screen’ but not noticeable to clinicians during the target activities of interest is no more useful than a paper reminder placed in such a manner that clinicians must deviate from their usual charting activities in order to find it.

Thus, from an operational point of view, the focus of this review should be regarded as evaluating 'point-of-care computer

reminders'. By 'point of care' we refer to delivery of the computer reminder to clinicians at the time they are engaged in the target activity of interest, such as prescribing medications, documenting clinical encounters in the medical record, and ordering investigations.

Operationally, we considered a reminder to qualify as delivered at the point of care if the following three criteria applied.

1. The reminder was delivered via the computer system routinely used by the providers targeted by the intervention - typically an electronic medical record or computerised order entry program. For instance, a dedicated computer used solely for performing dose calculations for anticoagulants would not count as 'on-screen/point of care', since it requires clinicians to depart from their usual workflow in order to avail themselves of the reminder or decision support provided by this separate system. We excluded such systems because they in effect require providers to remember to use the reminder system, thus undermining the fundamental purpose of a reminder.
2. The reminder was accessible from within the routinely used clinical information system (typically via a pop-up screen or an icon that indicates the availability of the reminder or decision support feature). A decision support module that could only be accessed by remembering to call up a separate program or website would not count as a point of care reminder (again, because depending on clinicians' remembering to call up the program without any prompting violates the notion of a 'reminder').
3. The reminder targeted the person responsible for the relevant clinical activity. For instance, if handwritten physician orders were entered by a clerk or pharmacist into a computer order entry system, any alert or decision support delivered via the computer system would not qualify as 'point of care' since, for the physician, it was the handwritten order that occurred at the point of care.

For settings without general computer order entry or electronic medical record systems, we allowed the possibility that some specific activities might still routinely occur using a computer system. For instance, an ambulatory clinic might have developed a computer-based system for supporting preventive care activities, even if the rest of the ambulatory record remained paper-based. Or, a hospital might have developed a computer program for ordering certain high-risk drugs (for example chemotherapy or anticoagulants). If a study documented that over 90% of the target activity occurred using the computer system, we regarded such a system as delivering a *de-facto* point of care computer reminder (since the documentation of > 90% use of the computer system for that activity implies that providers would generally not have to remember to use to the reminder).

Types of outcome measures

Eligible outcomes

In order to enhance the interpretability of the results, we categorised eligible outcomes as follows.

- *Dichotomous process adherence outcomes*: the percentage of patients receiving a target process of care (e.g. prescription of a specific medication, documentation of performance of a specific task, such as referral to a consultant) or whose care was in compliance with an overall guideline.
- *Dichotomous clinical outcomes*: true clinical endpoints (such as death or development of a pulmonary embolism), as well as surrogate or intermediate endpoints, such as achievement of a target blood pressure or serum cholesterol level.
- *Continuous clinical outcomes*: various markers of disease or health status (e.g. mean blood pressure or cholesterol level).
- *Continuous process outcomes*: any continuous measure of how providers delivered care (e.g. duration of antibiotic therapy, time to respond to a critical lab value).

We planned to include studies in the analysis only if they reported at least one clinical or process outcome (i.e. we excluded articles that reported only costs, lengths of stay, and other measures of resource use). As it turned out, meaningful analyses were possible only with the measures of process adherence. For these measures, in order to permit pooling across studies, we required that studies present data as the absolute percentage of patients who received the target process care in each study group (or in a manner that allowed us to calculate these percentages). For instance, we would not include a study that only reported the odds of patients receiving the process of care in the intervention group compared with the control. We made this decision partly because initial review revealed that the vast majority of studies reported their data as percentages of patients who received the process of interest, and partly because this format is most conducive to conveying the expected impacts of computer reminders, namely absolute improvements in adherence to a target process of care or clinical behaviour.

Primary outcomes

Although we planned to include any otherwise eligible study that reported the effect of computerised reminders on clinical outcomes, evaluating the impact of reminders on adherence to target processes of care represented the primary goal of our analysis. We recognise that improving patient outcomes represents the ultimate goal of any quality improvement activity. However, we focused on process improvements for this review because we wanted to capture the degree to which computer reminders achieve their main goal, namely changing provider behaviour (Mason 1999). The degree to which such behaviour changes ultimately improve patient outcomes will vary depending on the strength of the relationship between the targeted process of interest and patient level outcomes. In some cases, no such relationship may exist. For instance, the incentive to improve appropriate antibiotic use is usually the population level goal of reducing emergence of resistant microorganisms, not improving the outcomes of care for individual patients. In other cases, a presumed relationship between a given process of care and patient outcomes may be incorrect (for example we would no longer expect a reminder that encourages the use of hormone replacement therapy to improve cardiovascular outcomes in post-menopausal women). Consequently, if we had focused on improvements in clinical endpoints and found that reminders achieved negligible improvements in such outcomes, we would not know if this reflected consistent failure of computer reminders to achieve their intended goal (changes in provider behaviour) or the fact that reminders had targeted processes with limited connections to patient outcomes.

Direction of improvements

Some studies target quality problems that involve 'underuse,' so that improvements in quality correspond to increases in the percentage of patients who receive a target process of care (for example increasing the percentage of patients who receive the influenza vaccine). However, other studies target 'overuse', so that improvements correspond to reductions in the percentage of patients receiving inappropriate or unnecessary processes of care (for example reducing the percentage of patients who receive antibiotics for viral upper respiratory tract infections). In order to standardise the direction of effects, all process outcomes were defined so that higher values represented an improvement. For example, data from a study aimed at reducing the percentage of patients receiving inappropriate medications would be captured as the complementary percentage of patients who did not receive inappropriate medications. Increasing this percentage of patients for whom providers did not prescribe the medications would thus represent an improvement.

Search methods for identification of studies

Electronic searches

We searched the MEDLINE database up to July 2008 using Medical Subject Headings for relevant forms of clinical information systems (for example Medical Order Entry Systems, Point-of-Care Systems, Ambulatory Care Information Systems) and combinations of text words such as 'computer' or 'electronic' with terms such as 'reminder', 'prompt', 'alert', 'cue', and 'support' (Appendix 1 to Appendix 2). We applied a methodological filter for any type of clinical trial. We also searched the EMBASE, CINAHL and CENTRAL databases using modified search strategies up to July 2008. In addition,we retrieved all articles related to computers and reminder systems or decision support from the Cochrane Effective Practice and Organisation of Care Group (EPOC) database (EPOC 2008) Finally, we scanned bibliographies from key articles. For non-English language articles, we screened English translations of titles and abstracts and pursued full-text translation where possible (i.e. either to include or confirm exclusion).

Data collection and analysis

Study selection and data abstraction

Two investigators (from KS, AJ, AM) independently screened citations and abstracted included articles using a structured data entry form. In the initial screening, authors based their judgments about inclusion and exclusion solely on the titles and abstracts, but promoted articles to the next stage of the screening process whenever a decision could not be made with confidence. For the second stage of screening, we obtained full text for all references, with each article again judged independently by two authors.

Two authors independently abstracted the following information from articles that met all the inclusion criteria after the second stage of screening: clinical setting, participants, methodological details, characteristics of the reminders design and content, the presence of co-interventions (for example educational materials or performance report cards distributed to clinicians in both study groups), and outcomes. The data abstraction form (available upon request) was based on the checklist developed by the Cochrane EPOC Group (EPOC 2008). The form was pilot tested and revised iteratively prior to its use for final data abstraction. We resolved discrepancies between authors during either the screening or abstraction stages by discussion between the two authors to achieve consensus. When a conflict could not be resolved, a third author was consulted to achieve consensus or generate a majority decision.

Quality assessment

As part of the data abstraction process, authors assessed the following quality criteria based on the Cochrane EPOC Group Data Collection Checklist: concealment of allocation, blinded assessment of primary outcomes, proportion of patients/providers followed up, baseline disparities in process adherence or outcomes in the study groups, protection against contamination, and unit of analysis errors (EPOC 2008).

*Data a*nalysis

We anticipated that the eligible studies would exhibit significant heterogeneity, due to variations in target clinical behaviours, patient and provider populations, methodological features, characteristics of the interventions, and the contexts in which they were delivered. One approach for addressing these sources of variation would involve meta-regression. Given the number of potentially relevant covariates, however, meta-regression would require many more studies than we anticipated finding. We also expected that many eligible studies would assign intervention status to the provider, rather than the patient, but would not take into account 'cluster effects' in the analysis (i.e. they would exhibit 'unit of analysis errors'). Performing either a conventional meta-analysis or meta-regression using studies with unit of analysis errors would require us to make a number of assumptions about the magnitude of unreported parameters, such as the intra-class correlation coefficients and the distributions of patients across clusters, in order to avoid spurious precision in 95% confidence intervals.

To preserve the goal of providing a quantitative assessment of the effects associated with computerised reminders, without resorting to numerous assumptions or conveying a misleading degree of confidence in the results, we chose to report the median improvement in process adherence (and inter-quartile range) among studies that shared specific features of interest. This approach was first developed in a large review of strategies to foster the implementation of clinical practice guidelines (Grimshaw 2004) and subsequently applied to reviews of quality improvement strategies in a series of reports for the US Agency for Healthcare Research and Quality (Shojania 2004a; Shojania 2004b; Steinman 2006; Walsh 2006).

This method of reporting the median effect sizes across groups of studies involves two distinct uses of the term 'median'. First, in order to handle multiple outcomes within individual studies, we calculated for each study the median improvement in process adherence across the various outcomes reported by that study. For example, if a study reported 10 process adherence outcomes, we would calculate the absolute difference between intervention and control values for each outcome in order to obtain the median improvement (and interquartile range) across all 10 such differences. This median would then contribute the single effect size for that study. We also captured whenever a study identified a primary outcome and separately analysed those studies. Further, we performed a sensitivity analysis in which, instead of the median outcome, we used the best outcome from each study. With each study then represented by a single, median outcome, we then

calculated the median effect size and interquartile range across all included studies. It is this second use of the 'median' that is crucial to the method. Instead of providing a conventional meta-analytic mean (an average weighted on the basis of the precision of the results from each study), we highlight the median effect achieved by included studies, along with an interquartile range for these effects.

The main potential drawback of this method of reporting the median effects of an intervention across a group of studies lies in the equal weight given to all studies (for example no weighting occurs on the basis of study precision). Note, however, that by using the median rather than the mean, the summary estimate is less likely to be driven by a handful of outlying results (such as large effects from small or methodologically poor studies). Moreover, we included an analysis of the impact of study size and various other methodological features on reported effect size. For instance, we compared the median effects across large and small studies (where large was defined as greater than or equal to the median sample size across all included studies). We performed the analysis of potential associations between study size and effect magnitude using various measures of sample size, including the numbers of patients (or episodes of care) without any adjustment for clustering, the effective sample size taking into account cluster effects (using values for intra-class correlation coefficients available in the published literature (Campbell 2000)) and, finally, using the numbers of providers (or other cluster units) as the sample size.

We also compared the median effects across studies with and without various methodological markers of study quality, as well as certain features of the study context (for example ambulatory versus inpatient setting) and characteristics of the reminders (for example inclusion of patient-specific information versus a generic alert, provision of an explanation for the reminder, requiring users to enter a response to the reminder before continuing with their work, requiring users to navigate through more than one reminder screen). We made all such comparisons using a non-parametric rank-sum test (Mann-Whitney). We performed all statistical analyses using SAS version 9.1 (SAS Institute, Inc, Cary, NC).

RESULTS

Description of studies

Results of the search

Our search identified 2036 citations, of which 1662 were excluded at the initial stage of screening and an additional 374 on full-text review, yielding a total of 28 articles that met all inclusion criteria (Figure 4)(Bates 1999; Christakis 2001; Dexter 2001; Eccles 2002a; Filippi 2003; Flottorp 2002; Frank 2004; Hicks 2008; Judge 2006; Kenealy 2005; Kralj 2003 - classified, excluded; Krall 2004; Kucher 2005; McCowan 2001; Meigs 2003; Overhage 1996; Overhage 1997; Peterson 2007; Rothschild 2007; Roumie 2006 - classified, excluded; Safran 1995; Sequist 2005; Tamblyn 2003; Tape 1993; Tierney 2003; Tierney 2005; van Wyk 2008; Zanetti 2003). Four studies contained two comparisons (Eccles 2002a; Flottorp 2002; Kenealy 2005; van Wyk 2008), resulting in 32 included comparisons.

Of the 32 included comparisons, 19 came from US centers and 24 took place in outpatient settings (see 'Characteristics of included studies'). Most (26) trials used a true randomised design, with only six comparisons involving a quasi-random design (typically allocating intervention status on the basis of even or odd provider identification numbers). Twenty-six of the 32 included comparisons allocated intervention status at the level of providers or provider groups, rather than allocating patients (i.e. they were cluster trials).

Risk of bias in included studies

Allocation

Of the 32 comparisons in the review, concealed allocation definitely occurred in 14 comparisons (Christakis 2001; Dexter 2001; Flottorp 2002; Frank 2004; Kenealy 2005; McCowan 2001; Meigs 2003; Rothschild 2007; Roumie 2006 - classified, excluded; Safran 1995; van Wyk 2008). The process of allocation concealment was unclear in 14 comparisons (Bates 1999; Eccles 2002a; Filippi 2003; Hicks 2008; Judge 2006; Krall 2004; Overhage 1996; Overhage 1997; Peterson 2007; Sequist 2005; Tierney 2003; Tierney 2005; Tamblyn 2003) and not done in four comparisons (Kralj 2003 - classified, excluded; Kucher 2005; Tape 1993; Zanetti 2003).

Incomplete outcome data

The proportion of eligible practices or providers with complete follow up was reported in 14 comparisons (Christakis 2001; Flottorp 2002; Kenealy 2005; Krall 2004; McCowan 2001; Meigs 2003; Overhage 1997; Rothschild 2007; Roumie 2006 - classified, excluded; Tamblyn 2003; van Wyk 2008). The proportion of eligible patients with complete follow up was reported in 12 comparisons (Filippi 2003; Hicks 2008; Kucher 2005; Meigs 2003; Overhage 1997; Rothschild 2007; Roumie 2006 - classified, excluded; Safran 1995; Tamblyn 2003; Tierney 2003; Tierney 2005; Zanetti 2003). The number of subjects (professionals, practices or patients) lost to follow up was not clear in 11 comparisons (Bates 1999; Dexter 2001; Eccles 2002a; Frank 2004; Judge 2006; Kralj 2003 - classified, excluded; Overhage 1996; Peterson 2007; Sequist 2005; Tape 1993).

Baseline disparities between study groups

Only seven comparisons reported data in a format that permitted calculation of baseline disparities between study groups. Across these studies, the median difference between adherence in the intervention and control groups was 0.00% (interquartile range (IQR): 2.0% greater adherence in the control to 0.0%).

Unit of analysis errors

Of the 26 comparisons with a clustered design, only 12 analysed their results in a manner that took clustering effects into account. Thus, the remaining 14 clustered comparisons exhibited unit of analysis errors.

Other quality criteria

Blinded assessment of study outcomes was generally not relevant, as data were typically derived from electronic systems that documented delivery of the target processes of care. Though not the focus of the review, many of the clinical outcomes were also objective ones, such as laboratory data, and so also did not require blinded assessment.

Effects of interventions

See: **Summary of findings 1** Summary of findings

Of the 32 comparisons that provided analysable results for improvements in process adherence, (Bates 1999; Christakis 2001; Dexter 2001; Eccles 2002a; Filippi 2003; Flottorp 2002; Frank 2004; Hicks 2008; Judge 2006; Kenealy 2005; Kralj 2003 - classified, excluded; Krall 2004; Kucher 2005; McCowan 2001; Meigs 2003; Overhage 1996; Overhage 1997; Peterson 2007; Rothschild 2007; Roumie 2006 - classified, excluded; Safran 1995; Sequist 2005; Tamblyn 2003; Tape 1993; Tierney 2003; Tierney 2005; van Wyk 2008; Zanetti 2003), 21 reported outcomes involving prescribing practices, six specifically targeted adherence to recommended vaccinations, 13 reported outcomes related to test ordering, three captured documentation, and seven reported adherence to miscellaneous other processes (for example composite compliance with a guideline).

Only nine comparisons reported pre-intervention process adherence for intervention and control groups. For these comparisons, the marginal improvement in the intervention (i.e. the median improvement in the intervention group minus the improvement in the control group) was 3.8% (IQR): 0.4% to 7.9%).

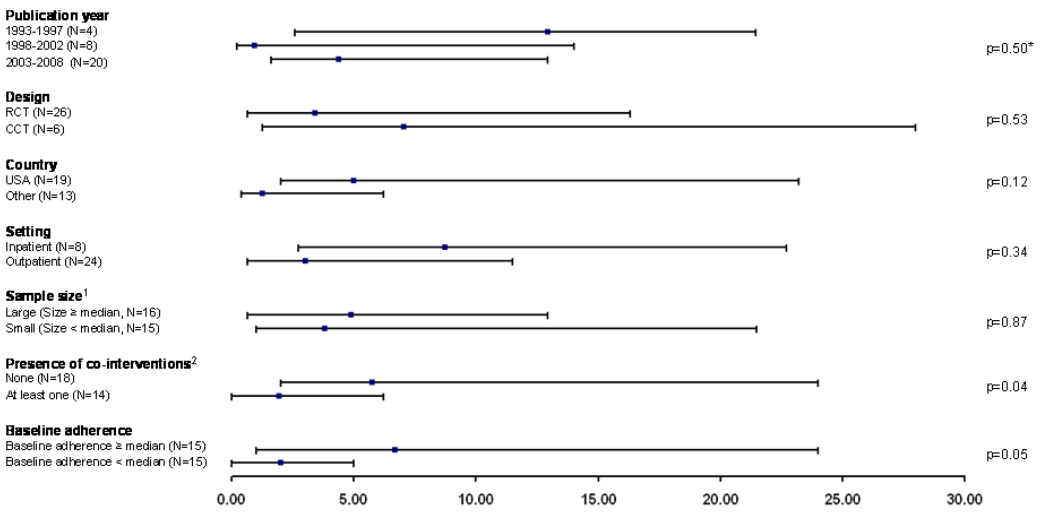
Given the small number of studies that reported baseline adherence, improvements attributable to interventions were calculated as the absolute difference in post-intervention adherence (i.e. the post-intervention improvement in the target process of care observed in the intervention group minus that observed in the control group). Using this post-intervention difference between study groups, the median improvements in process adherence associated with computer reminders were: 4.2 % (IQR: 0.8% to 18.8%) across all process outcomes, 3.3% (IQR: 0.5% to 10.6%) for improvements in prescribing behaviours, 3.8% (IQR: 0.5% to 6.6%) for improvements in vaccination, and 3.8% (IQR: 0.4% to 16.3%) for test ordering behaviours (Table 1). Table 1 also shows the results obtained when we used the outcome with the largest improvement from each study instead of the outcome with the median improvement.

Eight comparisons reported dichotomous clinical endpoints; intervention patients experienced a median absolute improvement of 2.5% (IQR: 1.3% to 4.2%). These endpoints included intermediate endpoints, such as blood pressure and cholesterol targets, as well as clinical outcomes, such as development of pulmonary embolism and mortality. Blood pressure represented the most commonly reported outcome. Patients in intervention groups experienced a median reduction in their systolic blood pressure of 1.0 mmHg (IQR: 2.3 mmHg reduction to 2.0 mmHg increase). For diastolic blood pressure, the median reduction was 0.2 mmHg (IQR: 0.8 mm reduction to 1.0 mm increase).

Impacts of study features on effect sizes

There were sufficient comparisons involving process adherence to permit various analyses of potential associations between various study features and the magnitude of effects (Figure 1). The six quasi-randomised controlled trials reported larger improvements in process adherence than the 26 truly randomised comparisons (7.0%, IQR: 1.2% to 28.0% versus 3.4%: IQR 0.6% to 16.3%), but this difference was not statistically significant (P = 0.53). Sample size did not correlate with effect size, whether calculated on the basis of numbers of patients or providers (Figure 1).

Figure 1. Median effects for process adherence by study feature



* Kruskall-Wallis test
[1] Results for sample size used raw numbers of patients, without adjusting for cluster effects. Adjusting for clustering did not alter the results, nor did using the number of clusters instead of the number of patients. The total number of comparisons for the sample size analysis is 31, because 1 study did not report number of patients.
[2] Result compares the effect sizes of comparisons involving computer reminders alone versus usual care (i.e. no co-interventions) and reminders plus one or more other quality improvement interventions versus those other interventions alone.

One might expect studies with low adherence in control groups to report larger improvements in care, but in fact studies with control adherence rates higher than the median across all studies had a non-significant trend towards larger effect sizes (Figure 1). We analysed the potential impact of baseline adherence in several other ways (for example studies with baseline adherence in top quartile versus all others to look for a 'ceiling effect', and studies with baseline adherence in bottom quartile versus all others to look for a floor effect) but found no indication that baseline adherence significantly affected the magnitude of effect in the intervention group.

Interventions that targeted inpatient settings showed a trend towards larger improvements in processes of care than did those that occurred in outpatient settings: 8.7% (IQR: 2.7% to 22.7%) versus 3.0% (0.6% to 11.5%) for outpatient settings (P = 0.34). However, all interventions delivered in inpatient settings occurred at Brigham and Women's Hospital in Boston or the Regenstreif Institute at the University of Indiana. Both of these institutions have mature 'homegrown' computerized provider order entry systems, and the recipients of computer reminders from these institutions consisted primarily of physician trainees, either of which factors may be more relevant than the fact of the inpatient setting.

Studies from the US reported slightly larger improvements in process adherence: 5.0% (IQR: 2.0% to 23.2%) versus 1.2% (IQR: 0.4% to 6.2%) for non-US studies), but this difference was not significant (P = 0.12). Moreover, this trend at least partly reflected the results of studies from US institutions with long track records with clinical information systems (for example the Regenstreif Institute and Brigham and Women's Hospital in Boston).

Grouping studies on the basis of track records in clinical informatics (for example analysing studies from Brigham and Women's Hospital, the Regenstreif Institute and Vanderbilt University versus all others) did not result in significant differences, except in the case of Brigham and Women's Hospital. The four studies from Brigham and Women's Hospital by themselves reported significantly higher improvements in process adherence than all other studies: 16.8% (IQR: 8.7% to 26.0%) versus 3.0% (IQR: 0.5% to 11.5%; P = 0.04).

Lastly, the magnitude of effects attributable to computer reminders appeared to vary with the presence of co-interventions (delivered to intervention and control groups). The 32 comparisons that reported process adherence outcomes included 18 that evaluated a computer reminder versus usual care and 14 that evaluated a computer reminder plus at least one other quality improvement intervention (for example educational materials) versus this same co-intervention in the control group. Comparisons involving no co-interventions (that is computer reminder alone versus usual care) showed a median improvement in process adherence of 5.7% (IQR: 2.0% to 24.0%), whereas studies of multifaceted interventions (that is computer reminders plus additional interventions versus those additional interventions alone) showed a median improvement in adherence of only 1.9% (IQR: 0.0% to 6.2%; P = 0.04 for this difference).

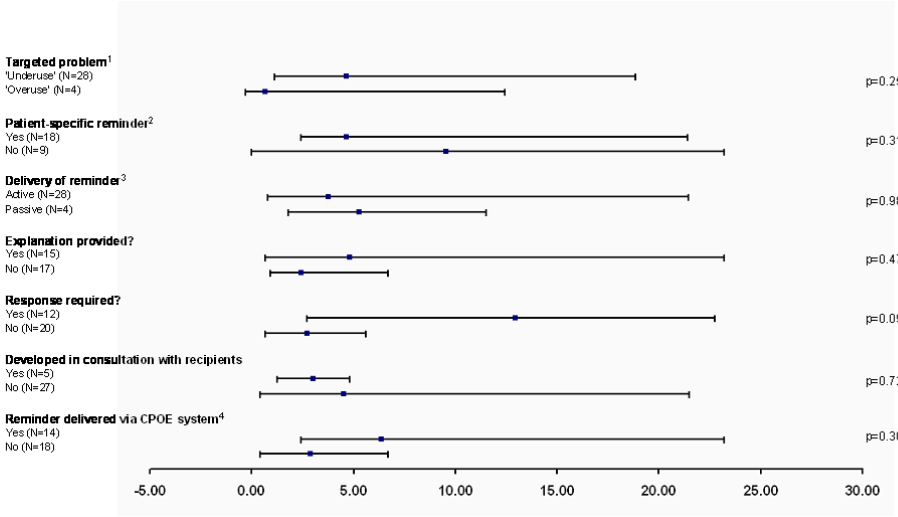
This apparent difference might reflect a ceiling effect, with co-interventions delivered to the intervention and control groups leaving little room for computer reminders to demonstrate additional improvements. If this were the case, one would expect higher post-intervention adherence rates in the control groups of studies that combined computer reminders with other interventions. However, the opposite proved true: post-intervention values for process adherence (in both intervention and control groups) were in fact slightly higher in the studies involving comparisons of computer reminders by themselves, not in the studies involving additional interventions.

This relationship between comparison type and effect size at least partially reflected confounding by other studies features. For instance, dropping the four studies from Brigham and Women's Hospital from the analysis substantially decreased the magnitude of the difference between studies with and without co-interventions (median improvement of 0.9%, IQR: 0.0% to 5.0% versus 3.8%, IQR: 1.2% to 23.2%), and the difference was no longer statistically significant (P = 0.08). Also, of note, none of the P values reported in the analysis adjusted for multiple comparisons nor was stratification by the presence of co-interventions a pre-specified hypothesis for our analysis, further adding to the possibility that the observed difference reflects a chance association.

Features of computer reminders

We analysed a number of characteristics of the computer reminders (or the larger clinical information system) to look for associations with the magnitude of impact (Figure 2). The degree of improvement did not differ significantly between studies based on the type of quality problem targeted (underuse versus overuse of a given process of care), the conveyance of patient-specific information versus a more generic alert, provision of an explanation for the alert, whether or not the reminder conveyed a specific recommendation, whether or not the authors of the study had developed the reminder, or the type of system used to deliver the reminder (CPOE versus electronic medical record).

Figure 2. Median effects for process adherence by reminder feature



[1]Underuse' refers to targeting quality improvements that correspond to increasing the percentage of patients who receive a target process of care (e.g. increasing the percentage of patients receiving the influenza vaccine). 'Overuse' refers to targeting improvements that correspond to reductions in the percentage of patients receiving inappropriate care (e.g. reducing the percentage of patients who receive antibiotics for viral upper respiratory tract infections).
[2] Reminders with no patient specific information were those triggered on the basis of demographic triggers (e.g. age) or the intent to order a medication or investigation irrespective of any features of the patient involved (e.g. a reminder triggered by any order for heparin or any request for a certain radiologic investigation), as opposed to patient-specific laboratory results (e.g. a reminder related to the patient's serum creatinine) or combinations of medications or laboratory values exhibited by the patient. The sample size is reduced due to inability to accurately assess the presence or absence of the feature
[3] Active reminders were those that appeared automatically when triggering conditions were met, as opposed to passive reminders, where, for instance, users might be presented with the option to click on a link to receive decision support related to their current task. In some informatics context, this distinction is referred to as "push" vs. "pull".
[4] CPOE – computerized order entry system; reminders systems without CPOE were typically electronic medical record systems.

There was a trend towards larger effects with reminders that required users to enter a response of some kind (12.9%, IQR 2.7% to 22.7%) versus those that did not (2.7%, IQR: 0.6% to 5.6%; P = 0.09). However, this trend was confounded by the fact that all four comparisons from Brigham and Women's Hospital involved reminders that required responses from users. Dropping these four studies decreased the median effect of reminders that required user responses to 10.6% (IQR: 0.3% to 21.4%) and removed any appearance of statistical significance (P = 0.48). Of note, though, the magnitude of the difference remains substantial (10.6% versus 2.7%); it is possible that the lack of significance reflects lack of power.

We also analysed whether effect sizes differed between reminders that were 'pushed' onto users (that is users automatically received the reminder) versus reminders that required users to perform some action to receive it (that is users had to 'pull' the reminders). Only four comparisons involved 'pull' reminders and these showed comparable effects to 'push' reminders. Of note, however, one trial (van Wyk 2008) directly compared these two modes of reminder delivery. In this three-armed cluster-RCT of reminders for screening and treatment of hyperlipidemia, patients cared for at practices randomised to automatic alerts were more likely to undergo testing for hyperlipidemia and receive treatment than were patients seen at clinics where reminders were delivered to clinicians only 'on-demand.'

Sensitivity analysis

We reanalysed the potential predictors of effect size (study features and characteristics of the reminders) using a variety of alternate choices for the representative outcome from each study, including the outcome with the middle value (rather than a calculated median) and the best outcome (that is the outcome associated with the largest improvement in process adherence). None of these analyses substantially altered the main findings, including the lack of any significant association between study or reminder features and the magnitude of effects achieved by computer reminders. Of note, using the best outcome from each study rather than the median outcome, improvements attributable to reminders in studies at Brigham and Womens Hospital were no longer significantly larger than those achieved in studies from other centers (16.8%, IQR: 8.7% to 26.0% versus 4.6%, IQR: 2.0% to 13.4%; P = 0.09 for the comparison). However, the difference still appears large, so loss of significance may simply reflect the lack of power.

DISCUSSION

Across 32 comparisons, computer reminders achieved small to modest improvements in care. The absolute improvement in process adherence was less than 4% for half of the included comparisons. Even when we included the best outcome from each comparison, the median improvement was only 5.6%. For improvements in prescribing, perhaps the behaviours of greatest general interest, improvements were even smaller.

With the upper quartile of reported improvements beginning at a 15% increase in process adherence, some studies clearly did show larger effects. However, we were unable to identify any study or reminder features that predicted larger effect sizes, except for a statistically significant (albeit unadjusted for multiple comparisons) difference in effects seen in studies involving the computer order entry system at Brigham and Women's Hospital. A trend towards larger effects was seen for reminders that required users to enter a response in order to proceed, but this finding may have been confounded by the uneven distribution of studies from Brigham and Women's Hospital. Thus, we do not know if the success of computer reminders at the Brigham partially reflects the design of reminders requiring user responses or if other features of the computer system or institutional culture of Brigham play the dominant role.

The finding that comparisons of computer reminders alone versus usual reported larger effect sizes than comparisons involving computer reminders and other co-interventions represented an unexpected finding. Exploratory analyses did not reveal a plausible explanation for this result except that it may have reflected uneven distribution of confounders. One additional explanation might be that investigators chose to incorporate computer reminders in multifaceted interventions when attempting to change more complex (and therefore difficult to change) behaviours than those addressed by reminders alone. However, this unexpected finding may also constitute a chance association, especially as none of the P values reported in the analysis adjust for multiple comparisons.

A major potential limitation of our analysis was the heterogeneity of the interventions and the variable degree with which they were reported, including limited descriptions of key intervention features of the reminders and the systems through which they were delivered. We attempted to overcome this problem by abstracting basic attributes, such as whether user responses were required and whether or not the reminder contained patient-specific information, but heterogeneity within even these apparently straightforward categories could mask important differences in effects. Also, other characteristics which we found difficult to operationalise for example the 'complexity' of the reminder), or which were inadequately reported, may also correlate with important differences in impact. This problem of limited descriptive detail of complex interventions and the resulting potential for substantial heterogeneity among included interventions in systematic reviews has been consistently encountered in the literature (Grimshaw 2003; Ranji 2008; Shojania 2005; Walsh 2006).

Our focus on the median effects across studies represents another potential limitation. However, as outlined in the 'Methods' section, we chose this approach precisely to avoid spurious precision due to heterogeneity and clustering effects that could not be taken into account in many studies. This approach is becoming increasingly common in Cochrane Reviews of interventions to change practice (Grimshaw 2004; Jamtvedt 2006; O'Brien 2007) and has also been used in other evidence syntheses (Grimshaw 2004; Shojania 2004b; Steinman 2006; Walsh 2006). This method conveys the range of effects associated with the intervention of interest and also allows for analysis of factors associated with effect size.

Additional studies continue to appear and we plan to assess eligible new studies formally for inclusion in six months. At that time we will also include a study that had previously been excluded as a time series, but which we have since decided merits inclusion as a controlled clinical trial (Durieux 2000 - classified, excluded).

In summary, computer reminders delivered at the point of care have achieved variable improvements in target behaviours and processes of care. The small to modest median effects shown in our analysis may hide larger effects. However, the current literature does not suggest which features of the reminder systems, the systems with which they are delivered, or which target problems might consistently predict larger improvements.

AUTHORS' CONCLUSIONS

Implications for practice

On-screen computer reminders may become more prevalent as healthcare institutions advance in the use of computer technology. There appears to be a wide range of effects of the intervention, making it difficult to provide specific suggestions about how to maximize the benefits.

Implications for research

Although some studies have clearly shown substantial improvements in care from point of care computer reminders it is concerning that the majority of studies have shown fairly small improvements across a range of process types. This finding of small to modest improvements is not unique to computer reminders. As had been said before, there are no 'magic bullets' when it comes to changing provider behavior and improving care (Shojania 2005; Oxman 1995). However, given that the opportunity to deliver computer reminders at the point of care represents one of the major incentives to implementing sophisticated clinical information systems, future research will need to identify key factors (related to the target quality problem or the design of the reminder) that reliably predict larger improvements in care from these expensive technologies.

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CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Abdel-Kader 2011

Study characteristics	
Methods	Cluster RCT
Participants	University-based outpatient general internal medicine practice, USA 248 patients, 30 providers
Interventions	Two reminders that were activated for patients with moderate to advanced chronic kidney disease (one suggested a referral to a nephrologist, a second suggested albumin quantification if not done within prior year)
Outcomes	Process adherence (testing, documentation, other), clinical endpoint (laboratory test results, e.g. creatinine, hemoglobin)
Co-Interventions	Educational: Multiple (>1) educational sessions for providers in both control and intervention groups Beyond Clinician Education: None

Abdel-Kader 2011 *(Continued)*

CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Ansari 2003

Study characteristics

Methods	Cluster RCT
Participants	Academically affiliated medical center, San Francisco, USA (San Francisco Veterans Affairs Medical Center) 115 patients, 49 providers of primary care for patients with congestive heart failure
Interventions	CDSS encouraging beta-blocker use in eligible patients with heart failure
Outcomes	Process adherence (prescribing), clinical endpoint (three outcomes related to hospitalization, mortality)
Co-Interventions	Educational: Distribution of educational materials and multiple (>1) educational sessions for providers in both control and interventions groups Beyond Clinician Education: Provision of list of patients eligible for beta-blocker therapy, patient letter encouraging discussion of beta-blocker therapy with provider in intervention group
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Ansari 2003 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Arts 2017

Study characteristics

Methods	Cluster RCT
Participants	General practice clusters, the Netherlands 781 patients, 39 general practitioners across 18 practices
Interventions	CDSS determined recommended stroke prevention treatment based on patient risk status and informed the provider of discrepancies between current and recommended treatment
Outcomes	Process adherence (other)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Ambush, considered alert fatigue in design, conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, makes care recommendation, other concurrent CDSS, 'push' mode of delivery, targeted overuse and underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias)	Low risk	

Arts 2017 *(Continued)*

All outcomes	
Baseline characteristics similar?	Low risk
Unit of analysis error	Low risk

Awdishu 2016

Study characteristics	
Methods	Cluster RCT
Participants	Inpatient and outpatient settings of academic medical center, San Diego, USA (University of California, San Diego) 1278 patients, 514 providers
Interventions	CDSS monitoring patient creatinine clearance and notifying physicians of necessity for renal dose adjustment or discontinuation of medications for patients with impaired renal function
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes – required acknowledgment of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, makes care recommendation, possible to execute desired action, 'push' mode of delivery, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Baandrup 2010

Study characteristics	
Methods	Cluster CCT
Participants	Two municipalities, Denmark 602 patients
Interventions	Reminder that popped up every time antipsychotic polypharmacy was about to be prescribed
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Multiple (>1) educational sessions for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, 'push' mode of delivery, targeted overuse
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	High risk	

Baer 2013

Study characteristics	
Methods	Cluster CCT
Participants	Primary care clinics affiliated with regional academic medical network, USA (Partners HealthCare System) 15 495 patients, 5 practices
Interventions	Patient self-administered web-based risk appraisal tool completed in waiting area that sends patient-entered information on family history of cancer to electronic health record for clinicians to view. If accepted, populates coded fields and generates reminders about colon and breast cancer screening based on familial risk.

Baer 2013 *(Continued)*

Outcomes	Process adherence (documentation)
Co-Interventions	Educational: Distribution of educational materials to providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Developed by study investigators, makes care recommendation
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Bates 1999

Study characteristics

Methods	RCT
Participants	All inpatients at academic medical center, Boston, USA (Brigham and Women's Hospital) 939 episodes of care
Interventions	Reminder that was generated at the time a test that appeared to be redundant was ordered, prompting providers to consider cancelling the test
Outcomes	Process adherence (testing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse

Bates 1999 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	

Beeler 2014

Study characteristics

Methods	Cluster RCT
Participants	Academic medical center, Switzerland (University Hospital Zurich) 15 736 patients, 6 departments
Interventions	CDSS displayed for patients who did not receive a thromboprophylaxis order within the first 6h of admission or transfer. To improve specificity, he algorithm checked for thromboprophylaxis orders that were active within the 0–30h time frame after admission or transfer.
Outcomes	Process adherence (prescribing), clinical endpoint (four outcomes pertaining to bleeding, heparin-induced thrombocytopenia, venous thromboembolism)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, makes care recommendation, other concurrent CDSS, 'push' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias)	Low risk	

Beeler 2014 *(Continued)*

All outcomes	
Baseline characteristics similar?	Low risk
Unit of analysis error	High risk

Bell 2010

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practice-based research network, USA (Children's Hospital of Philadelphia Pediatric Research Consortium) 19 450 patients, 12 practices
Interventions	Decision support for patients with asthma to improve adherence to national guidelines, including data-entry tool, standardized documentation templates, order sets, and action/care plan for families
Outcomes	Process adherence (prescribing, documentation, other)
Co-Interventions	Educational: Education session for providers in both intervention and control groups Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Appearance differed based on urgency, conveyed patient-specific information, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Bennett 2018

Study characteristics		
Methods		
Participants		
Interventions		
Outcomes		
Co-Interventions		
CDSS Features - Acknowledgement of CDSS Required		
CDSS Features - Other		
Notes		

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	N/A

Bernstein 2017

Study characteristics	
Methods	Cluster RCT
Participants	Internal medicine units, two academic medical centers, New Haven, USA (Yale New Haven Hospital and unnamed) 19 902 patients, 254 physicians
Interventions	Prompts physicians to refer smoking patients to a quitline, order tobacco cessation therapies, and document the patients' smoking status
Outcomes	Process adherence (prescribing, documentation, other)
Co-Interventions	Educational: Single educational session for providers in intervention group Beyond Clinician Education: Audit and feedback in intervention group

Bernstein 2017 *(Continued)*

CDSS Features - Acknowledgement of CDSS Required	Yes – required acknowledgment of the CDSS but not documentation of action taken
CDSS Features - Other	Ambush, considered alert fatigue in design, conveyed patient-specific information, developed by study investigators, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, required provider input of clinical data, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	

Beste 2015

Study characteristics

Methods	Cluster RCT
Participants	Eight VA facilities in the Pacific Northwest, USA 2884 patients
Interventions	CDSS intended to improve hepatocellular carcinoma surveillance by reminding clinicians to perform liver ultrasounds for patients with cirrhosis who had not received surveillance in the preceding 6 months
Outcomes	Process adherence (testing, other)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, developed by study investigators, included supporting information on-screen, makes care recommendation, other concurrent CDSS, possible to execute desired action, 'push' mode of delivery, targeted underuse, user workflow considered in design

Beste 2015 *(Continued)*

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	High risk	

Boustani 2012

Study characteristics	
Methods	RCT
Participants	General medical ward, academic medical center, Indianapolis, USA (Wishard Memorial Hospital) 424 patients
Interventions	Reminder notifying physicians of presence of cognitive impairment, recommending early geriatric consultation, and suggesting discontinuation of urinary catheterization, physical restraints, and anti-cholinergic drugs
Outcomes	Process adherence (prescribing, other), clinical endpoint (30-day mortality, 30-day readmission, hospital adverse event, mean length of hospital stay, home discharge)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, interruptive, makes care recommendation, other concurrent CDSS, 'push' mode of delivery, targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A

Boustani 2012 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Low risk
Baseline characteristics similar?	Low risk

Campbell 2019

Study characteristics		
Methods		
Participants		
Interventions		
Outcomes		
Co-Interventions		
CDSS Features - Acknowledgement of CDSS Required		
CDSS Features - Other		
Notes		
Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	

Chak 2018

Study characteristics	
Methods	RCT
Participants	Primary care clinics affiliated with academic medical center, USA (University of California, Davis Health System) 2987 patients

Chak 2018 *(Continued)*

Interventions	Reminder to screen foreign-born Asian and Pacific Islander patients for chronic hepatitis B
Outcomes	Process adherence (testing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Ambush, 'pull' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	

Chaturvedi 2019

Study characteristics

Methods	
Participants	
Interventions	
Outcomes	
Co-Interventions	
CDSS Features - Acknowledgement of CDSS Required	
CDSS Features - Other	
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement

Chaturvedi 2019 *(Continued)*

Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	High risk	

Co 2010

Study characteristics	
Methods	Cluster RCT
Participants	Pediatric primary care practices, USA 412 patients, 79 providers, 12 practices
Interventions	Reminder to assess attention-deficit/hyperactivity disorder (ADHD) symptoms every 3 to 6 months and ADHD note template with structured fields for symptoms, treatment effectiveness, and adverse effects
Outcomes	Process adherence (documentation, other)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, other concurrent CDSS, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Cote 2008a

Study characteristics	
Methods	Cluster CCT
Participants	Cardiology telemetry and coronary care units in an academic medical center, Chicago, USA (Northwestern Memorial Hospital) 307 patients, 8 residents
Interventions	CDSS triggered when nonsteroidal anti-inflammatory drugs were ordered suggesting gastrointestinal bleeding prophylaxis in high risk patients
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, included supporting information on-screen, interruptive, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	High risk	

Cote 2008b

Study characteristics	
Methods	Cluster CCT
Participants	Cardiology telemetry and coronary care units in an academic medical center, Chicago, USA (Northwestern Memorial Hospital) 320 patients, 8 residents

Cote 2008b *(Continued)*

Interventions	CDSS triggered when nonsteroidal anti-inflammatory drugs were ordered suggesting gastrointestinal bleeding prophylaxis in high risk patients
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Single educational session for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, included supporting information on-screen, interruptive, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	High risk	

Davis 2007

Study characteristics

Methods	Cluster RCT
Participants	Outpatient teaching pediatric clinic (Pediatric Care Center at the University of Washington) and rural/semi-urban primary care pediatric clinic (Skagit Pedatrics), WA, USA 12 195 episodes of care, 88 providers
Interventions	CDSS presenting real-time evidence to providers based on prescribing practices for acute otitis media, allergic rhinitis, sinusitis, constipation, pharyngitis, croup, urticaria, and bronchiolitis
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None

Davis 2007 *(Continued)*

CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse and underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	

Dean 2015

Study characteristics

Methods	Cluster CCT
Participants	Seven urban emergency departments, Utah, USA (Intermountain Healthcare) 4758 patients
Interventions	CDSS that calculated probability of pneumonia diagnosis and clinical severity using electronic clinical information, provided disposition and treatment recommendations
Outcomes	Process adherence (other), Clinical endpoint (30-day and inpatient mortality, hospitalization, 7-day readmission, pleural effusion)
Co-Interventions	Educational: Single educational session for providers and academic detailing in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, developed in consultation with users, included supporting information on-screen, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Dean 2015 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	N/A
Unit of analysis error	Unclear risk	N/A

Dexter 2001

Study characteristics

Methods	Cluster RCT
Participants	General medicine inpatient service, urban teaching hospital, Indianapolis, USA (Wishard Memorial Hospital) 6371 patients, 8 provider teams
Interventions	Rule-based CDSS generating prewritten orders for four preventive therapies (two vaccinations, prophylactic aspirin for cardiovascular disease, and venous thromboembolism prophylaxis)
Outcomes	Process adherence (prescribing, vaccination)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias)	Low risk	

Dexter 2001 *(Continued)*

All outcomes		
Baseline characteristics similar?	Low risk	
Unit of analysis error	Unclear risk	N/A

Diaz 2018

Study characteristics		
Methods	Cluster RCT	
Participants	Pediatric emergency and urgent departments, two children's hospitals, Delaware Valley and FL, USA (Nemours Children's Health System) 50 patients, 28 physicians	
Interventions	Prompts physicians to perform a neurovascular and musculoskeletal examination for patients with suspected elbow fracture	
Outcomes	Process adherence (documentation)	
Co-Interventions	Educational: Single educational session for providers in both the control and intervention groups Beyond Clinician Education: Audit and feedback in both the control and intervention groups	
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken	
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse, user workflow considered in design	
Notes		
Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	High risk	

Diaz 2019

Study characteristics	
Methods	Cluster RCT
Participants	Primary care settings, Delaware Valley and FL, USA (Nemours Children's Health System) 1051 patients, 13 physicians
Interventions	Guided physicians on how to screen for adolescent idiopathic scoliosis
Outcomes	Process adherence (documentation)
Co-Interventions	Educational: Single educational session for providers in both control and intervention groups Beyond Clinician Education: Audit and feedback in both control and intervention groups
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Decision support was complex, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	High risk	

Downs 2006

Study characteristics	
Methods	Cluster RCT
Participants	General practices in Central Scotland and London, UK 236 patients, 18 practices
Interventions	CDSS producing prompts for the investigation and management of dementia
Outcomes	Process adherence (other), clinical endpoint (diagnosis of dementia)
Co-Interventions	Educational: None

Downs 2006 *(Continued)*

	Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Dregan 2014

Study characteristics	
Methods	Cluster RCT
Participants	Family practices within large research network, UK (Clinical Practice Research Datalink) 11 391 patients, 104 practices
Interventions	CDSS activated for patients on practice stroke register inviting physician to access prompts reminding them to adhere to guideline-based secondary prevention (blood pressure control, recording strokes as hemorrhagic versus infarction, prescription of statins, and prescription of antiplatelet drugs)
Outcomes	Process adherence (prescribing), clinical endpoint (blood pressure and cholesterol targets)
Co-Interventions	Education: Distribution of educational materials to providers in both control and intervention groups Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, developed in consultation with users, included supporting information on-screen, makes care recommendation, 'pull' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Dregan 2014 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Eccles 2002a

Study characteristics

Methods	Cluster RCT
Participants	Ambulatory general practices, UK 2335 patients, 60 practices
Interventions	Patient-specific CDSS suggesting evidence-based management for patients with angina (Control group received CDSS suggesting evidence-based management for patients with asthma)
Outcomes	Process adherence (documentation)
Co-Interventions	Educational: Distribution of educational materials to providers in both control and intervention groups; single educational session for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, makes care recommendation, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not reported

Eccles 2002a *(Continued)*

Baseline characteristics similar?	Low risk
Unit of analysis error	Low risk

Eccles 2002b

Study characteristics	
Methods	Cluster RCT
Participants	Ambulatory general practices, UK 2363 patients, 60 practices
Interventions	Patient-specific CDSS suggesting evidence-based management for patients with asthma (Control group received CDSS suggesting evidence-based management for patients with angina)
Outcomes	Process adherence (documentation)
Co-Interventions	Educational: Distribution of educational materials to providers in both control and intervention groups; single educational session for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, makes care recommendation, targeted underuse
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Feder 2011

Study characteristics

Feder 2011 *(Continued)*

Methods	Cluster RCT
Participants	General practices in two urban primary care trusts, UK (Bristol and Hackney) 143 868 patients, 48 practices
Interventions	Template in the electronic medical record linked to diagnoses for women experiencing domestic violence, such as depression, anxiety, irritable bowel syndrome, pelvic pain, and assault
Outcomes	Process adherence (documentation, other)
Co-Interventions	Educational: Distribution of educational materials; multiple (>1) educational sessions for providers in intervention group Beyond Clinician Education: Audit and feedback; ad-hoc telephone conversations and email exchanges with clinicians about referrals or advice; simplified referral pathway in intervention group
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Field 2009

Study characteristics

Methods	Cluster RCT
Participants	Academically affiliated long-term care facility, Canada 833 patients, 22 units
Interventions	CDSS providing patient-specific recommendations in real-time for adjusting dose and frequency of medications for residents with renal insufficiency
Outcomes	Process adherence (prescribing)

Field 2009 *(Continued)*

Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, 'push' mode of delivery, targeted overuse and underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	High risk	

Fiks 2009

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practice-based research network, USA (Children's Hospital of Philadelphia Pediatric Research Consortium) 23 418 episodes of care, 11 919 patients, 20 practices
Interventions	Reminder for influenza vaccine at office visits for children with asthma who were due for vaccine
Outcomes	Process adherence (vaccination)
Co-Interventions	Educational: Distribution of educational materials to providers and single educational session for providers in both control and intervention groups Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Ambush, conveyed patient-specific information, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse

Fiks 2009 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Fiks 2013

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practice-based research network, USA (Children's Hospital of Philadelphia Pediatric Research Consortium) 11 245 patients, 22 practices
Interventions	Reminder for all routine adolescent vaccinations appearing prominently whenever patient encounter was opened within the electronic health record
Outcomes	Process adherence (prescribing), clinical endpoint (outcomes pertaining to HPV vaccination status)
Co-Interventions	Educational: Single educational session for providers in intervention group Beyond Clinician Education: Audit and feedback for providers in intervention group
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Ambush, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias)	Low risk	

Fiks 2013 *(Continued)*

All outcomes	
Baseline characteristics similar?	Low risk
Unit of analysis error	Low risk

Filippi 2003

Study characteristics	
Methods	Cluster RCT
Participants	Ambulatory general practices, Italy 15 343 patients, 300 providers
Interventions	CDSS reminding providers to consider antiplatelet therapy in patients with diabetes
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Distribution of educational materials to providers in both control and intervention groups Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Ambush, conveyed patient-specific information, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	High risk	

Flottorp 2002a

Study characteristics	

Flottorp 2002a *(Continued)*

Methods	Cluster RCT
Participants	Ambulatory general practices, Norway 9887 episodes of care, 120 practices
Interventions	Display of guidelines for appropriate use of antibiotics and laboratory testing in women with suspected urinary tract infection (control patients received identical interventions, but targeted to improve management of sore throat)
Outcomes	Process adherence (prescribing, testing, other)
Co-Interventions	Educational: Educational materials for providers and patients, educational workshops for providers in intervention group Beyond Clinician Education: Financial incentives for providers in intervention group
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Flottorp 2002b

Study characteristics

Methods	Cluster RCT
Participants	Ambulatory general practices, Norway 16 939 episodes of care, 120 practices
Interventions	Display of guidelines for appropriate use of antibiotics and laboratory testing for patients with sore throat (control patients received identical interventions, but targeted to improve management of urinary tract infection in women)
Outcomes	Process adherence (prescribing, testing, other)

Flottorp 2002b *(Continued)*

Co-Interventions	Educational: Educational materials for providers and patients, educational workshops for providers in intervention group Beyond Clinician Education: Financial incentives for providers in intervention group
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Frank 2004

Study characteristics

Methods	Quasi-RCT
Participants	Urban ambulatory practice, Australia 10507 patients, 10 providers
Interventions	CDSS for 12 preventive care activities (e.g. vaccinations; screening for cervical cancer, diabetes, and lipids; and documentation of allergies, weight, smoking, and blood pressure)
Outcomes	Process adherence (testing, documentation, vaccination)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, 'push' mode of delivery, targeted underuse
Notes	

Frank 2004 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	

Gill 2009

Study characteristics

Methods	Cluster RCT
Participants	Primary care clinics in a national network of practices using same EHR, USA (Medical Quality Improvement Consortium) 64 150 patients, 105 providers, 25 offices
Interventions	Prompts during office visit regarding suboptimal screening, risk stratification, and management of dyslipidemia
Outcomes	Process adherence (prescribing, testing), clinical endpoint (3 outcomes pertaining to lipid targets)
Co-Interventions	Educational: None Beyond Clinician Education: Reporting tool to identify patients outside of office visits with suboptimal lipid care with standardized letter notifying these patients of their status in the intervention group
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Ambush, conveyed patient-specific information, interruptive, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	

Gill 2009 *(Continued)*

Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	N/A

Gill 2011

Study characteristics	
Methods	Cluster RCT
Participants	National network of ambulatory practices using same EHR, USA (Centricity Healthcare User Research Network) 5234 patients, 119 clinicians, 27 offices
Interventions	Reminder suggesting adherence to guidelines for reducing gastrointestinal complications for patients on nonsteroidal anti-inflammatory drugs
Outcomes	Process adherence (other)
Co-Interventions	Educational: Distribution of educational materials and multiple (>1) educational sessions for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Ambush, conveyed patient-specific information, developed in consultation with users, interruptive, 'push' mode of delivery, targeted overuse and underuse, user workflow considered in design
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Gonzales 2013

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practices in integrated health care delivery system, PA, USA (Geisinger Health System) 8136 episodes of care, 22 practices
Interventions	CDSS providing structured template for documenting relevant history and physical examination elements in patients with acute respiratory tract infections. A clinical algorithm categorized the probability of having pneumonia, and triggered the most appropriate order set for a given patient with relevant testing and treatment options.
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Distribution of educational materials to patients, single educational session for providers in intervention group Beyond Clinician Education: Audit and feedback for providers in intervention group; clinical champions in intervention group
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, possible to execute desired action, required provider input of clinical data, targeted overuse
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Goud 2009

Study characteristics	
Methods	Cluster RCT
Participants	Cardiac rehabilitation clinics, Netherlands 2787 patients, 21 clinics

Goud 2009 *(Continued)*

Interventions	Decision support that guided users through needs assessment procedure using structured dialogue and formulated patient-specific rehabilitation programme on the basis of the needs assessment data ('CARDSS')
Outcomes	Process adherence (other)
Co-Interventions	Educational: Single educational session for providers in intervention group Beyond Clinician Education: Helpdesk services and financial incentives directed at providers in intervention group
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, makes care recommendation, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Guiriguet 2016

Study characteristics

Methods	Cluster RCT
Participants	10 primary care centres, Barcelona, Spain 41 042 patients, 130 primary care physicians
Interventions	Prompted providers to promote patient participation in population-based colorectal cancer screening program
Outcomes	Process adherence (testing)
Co-Interventions	Educational: None Beyond Clinician Education: Colorectal cancer screening program
CDSS Features - Acknowledgement of CDSS Required	Not reported

Guiriguet 2016 *(Continued)*

CDSS Features - Other	Ambush, conveyed patient-specific information, decision support was complex, makes care recommendation, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Gulliford 2014

Study characteristics

Methods	Cluster RCT
Participants	Family practices within large research network, UK (Clinical Practice Research Datalink) 603 409 patients, 100 practices
Interventions	CDSS encouraging either a no-antibiotic or a delayed-antibiotic approach during consultations with adults with acute respiratory tract infections
Outcomes	Process adherence (prescribing,** other**), clinical endpoint (various outcomes pertaining to specialist consultation and antibiotic prescription)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, included supporting information on-screen, makes care recommendation, 'pull' mode of delivery, targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement

Gulliford 2014 *(Continued)*

Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Unclear risk	N/A

Gulliford 2019

Study characteristics		
Methods		
Participants		
Interventions		
Outcomes		
Co-Interventions		
CDSS Features - Acknowledgement of CDSS Required		
CDSS Features - Other		
Notes		
Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Gupta 2014

Study characteristics	
Methods	RCT
Participants	Academic medical center, CA, USA (VA Palo Alto Health Care System) 89 patients
Interventions	Reminder directing providers of patients who are candidates for implantable cardiac defibrillator to consider referral for consultation
Outcomes	Process adherence (documentation, other)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	

Gurwitz 2008

Study characteristics	
Methods	Cluster RCT
Participants	Academic long-term care facilities, Canada and USA 1118 patients, 29 units, 2 facilities
Interventions	CDSS linked with CPOE intended to prevent adverse drug events by flagging serious drug-drug interactions and high-risk prescriptions
Outcomes	Clinical endpoint (preventable adverse drug events)
Co-Interventions	Educational: None

Gurwitz 2008 *(Continued)*

	Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, interruptive, 'push' mode of delivery, targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Unclear risk	N/A

Hicks 2008

Study characteristics

Methods	Cluster RCT
Participants	Community- and hospital-based primary care clinics affiliated with large urban academic medical center, Boston, USA (Brigham and Women's Hospital) 1834 patients, 12 clinics
Interventions	CDSS with guideline-based reminders for management of patients with hypertension
Outcomes	Process adherence (prescribing), clinical endpoint (uncontrolled blood pressure)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, included supporting information on-screen, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Hicks 2008 *(Continued)*

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Holt 2010

Study characteristics	
Methods	CCT
Participants	General practices, West Midlands, UK 36 092 patient, 18 practices
Interventions	Reminder that encouraged cardiovascular risk stratification (‘e Nudge’)
Outcomes	Process adherence (documentation), clinical endpoint (cardiovascular events)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Ambush, conveyed patient-specific information, included supporting information on-screen, interruptive, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Unclear risk	N/A

Holt 2017

Study characteristics		
Methods	Cluster RCT	
Participants	46 primary care practices, Central and South East England, UK 6429 patients	
Interventions	Reminded physicians to prescribe oral anticoagulants for eligible patients with atrial fibrillation	
Outcomes	Process adherence (prescribing), Clinical endpoint (8 outcomes pertaining to stroke, transient ischemic attack, and haemorrhage)	
Co-Interventions	Educational: None Beyond Clinician Education: None	
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken	
CDSS Features - Other	Ambush, conveyed patient-specific information, decision support was complex, developed by study investigators, interruptive, makes care recommendation, 'push' mode of delivery, targeted underuse	
Notes		
Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Unclear risk	N/A

Hoye 2013

Study characteristics	
Methods	CCT nested within cluster RCT
Participants	Urban and rural practices in 11 counties participating in continuing medical education groups, Norway 16 188 dispensed prescriptions, 156 providers

Hoye 2013 *(Continued)*

Interventions	CDSS triggered when printing a prescription for antibiotics for respiratory tract infection requesting confirmation that the prescription was a delayed prescription
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Multiple (>1) educational sessions for providers in both control and intervention arms Beyond Clinician Education: Audit and feedback in both control and intervention arms
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, interruptive, 'push' mode of delivery, targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Judge 2006

Study characteristics	
Methods	Cluster RCT
Participants	Academically-affiliated long-term care facility, Canada 3843 episodes of care, 7 wards
Interventions	CDSS intended to improve medication safety at the time of order entry by flagging potential severe drug interactions, recent abnormal lab test results, requirement of special monitoring, dose reduction in elderly patients, or requirement of prophylactic measures
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, 'push' mode of delivery, targeted overuse, user workflow considered in design

Judge 2006 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	High risk	

Karlsson 2018

Study characteristics

Methods	Cluster RCT
Participants	42 primary care clinics, Östergötland, Sweden 14 800 patients
Interventions	Reminder to initiate anticoagulation therapy for eligible patients with atrial fibrillation or atrial flutter
Outcomes	Process adherence (other), Clinical endpoint (various outcome pertaining to stroke, transient ischemic attack, bleeding)
Co-Interventions	Educational: Distribution of educational materials and for providers in both the control and intervention groups; single educational session for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Ambush, conveyed patient-specific information, decision support was complex, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	

Karlsson 2018 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Low risk
Baseline characteristics similar?	Low risk
Unit of analysis error	Low risk

Kenealy 2005

Study characteristics	
Methods	Cluster RCT
Participants	Outpatient general practices, Auckland, New Zealand 2662 patients, 52 providers, 33 practices
Interventions	Icon suggesting diabetes screening for patients considered eligible for screening
Outcomes	Process adherence (testing)
Co-Interventions	Educational: Distribution of educational materials and single educational session for providers in both control and interventions groups Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, makes care recommendation, 'pull' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Krall 2004

Study characteristics	
Methods	Cluster RCT
Participants	Ambulatory family and internal medicine practices, regional managed care group, USA (Kaiser Permanente Northwest) 1076 patients, 100 providers
Interventions	Patient-specific CDSS encouraging prescription of ASA for primary or secondary prevention in patient population at high risk of cardiovascular disease
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Ambush, considered alert fatigue in design, conveyed patient-specific information, included supporting information on-screen, interruptive, other concurrent CDSS, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	High risk	

Kucher 2005

Study characteristics	
Methods	Quasi-RCT
Participants	Academic medical center, Boston, USA (Brigham and Women's Hospital) 2506 patients, 120 providers
Interventions	CDSS encouraging deep-vein thrombosis prophylaxis among high-risk hospitalized patients

Kucher 2005 *(Continued)*

Outcomes	Process adherence (prescribing, other), clinical endpoint (8 outcomes pertaining to pulmonary embolism, venous thromboembolism, deep vein thrombosis, hemorrhage, mortality)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, developed in consultation with users, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	

Lee 2019

Study characteristics

Methods
Participants
Interventions
Outcomes
Co-Interventions
CDSS Features - Acknowledgement of CDSS Required
CDSS Features - Other
Notes

Risk of bias

Bias	Authors' judgement	Support for judgement

Lee 2019 *(Continued)*

Allocation concealment (selection bias)	Low risk
Incomplete outcome data (attrition bias) All outcomes	Low risk
Baseline characteristics similar?	Low risk
Unit of analysis error	Low risk

Leibovici 2013

Study characteristics	
Methods	Cluster RCT
Participants	Internal medicine wards, academic medical center, Israel (Rabin Medical Center, Beilinson Campus) 1683 patients, 15 wards
Interventions	CDSS guiding empirical antibiotic treatment of inpatients with moderate to severe bacterial infections using patient-specific clinical data. It applies a cost-benefit model to rank antibiotic treatments according to their net benefit and offers advice (including no treatment).
Outcomes	Clinical endpoint (180-day survival)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, included supporting information on-screen, makes care recommendation, targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	

Leibovici 2013 *(Continued)*

Unit of analysis error	Low risk

Linder 2009-1

Study characteristics	
Methods	Cluster RCT
Participants	Primary care clinics in integrated regional system, USA (Partners HealthCare System) 21 961 episodes of care, 443 clinicians, 27 clinics
Interventions	Documentation-based decision support for patients with acute respiratory infections related to diagnosis, antibiotic selection, medication safety, and patient education ('ARI Smart Form')
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, makes care recommendation, possible to execute desired action, 'pull' mode of delivery, required provider input of clinical data, targeted overuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Linder 2009-2

Study characteristics	
Methods	Cluster RCT

Linder 2009-2 *(Continued)*

Participants	Primary care practices affiliated with two academic medical centers in a research network, USA (Partners Primary Care Practice-Based Research Network) 12 207 patients, 521 providers, 26 practices
Interventions	Smoking status icons, tobacco treatment reminders, and document-based decision support ('Smart Form') that facilitated ordering of medication and fax/e-mail counseling referrals
Outcomes	Process adherence (prescribing, documentation, other)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Lo 2009

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practices affiliated with two academic medical centers, USA (Partners HealthCare System) 2765 patients, 366 providers, 22 practices
Interventions	Non-interruptive, real-time CDSS recommending baseline lab testing when prescribing medications to patients lacking baseline labs
Outcomes	Process adherence (testing)
Co-Interventions	Educational: None

Lo 2009 *(Continued)*

	Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, developed by study investigators, makes care recommendation, other concurrent CDSS, 'push' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Locatelli 2009

Study characteristics

Methods	Cluster RCT
Participants	Academic and non-academic nephrology units in Bulgaria, Croatia, Germany, Italy, Latvia, Poland, Romania, Serbia and Montenegro 599 patients, 53 centres
Interventions	CDSS compiling data from patient visits generating guideline-based management prompts with arguments for and against the offered option in patients receiving dialysis with renal anemia
Outcomes	Process adherence (prescribing), clinical endpoints (various laboratory targets, including hemoglobin, ferritin levels, transferrin saturation)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, included supporting information on-screen, makes care recommendation, targeted underuse

Locatelli 2009 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	High risk	

Loo 2011a

Study characteristics

Methods	Cluster CCT
Participants	Primary care practice within an academic medical center, Boston, USA (Beth Israel Deaconess Medical Center) 3266 patients, 37 physicians, 2 offices
Interventions	Reminders for health care proxy designation, osteoporosis screening, and influenza and pneumococcal vaccinations in patients older than 65 years
Outcomes	Process adherence (testing, documentation, vaccination)
Co-Interventions	Educational: Distribution of educational materials and single education session to providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, included supporting information on-screen, other concurrent CDSS, 'pull' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A

Loo 2011a *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Low risk
Baseline characteristics similar?	Low risk
Unit of analysis error	Low risk

Loo 2011b

Study characteristics	
Methods	Cluster CCT
Participants	Primary care practice within an academic medical center, Boston, USA (Beth Israel Deaconess Medical Center) 3324 patients, 37 physicians, 2 offices
Interventions	Reminders for health care proxy designation, osteoporosis screening, and influenza and pneumococcal vaccinations in patients older than 65 years
Outcomes	Process adherence (testing, documentation, vaccination)
Co-Interventions	Educational: Distribution of educational materials and single educational session for providers in intervention group Beyond Clinician Education: Dedicated administrative assistant (‘panel manager’) who assisted patients and physicians in completing the four targeted practice behaviors in intervention group
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, makes care recommendation, other concurrent CDSS, 'pull' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Mann 2016

Study characteristics	
Methods	Cluster RCT
Participants	Two urban academic primary care practices, New York, USA 49 patients
Interventions	Guided physicians through counselling patients with prediabetes on lifestyle modifications
Outcomes	Clinical endpoint (various outcomes pertaining to weight, body mass index, HbA1C, lipids)
Co-Interventions	Educational: Distribution of educational material to patients in control group; single educational session for providers in intervention group Beyond Clinician Education: Distribution of pedometers to patients in intervention group; audit and feedback for providers in intervention group
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, developed in consultation with users, makes care recommendation, possible to execute desired action, 'pull' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Martins 2017

Study characteristics	
Methods	Cluster RCT
Participants	14 primary care centers in a health network, Portugal (Western Oporto) 23 432 patients, 123 primary care physicians (average), 9 health center servers

Martins 2017 *(Continued)*

Interventions	Modified electronic test ordering screen with colored indicators to illustrate high- and low-value screening tests
Outcomes	Process adherence (testing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, included supporting information on-screen, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	High risk	

Matheny 2008

Study characteristics

Methods	Cluster RCT
Participants	Primary care practices affiliated with two academic medical centers, USA (Partners HealthCare System) 2507 episodes of care, 303 providers, 20 outpatient clinics
Interventions	Electronic reminders delivered at time of office visits to increase rates of appropriate routine medication laboratory monitoring
Outcomes	Process adherence (testing)
Co-Interventions	Educational: None Beyond Clinician Education: None

Matheny 2008 *(Continued)*

CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, included supporting information on-screen, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Mazzaglia 2016

Study characteristics	
Methods	Cluster RCT
Participants	General practitioners within large research network, Italy (Health Search Network) 25 491 patients, 197 general practitioners
Interventions	Reminded providers to initiate pharmacological management for patients with high cardiovascular risk and suggested options to mitigate potential drug-drug interactions
Outcomes	Process adherence (prescribing*)
Co-Interventions	Educational: Distribution of educational materials to providers in both the control and intervention groups Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Ambush, conveyed patient-specific information, decision support was complex, included supporting information on-screen, makes care recommendation, 'push' mode of delivery, targeted overuse and underuse, user workflow considered in design
Notes	

Mazzaglia 2016 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

McCowan 2001

Study characteristics	
Methods	Cluster RCT
Participants	Outpatient general practices, UK 477 patients, 17 practices
Interventions	CDSS providing guideline-concordant suggestions for the management of patients with asthma
Outcomes	Process adherence (other), clinical endpoint (four outcomes pertaining to asthma exacerbation)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, makes care recommendation, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Unclear risk	N/A

McGinn 2013

Study characteristics	
Methods	Cluster RCT
Participants	Two large urban ambulatory primary care practices, academic medical center, NY, USA (Mount Sinai Medical Center) 984 patients, 168 providers
Interventions	Validated clinical prediction rule triggered by presentations suggestive of streptococcal pharyngitis or pneumonia inviting provider to complete risk score calculator with management recommendations given based on the score
Outcomes	Process adherence (prescribing, testing), clinical endpoint (ED and outpatient visits)
Co-Interventions	Educational: Distribution of educational materials to providers in control group; single educational session for providers in intervention groups Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, developed in consultation with users, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, required provider input of clinical data, targeted overuse, user workflow considered in design
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Meigs 2003

Study characteristics	
Methods	Cluster RCT
Participants	Primary care internal medicine practice at academic medical center, Boston, USA (Massachusetts General Hospital)

Meigs 2003 *(Continued)*

	598 patients, 26 providers
Interventions	CDSS displaying recommended target goals of care and last known values of relevant lab testing (e.g. HbA1C, creatinine, lipids) and links to other web-based care resources
Outcomes	Process adherence (testing), clinical endpoint (various outcomes pertaining to HbA1C, lipids, blood pressure)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, makes care recommendation, 'pull' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Mertens 2015

Study characteristics

Methods	Cluster RCT
Participants	36 adult primary care clinics, USA (Kaiser Permanente Northern California) 364 physicians
Interventions	Reminder to screen for alcohol use disorder embedded within larger intervention to provide brief motivational intervention to patients with unhealthy alcohol use and referral to treatment for patients with alcohol use disorder
Outcomes	Process adherence (other)
Co-Interventions	Educational: Different single educational session for providers in control and intervention groups

Mertens 2015 *(Continued)*

	Beyond Clinician Education: Local opinion leader endorsement and audit and feedback for intervention groups
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Ambush, possible to execute desired action, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	

Murray 2004

Study characteristics

Methods	Cluster RCT
Participants	Academic ambulatory internal medicine practice, Indianapolis, USA (Regenstrief Health Center) 352 patients
Interventions	CDSS suggesting evidence-based recommendations for the treatment of hypertension, including preventive care and monitoring for adverse drug reactions
Outcomes	Process adherence (prescribing). clinical endpoint (blood pressure)
Co-Interventions	Educational: Distribution of educational materials and multiple (>1) educational sessions for providers in both control and interventions groups Beyond Clinician Education: Patient-specific encounter form that included problem list and active drugs in both control and interventions groups
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse

Murray 2004 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Myers 2011a

Study characteristics	
Methods	Cluster RCT
Participants	Internal medicine inpatient setting, academic medical center, Philadelphia, USA (Hospital of the University of Pennsylvania) 39 providers
Interventions	'Hard-stop' reminder that appeared when entering unapproved abbreviations into the electronic progress notes to force correction
Outcomes	Process adherence (documentation)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, developed by study investigators, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A

Myers 2011a *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	N/A

Myers 2011b

Study characteristics		
Methods	Cluster RCT	
Participants	Internal medicine inpatient setting, academic medical center, Philadelphia, USA (Hospital of the University of Pennsylvania) 39 providers	
Interventions	Autocorrection CDSS that automatically replaced an unapproved abbreviation with the acceptable notation embedded within the electronic progress note	
Outcomes	Process adherence (documentation)	
Co-Interventions	Educational: None Beyond Clinician Education: None	
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken	
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, developed by study investigators, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse	
Notes		
Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Najafi 2019

Study characteristics	
Methods	
Participants	
Interventions	
Outcomes	
Co-Interventions	
CDSS Features - Acknowledgement of CDSS Required	
CDSS Features - Other	
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Nendaz 2010

Study characteristics	
Methods	Cluster CCT
Participants	Inpatient medical setting, Switzerland 721 patients, 4 medical services
Interventions	Reminder that computed patient-specific thromboembolic risk score and provided indication for thromboprophylaxis
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None

Nendaz 2010 *(Continued)*

	Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Ambush, conveyed patient-specific information, included supporting information on-screen, interruptive, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	

Overhage 1996

Study characteristics	
Methods	Cluster RCT
Participants	General medical ward, academic medical center, Indianapolis, USA (Wishard Memorial Hospital) 1622 episodes of care, 24 care teams
Interventions	Reminders suggesting orders for 22 preventive care measures in eligible patients
Outcomes	Process adherence (prescribing, testing, vaccination)
Co-Interventions	Educational: None Beyond Clinician Education: The same reminder(s) appeared on daily printed patient care report in intervention group
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, developed by study investigators, included supporting information on-screen, makes care recommendation, possible to execute desired action, 'pull' mode of delivery, targeted underuse
Notes	

Overhage 1996 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	N/A

Overhage 1997

Study characteristics

Methods	Cluster RCT
Participants	General medical ward, academic medical center, Indianapolis, USA (Wishard Memorial Hospital) 2181 patients, 86 providers, 6 provider teams
Interventions	Guideline-based reminders to consider implementing additional corollary orders as providers wrote orders for one of 87 selected tests or treatments. This CDSS intended to reduce errors of omission.
Outcomes	Process adherence (testing)
Co-Interventions	Educational: None Beyond Clinician Education: Drug utilization review program for both control and interventions groups
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	

Overhage 1997 *(Continued)*

Baseline characteristics similar?	Low risk
Unit of analysis error	Low risk

Palen 2010

Study characteristics	
Methods	Single cross-over cluster RCT
Participants	Ambulatory care clinics in an integrated care delivery system, Denver, USA (Kaiser Permanente of Colorado) 1460 patients, 171 providers, 8 clinics
Interventions	Reminder advising against ordering D-dimer testing for patient 65 years and older
Outcomes	Process adherence (testing)
Co-Interventions	Educational: Single educational session for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, included supporting information on-screen, interruptive, makes care recommendation, 'push' mode of delivery, targeted overuse
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	N/A
Unit of analysis error	Low risk	

Paul 2006

Study characteristics

Paul 2006 *(Continued)*

Methods	Cluster RCT
Participants	Academic medical centers in Israel, Germany and Italy 2326 patients, 15 wards, 3 hospitals
Interventions	CDSS guiding empirical antibiotic treatment of inpatients with moderate to severe bacterial infections using patient-specific clinical data. It applies a cost-benefit model to rank antibiotic treatments according to their net benefit and offers advice (including no treatment).
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, makes care recommendation, possible to execute desired action, targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Peiris 2015

Study characteristics

Methods	Cluster RCT
Participants	General practices and Aboriginal Community Controlled Health Services, Sydney region, Australia 38 725 patients, 60 sites
Interventions	CDSS providing patient-specific recommendations for management of cardiovascular disease based on patient's absolute risk
Outcomes	Process adherence (prescribing, testing, documentation, other)

Peiris 2015 *(Continued)*

Co-Interventions	Educational: Distribution of educational materials to patients in intervention group; multiple (>1) educational sessions for providers in intervention group Beyond Clinician Education: Audit and feedback in intervention group; sites in both control and intervention arms participating in existing QI initiatives continued with these programs at their discretion
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Appearance differed based on urgency, conveyed patient-specific information, makes care recommendation, 'pull' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Persell 2016a

Study characteristics

Methods	Cluster RCT
Participants	Large adult primary care practice affiliated with an academic medical center, Chicago, USA (Northwestern Medical Faculty Foundation) 206 patient visits, 7 physicians
Interventions	CDSS triggered by antibiotic prescription for acute respiratory infection that prompted clinicians to provide free-text justification that would be included in medical record
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Single educational session for providers in control and intervention groups Beyond Clinician Education: Financial incentives directed at providers in control and intervention groups
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken

Persell 2016a *(Continued)*

CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	N/A

Persell 2016b

Study characteristics

Methods	Cluster RCT
Participants	Large adult primary care practice affiliated with an academic medical center, Chicago, USA (Northwestern Medical Faculty Foundation) 187 patient visits, 7 physicians
Interventions	CDSS triggered by antibiotic prescription for acute respiratory infection that presented order set containing non-antibiotic treatments and patient education materials
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Single educational session for providers in control and intervention groups Beyond Clinician Education: Financial incentives directed at providers in control and intervention groups
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, interruptive, makes care recommendation, possible to execute desired action, targeted overuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement

Persell 2016b *(Continued)*

Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	N/A

Persell 2016c

Study characteristics		
Methods	Cluster RCT	
Participants	Large adult primary care practice affiliated with an academic medical center, Chicago, USA (Northwestern Medical Faculty Foundation) 231 patient visits, 8 physicians	
Interventions	CDSS triggered by antibiotic prescription for acute respiratory infection that prompted clinicians to provide free-text justification that would be included in medical record AND presented order set containing non-antibiotic treatments and patient education materials	
Outcomes	Process adherence (prescribing)	
Co-Interventions	Educational: Single educational session for providers in control and intervention groups Beyond Clinician Education: Financial incentives directed at providers in control and intervention groups	
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken	
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse, user workflow considered in design	
Notes		
Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	

Persell 2016c *(Continued)*

Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	N/A

Persell 2016d

Study characteristics	
Methods	Cluster RCT
Participants	Large adult primary care practice affiliated with an academic medical center, Chicago, USA (Northwestern Medical Faculty Foundation) 238 patient visits, 8 physicians
Interventions	CDSS triggered by antibiotic prescription for acute respiratory infection that presented order set containing non-antibiotic treatments and patient education materials
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Single educational session for providers in control and intervention groups Beyond Clinician Education: Audit and feedback in intervention group; Financial incentives directed at providers in control and intervention groups
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, interruptive, makes care recommendation, possible to execute desired action, targeted overuse, user workflow considered in design
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	N/A

Persell 2016e

Study characteristics	
Methods	Cluster RCT
Participants	Large adult primary care practice affiliated with an academic medical center, Chicago, USA (Northwestern Medical Faculty Foundation) 342 patient visits, 8 physicians
Interventions	CDSS triggered by antibiotic prescription for acute respiratory infection that prompted clinicians to provide free-text justification that would be included in medical record
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Single educational session for providers in control and intervention groups Beyond Clinician Education: Audit and feedback in intervention group; Financial incentives directed at providers in control and intervention groups
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse, user workflow considered in design
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	N/A

Persell 2016f

Study characteristics	
Methods	Cluster RCT
Participants	Large adult primary care practice affiliated with an academic medical center, Chicago, USA (Northwestern Medical Faculty Foundation) 298 patient visits, 7 physicians

Persell 2016f *(Continued)*

Interventions	CDSS triggered by antibiotic prescription for acute respiratory infection that prompted clinicians to provide free-text justification that would be included in medical record AND presented order set containing non-antibiotic treatments and patient education materials
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Single educational session for providers in control and intervention groups Beyond Clinician Education: Audit and feedback in intervention group; Financial incentives directed at providers in control and intervention groups
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	N/A

Peterson 2007

Study characteristics

Methods	RCT
Participants	Academic medical center, USA 2981 patients, 778 providers
Interventions	Guided dosing system delivering advice about appropriate initial dosing for high-risk medications in elderly patients
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None

Peterson 2007 *(Continued)*

CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, makes care recommendation, possible to execute desired action, targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Unclear risk	N/A

Piazza 2019

Study characteristics

Methods	
Participants	
Interventions	
Outcomes	
Co-Interventions	
CDSS Features - Acknowledgement of CDSS Required	
CDSS Features - Other	
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	

Piazza 2019 *(Continued)*

Baseline characteristics similar?	Low risk

Player 2010

Study characteristics	
Methods	Cluster RCT
Participants	Primary care clinics in a national network of practices using same EHR, USA (Medical Quality Improvement Consortium) 54 037 patients, 119 providers, 27 offices
Interventions	Reminder embedded within encounter form suggesting guideline-based management of gastroesophageal reflux disease (GERD) and atypical GERD
Outcomes	Process adherence (prescribing, other)
Co-Interventions	Educational: Distribution of educational materials and multiple (>1) educational sessions for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Appearance differed based on urgency, conveyed patient-specific information, developed by study investigators, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Price 2017

Study characteristics

Price 2017 *(Continued)*

Methods	Cluster RCT
Participants	Primary care provincial research network, BC, Canada (University of British Columbia Department of Family Practice Research Network) 4825 patients, 28 primary care physicians, 8 practices
Interventions	Informed physicians of potentially inappropriate prescriptions in the elderly by application of 40 Screening Tool of Older People's Prescriptions (STOPP) rules
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Ambush, conveyed patient-specific information, decision support was complex, included supporting information on-screen, makes care recommendation, other concurrent CDSS, 'push' mode of delivery, targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Ronda 2018

Study characteristics	
Methods	
Participants	
Interventions	
Outcomes	
Co-Interventions	

Ronda 2018 *(Continued)*

CDSS Features - Acknowledgement of CDSS Required	
CDSS Features - Other	
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Rothschild 2007

Study characteristics	
Methods	Cluster RCT
Participants	Academic medical center, Boston, USA (Brigham and Women's Hospital) 453 providers
Interventions	CDSS encouraging guideline-concordant orders for the transfusion of blood products
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Distribution of educational materials to providers and educational sessions for providers in both control and intervention groups Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, 'push' mode of delivery, required provider input of clinical data, targeted overuse
Notes	
Risk of bias	

Rothschild 2007 *(Continued)*

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	

Safran 1995

Study characteristics	
Methods	Cluster CCT
Participants	Academic primary care clinic, Boston, USA (Beth Israel Hospital) 349 patients, 136 providers, 5 sites
Interventions	Reminder to adhere to recommended processes of care in HIV positive patients
Outcomes	Process adherence (other*),clinical endpoint (several outcomes pertaining to hospitalization, outpatient and ED visits)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, makes care recommendation, possible to execute desired action, targeted underuse
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	

Safran 1995 *(Continued)*

Unit of analysis error	High risk

Schnipper 2010

Study characteristics	
Methods	Cluster RCT
Participants	Primary care clinics within a regional academic medical network, USA (Partners HealthCare System) 7009 patients, 239 providers, 10 practices
Interventions	Documentation-based reminder for patients with coronary artery disease or diabetes that provided decision support with tailored recommendations for care
Outcomes	Process adherence (prescribing, testing, documentation)
Co-Interventions	Educational: Single educational session for providers in intervention group Beyond Clinician Education: Local opinion leaders' endorsement and audit and feedback in intervention group
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, makes care recommendation, 'pull' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Schriefer 2009

Study characteristics	
Methods	Cluster RCT
Participants	Academic family medicine clinic, USA (Mountain Area Health Education Center)

Schriefer 2009 *(Continued)*

	846 patients, 37 physicians, 4 physician teams
Interventions	Body mass index prompt during office visit in obese patients intended to increase diagnosis of obesity and referral for obesity treatment
Outcomes	Process adherence (prescribing, other)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	'Push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	High risk	

Sequist 2005

Study characteristics

Methods	Cluster RCT
Participants	Primary care clinics affiliated with regional academic medical network, USA (Partners HealthCare System) 6243 patients, 194 providers, 20 clinics (4 community health centers, 9 hospital-based clinics, 7 off-site practices)
Interventions	Display of patient-specific guideline-concordant recommendations for diabetes and coronary artery disease care
Outcomes	Process adherence (prescribing, other)
Co-Interventions	Educational: None Beyond Clinician Education: Option to print paper reminders for providers in both control and intervention groups

Sequist 2005 *(Continued)*

CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, developed by study investigators, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Sequist 2009

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practices affiliated with academic medical center, USA (Harvard Vanguard Medical Associates) 21 860 patients, 110 physicians, 11 sites
Interventions	Reminder during office visits for patients overdue for colorectal cancer screening
Outcomes	Process adherence (testing, other)
Co-Interventions	Educational: Single educational session for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Ambush, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	
Risk of bias	

Sequist 2009 *(Continued)*

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	N/A

Sequist 2011

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practices affiliated with academic medical center, USA (Harvard Vanguard Medical Associates) 7083 patients, 292 providers, 15 health centers
Interventions	Two reminders that triggered when chief complaint of chest pain was coded in EHR during office visit (one recommended ECG and aspirin for high risk patients, a second recommended against cardiac stress testing for low risk patients)
Outcomes	Process adherence (prescribing, testing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse and underuse
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	

Sequist 2011 *(Continued)*

Baseline characteristics similar?	Low risk
Unit of analysis error	Low risk

Sequist 2018a

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practices affiliated with academic medical center, USA (Harvard Vanguard Medical Associates 3947 patients, 153 primary care physicians
Interventions	Reminders to improve management of chronic kidney disease for high risk patients (referral to nephrologist, initiation of ACE inhibitor or ARB)
Outcomes	Process adherence (prescribing, other)
Co-Interventions	Educational: Distribution of educational materials to patients in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Ambush, conveyed patient-specific information, decision support was complex, included supporting information on-screen, makes care recommendation, possible to execute desired action, 'pull' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	N/A
Unit of analysis error	Low risk	

Sequist 2018b

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practices affiliated with academic medical center, USA (Harvard Vanguard Medical Associates) 3744 patients, 153 primary care physicians
Interventions	Reminders to improve management of chronic kidney disease for low risk patients (initiation of ACE inhibitor or ARB, annual laboratory test monitoring
Outcomes	Process adherence (prescribing, testing)
Co-Interventions	Educational: Distribution of educational materials to patients in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Ambush, conveyed patient-specific information, decision support was complex, included supporting information on-screen, makes care recommendation, possible to execute desired action, 'pull' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	N/A
Unit of analysis error	Low risk	

Silbernagel 2016

Study characteristics	
Methods	RCT
Participants	Inpatient units, academic health center, Switzerland (University Hospital Bern) 889 patients

Silbernagel 2016 *(Continued)*

Interventions	CDSS identified patients with atrial fibrillation who were not on oral anticoagulants (OAC), calculated CHA_2DS_2-VASc score, and provided recommendations for OAC prescription
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes – required acknowledgment of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, interruptive, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	N/A

Smith 2012

Study characteristics

Methods	Cluster RCT
Participants	Primary care practices, United Kingdom 911 patients, 29 practices
Interventions	Alert on patient record to flag at-risk status for severe asthma
Outcomes	Process adherence (prescribing, other), clinical endpoint (five outcomes pertaining to asthma exacerbation)
Co-Interventions	Educational: Single educational session for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken

Smith 2012 *(Continued)*

CDSS Features - Other	Ambush, conveyed patient-specific information, interruptive, 'push' mode of delivery, targeted overuse and underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Spirk 2017

Study characteristics

Methods	RCT
Participants	General internal medicine wards, academic health center, Switzerland (University Hospital Bern) 1593 patients
Interventions	Prompted clinicians to evaluate pulmonary embolism risk using risk calculator and recommended thromboprophylaxis for patients at high-risk
Outcomes	Process adherence (other), Clinical endpoint (mortality, venous thromboembolism, bleeding)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Ambush, considered alert fatigue in design, developed by study investigators, interruptive, makes care recommendation, 'push' mode of delivery, targeted overuse and underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	

Spirk 2017 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	

Stockwell 2015

Study characteristics	
Methods	Cluster Crossover RCT
Participants	Community-based pediatric clinics affiliated with academic medical center, NY, USA (New York–Presbyterian Hospital/ Columbia University Medical Center) 6593 episodes of care, 4 sites
Interventions	Noninterruptive influenza vaccination reminder using real-time query of hospital and city immunization information system
Outcomes	Process adherence (documentation, vaccination)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, developed in consultation with users, included supporting information on-screen, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Strom 2010

Study characteristics	
Methods	Cluster RCT
Participants	Inpatient setting, academic medical center, Philadelphia, USA (Hospital of the University of Pennsylvania and Penn Presbyterian Medical Center) 96 patients, 1971 providers
Interventions	Nearly 'hard stop' reminder intended to reduce concomitant orders ofwarfarin and trimethoprim- sulfamethoxazole
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Considered alert fatigue in design, conveyed patient-specific information, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Unclear risk	N/A
Unit of analysis error	Low risk	

Szilagyi 2015

Study characteristics	
Methods	Cluster RCT
Participants	Family medicine and pediatric practices participating in two practice-based research networks, USA (Greater Rochester PBRN and CORNET) 29 968 patients, 22 practices
Interventions	CDSS displaying a list of vaccines due at that visit to improve adolescent immunization rates

Szilagyi 2015 *(Continued)*

Outcomes	Process adherence (vaccination)
Co-Interventions	Educational: Multiple (>1) educational sessions for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Ambush, conveyed patient-specific information, developed by study investigators, interruptive, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	N/A

Tamblyn 2003

Study characteristics

Methods	Cluster RCT
Participants	Primary care practices, Quebec, Canada 12 560 encounters, 107 providers
Interventions	CDSS identifying clinically relevant prescribing problems in the elderly (drug-disease contraindications, drug interactions, drug-age contraindications, duration of therapy, and therapeutic duplication)
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Ambush, conveyed patient-specific information, included supporting information on-screen, makes care recommendation, 'push' mode of delivery, targeted overuse

Tamblyn 2003 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Tamblyn 2010

Study characteristics

Methods	RCT
Participants	Primary care research program using same EHR, Quebec, Canada (Medical Office of the 21st Century [MOXXI]) 2293 patients
Interventions	Cardiovascular medication tracking coupled with a nonadherence alert system for antihypertensive and lipid-lowering medications
Outcomes	Process adherence (other)
Co-Interventions	Educational: None Beyond Clinician Education: Electronic drug profile in both control and intervention groups
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Ambush, conveyed patient-specific information, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias)	Low risk	

Tamblyn 2010 *(Continued)*

All outcomes	
Baseline characteristics similar?	Low risk

Tamblyn 2015

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practices, Quebec, Canada 4447 patients, 81 primary care physicians
Interventions	Notified clinicians of patients with poorly managed asthma and provided access to guidelines, assessment tools and patient-specific recommendations (such as home care and monitoring)
Outcomes	Clinical endpoint (inhaled steroids to fast-acting beta agonist ratio, out-of-control asthma incident rate)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes – required acknowledgment of the CDSS but not documentation of action taken
CDSS Features - Other	Ambush, conveyed patient-specific information, decision support was complex, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Tamblyn 2018a

Study characteristics	

Tamblyn 2018a *(Continued)*

Methods	Cluster RCT
Participants	Urban primary care practices, Quebec, Canada 1261 patients, 76 primary care physicians
Interventions	Displayed out-of-pocket costs that patients would incur due to new initiation of anti-hypertensive medication and identified cost savings if switched to an alternative medication
Outcomes	Process adherence (prescribing)
Co-Interventions	Educational: Multiple (>1) educational sessions for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes – required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, required provider input of clinical data, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	N/A
Unit of analysis error	Low risk	

Tamblyn 2018b

Study characteristics

Methods	Cluster RCT
Participants	Urban primary care practices, Quebec, Canada 2331 patients, 76 primary care physicians
Interventions	Displayed out-of-pocket costs that patients would incur due to continuation of anti-hypertensive medication and identified cost savings if switched to an alternative medication
Outcomes	Process adherence (prescribing)

Tamblyn 2018b *(Continued)*

Co-Interventions	Educational: Multiple (>1) educational sessions for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes – required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, required provider input of clinical data, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	N/A
Unit of analysis error	Low risk	

Tang 2012

Study characteristics	
Methods	Cluster RCT
Participants	Academic general internal medicine clinic, Chicago, USA (Northwestern Medical Faculty Foundation) 2114 patients, 30 providers
Interventions	Point-of-care passive prompt for overweight patients directing providers to open evidence-based counseling template that, once completed, could open an order set for overweight patients
Outcomes	Process adherence (other)
Co-Interventions	Educational: Multiple (>1) educational sessions for providers in intervention group Beyond Clinician Education: Endorsement of local opinion leaders in intervention group
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse

Tang 2012 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Taveras 2014

Study characteristics

Methods	Cluster RCT
Participants	Pediatric ambulatory practices affiliated with academic medical center, USA (Harvard Vanguard Medical Associates) 378 patients, 9 practices
Interventions	CDSS triggered at time of well child care visit for a child with a BMI ≥ 95th percentile with links to evidence-based management of childhood obesity and a pre-populated standardized note specific for obesity
Outcomes	Process adherence (documentation)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Ambush, conveyed patient-specific information, developed by study investigators, included supporting information on-screen, interruptive, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	

Taveras 2014 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Low risk
Baseline characteristics similar?	Low risk
Unit of analysis error	Low risk

Taveras 2015a

Study characteristics	
Methods	Cluster RCT
Participants	Pediatric practices affiliated with academic medical center, USA (Harvard Vanguard Medical Associates) 378 patients, 9 practices
Interventions	Reminder for documentation and counselling for children with a body mass index equal to or greater than the 95th percentile
Outcomes	Process adherence (documentation), Clinical endpoint (body mass index)
Co-Interventions	Educational: Distribution of educational materials to patients in both control and intervention groups; Single educational session and access to educational resources such as motivational interviewing strategies for providers in intervention group Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes – required acknowledgment of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	
Risk of bias	

Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	

Taveras 2015a *(Continued)*

Unit of analysis error	Low risk

Taveras 2015b

Study characteristics	
Methods	Cluster RCT
Participants	Pediatric practices affiliated with academic medical center, USA (Harvard Vanguard Medical Associates) 355 patients, 9 practices
Interventions	Reminder for documentation and counselling for children with a body mass index equal to or greater than the 95th percentile
Outcomes	Process adherence (documentation), Clinical endpoint (body mass index)
Co-Interventions	Educational: Distribution of educational materials to patients in both control and intervention groups; Single educational session and access to educational resources such as motivational interviewing strategies for providers in intervention group Beyond Clinician Education: Study health coach conducting motivational counseling calls for families in intervention group
CDSS Features - Acknowledgement of CDSS Required	Yes – required acknowledgment of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Terrell 2009

Study characteristics	
Methods	Cluster RCT
Participants	Academic emergency department, Indianapolis, USA (Wishard Memorial Hospital) 210 episodes of care, 63 providers
Interventions	Reminder that advised against prescription of nine potentially inappropriate medications in patients ≥ age 65
Outcomes	Process adherence (Prescribing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS and documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted overuse
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Terrell 2010

Study characteristics	
Methods	Cluster RCT
Participants	Academic emergency department, Indianapolis, USA (Wishard Memorial Hospital) 2783 episodes of care, 42 providers
Interventions	Reminder that provided dosing recommendations for 10 high-risk medications when renal function was below threshold for dosage adjustment in patients being discharged from the emergency department
Outcomes	Process adherence (prescribing)

Terrell 2010 *(Continued)*

Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, interruptive, makes care recommendation, other concurrent CDSS, possible to execute desired action, 'push' mode of delivery, targeted overuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Tierney 2003

Study characteristics	
Methods	Cluster RCT
Participants	Academic primary care group practice, USA (Indiana University Medical Group-Primary Care) 378 patients, 4 clinics
Interventions	CDSS suggesting guideline-based recommendations for chronic heart failure and ischemic heart disease management
Outcomes	Process adherence (prescribing, vaccination), clinical endpoint (several outcomes pertaining to overall health status, ED visits and hospitalizations due to cardiac disease exacerbations)
Co-Interventions	Educational: Distribution of educational materials and multiple (>1) educational sessions for providers in both control and interventions groups Beyond Clinician Education: Use of local opinion leaders in intervention group
CDSS Features - Acknowledgement of CDSS Required	No

Tierney 2003 *(Continued)*

CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Tierney 2005

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practice-based research network, USA (Indiana University Medical Group-Primary Care) 363 patients, 4 hospital-based academic practices
Interventions	Display of patient-specific guideline-based suggestions for management of asthma and chronic obstructive pulmonary disease
Outcomes	Process adherence (prescribing, testing, vaccination), clinical endpoint (several outcomes related to overall health status, medication adherence, emergency visits, hospitalizations)
Co-Interventions	Educational: Distribution of educational materials and single educational session for providers in both control and interventions groups Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, included supporting information on-screen, makes care recommendation, other concurrent CDSS, possible to execute desired action, required provider input of clinical data, targeted underuse
Notes	
Risk of bias	

Tierney 2005 *(Continued)*

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Trick 2009

Study characteristics	
Methods	Cluster CCT
Participants	Internal medicine inpatient unit, public hospital, Chicago, USA (Cook County Hospital) 135 patients, 2 teams
Interventions	CDSS that pre-selects opt-out orders for influenza vaccination triggered by an order to discharge the patient
Outcomes	Process adherence (vaccination)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Interruptive, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	

Trick 2009 *(Continued)*

Unit of analysis error	High risk

Van Wyk 2008a

Study characteristics	
Methods	Cluster RCT
Participants	General practice clinics, Delft region, the Netherlands 62 536 patients, 46 physicians, 24 clinics
Interventions	Automatic display of patient-specific guideline recommendations for the screening and treatment of dyslipidemia
Outcomes	Process adherence (prescribing, testing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, makes care recommendation, 'push' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Van Wyk 2008b

Study characteristics	
Methods	Cluster RCT
Participants	General practice clinics, Delft region, the Netherlands

Van Wyk 2008b *(Continued)*

	56 675 patients, 51 physicians, 23 clinics
Interventions	User initiated display of patient-specific guidelines for screening and treatment of dyslipidemia
Outcomes	Process adherence (prescribing, testing)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	No
CDSS Features - Other	Conveyed patient-specific information, developed by study investigators, makes care recommendation, 'pull' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Walker 2010

Study characteristics

Methods	Cluster RCT
Participants	General practice clinics, Melbourne, Australia 2846 patients, 221 providers, 66 clinics
Interventions	Reminder that prompted discussion about chlamydia testing with women aged 16-24
Outcomes	Process adherence (testing)
Co-Interventions	Educational: Distribution of educational materials to providers in both intervention and control groups Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken

Walker 2010 *(Continued)*

CDSS Features - Other	Ambush, considered alert fatigue in design, interruptive, makes care recommendation, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Wexler 2010

Study characteristics	
Methods	Cluster RCT
Participants	Acute general medical service, academic medical center, Boston, USA (Massachusetts General Hospital) 128 patients, 42 residents, 7 teams
Interventions	Order template facilitating weight-based dosing of insulin intended to lower mean blood glucose in medical inpatient with type 2 diabetes
Outcomes	Clinical endpoint (hyper- and hypo-glycemia, basal insulin dose)
Co-Interventions	Educational: Distribution of educational materials and single educational session for providers in both intervention and control groups Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Conveyed patient-specific information, interruptive, 'push' mode of delivery, required provider input of clinical data, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement

Wexler 2010 *(Continued)*

Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Wilkinson 2019

Study characteristics		
Methods		
Participants		
Interventions		
Outcomes		
Co-Interventions		
CDSS Features - Acknowledgement of CDSS Required		
CDSS Features - Other		
Notes		
Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	
Unit of analysis error	Low risk	

Wright 2012

Study characteristics	
Methods	Cluster RCT
Participants	Primary care practices affiliated with academic medical center, Boston, USA (Brigham and Women's Hospital) 79 064 patients, 11 clinics
Interventions	Reminder using inference rules to suggest adding undocumented problems to the EHR problem list
Outcomes	Process adherence (documentation)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Ambush, considered alert fatigue in design, conveyed patient-specific information, developed by study investigators, included supporting information on-screen, interruptive, possible to execute desired action, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Baseline characteristics similar?	Low risk	
Unit of analysis error	High risk	

Wu 2018

Study characteristics	
Methods	RCT
Participants	Intensive and coronary care units, cardiology wards, and cardiac surgery wards, Guangdong, China (Guangdong General Hospital) 875 patients

Wu 2018 *(Continued)*

Interventions	Monitored the serum creatinine levels of hospitalized adult patients and alerted physicians to suspected cases of acute kidney injury
Outcomes	Process adherence (other), Clinical endpoint (renal replacement therapy, renal recovery, death)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Developed by study investigators, 'push' mode of delivery, targeted underuse
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	

Zanetti 2003

Study characteristics

Methods	Quasi-RCT
Participants	Cardiac surgery service, academic medical center, Boston, USA (Brigham and Women's Hospital) 273 patients
Interventions	CDSS supplemented by audible alarm reminding operating room staff to consider second dose of prophylactic antibiotics for prolonged surgeries
Outcomes	Process adherence (prescribing), clinical endpoint (surgical-site infection)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Yes - required acknowledgement of the CDSS but not documentation of action taken
CDSS Features - Other	Developed by study investigators, included supporting information on-screen, interruptive, makes care recommendation, possible to execute desired action, 'push' mode of delivery, targeted underuse

Zanetti 2003 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	N/A
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	N/A
Baseline characteristics similar?	Low risk	

Zera 2015

Study characteristics

Methods	Cluster RCT
Participants	Primary care clinics affiliated with regional academic medical network, USA (Partners HealthCare System) 847 patients, 26 physician clusters
Interventions	Identified women with a history of gestational diabetes and recommended screening for type 2 diabetes
Outcomes	Process adherence (testing), Clinical endpoint (diabetes diagnosis)
Co-Interventions	Educational: None Beyond Clinician Education: None
CDSS Features - Acknowledgement of CDSS Required	Not reported
CDSS Features - Other	Ambush, conveyed patient-specific information, decision support was complex, developed by study investigators, included supporting information on-screen, makes care recommendation, other concurrent CDSS, possible to execute desired action, 'push' mode of delivery, targeted underuse, user workflow considered in design
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias)	Low risk	

Zera 2015 *(Continued)*

All outcomes	
Baseline characteristics similar?	Low risk
Unit of analysis error	Low risk

CPOE: Computerized provider order entry; EMR: electronic medical record; RCT: randomised controlled trial; CCT: Controlled clinical trial; *: Some of the outcomes within this category are continuous (as opposed to dichotomous); **: All of the outcomes within this category are continuous (as opposed to dichotomous).

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Acevedo 2018	Not a point-of-care reminder
Adelman 2013	Not a computerized decision support system
Allen 2016	Targeted multiple disciplines and physician data could not be isolated
ALMohiza 2016	Not a point-of-care reminder
Anchala 2015	Not part of routine care
Apkon 2005a	Not part of routine care
Åsberg 2010	Not part of routine care
Barkun 2013	Not a computerized decision support system
Beck 2015	Excluded topic: specialized perfusionist-directed system
Beeckman 2013	Targeted non-physicians
Bernacki 2015	Not a computerized decision support system
Bhardwaja 2011	Not an on-screen computer reminder
Bindels 2004	Not part of routine care
Biswas 2018	Not a point-of-care reminder
Bosworth 2009	Ineligible comparison: head-to-head designl
Caballero-Ruiz 2017	Not a point-of-care reminder
Cannon 2000	Not a point-of-care reminder
Chien 2017	Not directly related to patient care
Clarke 2016	Not on-screen computerized decision support system
Collins 2018	CDSS present in pre-randomization phase

Study	Reason for exclusion
Colpaert 2012	Ineligible study design
Crosson 2012	Not a computerized decision support system
Curran 2010	Not a computerized decision support system
Curtain 2011	Targeted non-physicians
Dekarske 2015	Targeted multiple disciplines and physician data could not be isolated
Dexter 2004	Ineligible comparison: head-to-head design
Dixon 2017	Ineligible study design
Dragan 2015	Excluded topic: simulation
Duffy 2016	Targeted non-physicians
Dumont 2012	Not part of routine care
Durieux 2000	Ineligible study design
Dykes 2010	Targeted non-physicians
Edmiston 2016	Not a computerized decision support system
Eisenstein 2011	Not a point-of-care reminder
Elliott 2017	Targeted non-physicians
Feldstein 2006	Not a point-of-care reminder
Fitzgerald 2011	Not part of routine care
Fitzpatrick 2017	Inappropriate control
Flamm 2013	Ineligible study design
Flanagan 1999	Not a point-of-care reminder
Foy 2011	Not on-screen computerized decision support system
Freundlich 2013	Not directly related to patient care
Fricton 2011	Excluded topic: dental clinics
Gallagher 2016	Not a point-of-care reminder
Goetz 2013	Outcome reported in ineligible format
Grace 2011	Not a computerized decision support system
Hagiwara 2013	Excluded topic: simulation
Hains 2012	Not part of routine care

Study	Reason for exclusion
Harpole 1997	Ineligible comparison: head-to-head design
Heiman 2004	Not a point-of-care reminder
Herasevich 2011	Not a computerized decision support system
Holmes 2015	Targeted non-physicians
Hooper 2012	Not on-screen computerized decision support system
Humphrey 2011	Not a point-of-care reminder
Ignatov 2016	Excluded topic: specialized system aiding in quantitative cardiotocography interpretation
James 1993	Not a computerized decision support system
James 2015	Not part of routine care
Johnson 2010	Not directly related to patient care
Keitel 2017	Not part of routine care
Kim 2017	Ineligible study design
Kollef 2014	Excluded topic: expert system
Kostopoulou 2015	Excluded topic: simulation
Kralj 2003	Ineligible study design
Kuhn 2015	Ineligible study design
Kurian 2009	Not part of routine care
Lee 2009	Targeted non-physicians
Lee 2016	Not a computerized decision support system
Luders 2010	Not on-screen computerized decision support system
Luna 2017	Ineligible comparison: head-to-head design
Magnus 2012	Ineligible study design
Mainous 2013	Outcome reported in ineligible format
Mann 2011	Targeted non-physicians
Manns 2012	Ineligible comparison: head-to-head design
Martens 2007	Outcome reported in ineligible format
Martí 2017	Not an on-screen computerized decision support system
Martinez 2018	Not part of routine care

Study	Reason for exclusion
Mayne 2014	Outcome reported in ineligible format
McAvoy 2013	Not on-screen computerized decision support system
McCormick 2016	Excluded topic: specialized anesthesiologist-directed system
McDonald 1992	Not on-screen computerized decision support system
McGreevey 2013	Excluded topic: order set
McGregor 2006	Not a point-of-care reminder
Mehta 2016	Ineligible study design
Montgomery 2000	Not a computerized decision support system
Muth 2018	Not part of routine care
Nieuwlaat 2012	Not a point-of-care reminder
Ornstein 1991	Not on-screen computerized decision support system
Palen 2006	Ineligible comparison or inappropriate control
Pang 2015	Non-study
Panjasawatwong 2015	Excluded topic: specialized anesthesiologist-directed system
Peremans 2010	Excluded topic: simulation
Pielmeier 2012	Duplicate publication
Poller 1993	Not a point-of-care reminder
Raebel 2007	Targeted non-physicians
Raja 2015	Not a computerized decision support system
Rapoport 2018	Not part of routine care
Rathlev 2016	Targeted multiple disciplines and physician data could not be isolated
Reeve 2008	Targeted non-physicians
Ribeiro-Vaz 2012	Ineligible study design
Robbins 2012	Ineligible comparison: head-to-head design
Rodriguez-Aldrete 2016	Not a point-of-care reminder
Rood 2005	Ineligible comparison: head-to-head design
Roumie 2006	Not a point-of-care reminder
Roy 2009	Not a point-of-care reminder

Study	Reason for exclusion
Roy 2016	Insufficient description of CDSS aspect of intervention
Safran 1993	Duplicate publication
Schnipper 2010-2	Excluded topic: order set
Schwarz 2012	Ineligible comparison: head-to-head design
Shelley 2015	Not an on-screen computerized decision support system
Silva 2013	Not a computerized decision support system
Simon 2006	Ineligible comparison: head-to-head design
Skinner 2015	Ineligible comparison: head-to-head design
Slok 2016	Targeted multiple disciplines and physician data could not be isolated
Strom 2010-2	Ineligible comparison: head-to-head design
Sundaram 2009	Not on-screen computerized decision support system
Suresh 2018	Targeted multiple disciplines and physician data could not be isolated
Tamblyn 2008	Ineligible comparison: head-to-head design
Tamblyn 2012	Ineligible comparison: head-to-head design
Thomas 2004	Not a point-of-care reminder
Thomas 2018	Outcome reported in ineligible format
Tollitt 2018	Not a point-of-care reminder
Tsai 2016	Inappropriate intervention
van Doormaal 2009	Ineligible study design
van Wijk 2001	Ineligible comparison: head-to-head design
Weiss 2013	Inappropriate control
Welch 2015	Not part of routine care
Were 2011	Not on-screen computerized decision support system
Williams 2010	Ineligible study design
Williams 2011	Targeted non-physicians
Wilson 2015	Not part of routine care
Wipfli 2016	Excluded topic: simulated scenarios
Woller 2018	Ineligible study design

Study	Reason for exclusion
Zhu 2018	Not a computerized decision support system
Ziemer 2006	Not on-screen computerized decision support system

Characteristics of studies awaiting classification *[ordered by study ID]*

Christakis 2001

Methods	Cluster-RCT
Participants	Outpatient pediatric teaching clinic, Seattle, USA (University of Washington) 1339 episodes of care, 38 providers
Interventions	Displaying evidence regarding the use and duration of antibiotics for otitis media in children
Outcomes	Process adherence (prescribing)
Notes	System for delivery of reminder: CPOE

Christakis 2001a

Methods	Cluster RCT
Participants	Pediatric primary outpatient teaching clinic, Seattle, USA (University of Washington) 1339 episodes of care, 38 providers
Interventions	CDSS presenting real-time evidence to providers prescribing antibiotics for otitis media
Outcomes	Process adherence (prescribing)
Notes	

Durieux 2000 - classified, excluded

Methods	
Participants	
Interventions	
Outcomes	
Notes	

Forrest 2013

Methods	Cluster RCT
Participants	Primary care practice-based research network, USA (Children's Hospital of Philadelphia) 91 providers, 12 practices
Interventions	Multicomponent CDSS intended to improve adherence to guidelines for acute otitis media and otitis media with effusion (display of relevant clinical information; data gathering tool; and generation of patient-specific orders for treatment, progress note, and discharge instructions) Co-intervention (apart from education): Audit and feedback Required acknowledgement of the CDSS only
Outcomes	Process adherence (prescribing, other)
Notes	

Fortuna 2009

Methods	Cluster RCT
Participants	Primary care practices affiliated with academic medical center, USA (Harvard Vanguard Medical Associates) 177 providers, 9 sites
Interventions	Reminder to decrease prescribing of heavily marketed hypnotic medications by recommending an alternative medication and providing prescribing information and patient education materials Co-intervention (education only): Distribution of educational materials and single educational session for providers
Outcomes	Process adherence (prescribing)
Notes	

Kralj 2003 - classified, excluded

Methods	Cluster-CCT
Participants	Two community oncology outpatient practices, USA 2170 episodes of care, 2 practices
Interventions	Prompting providers to order erythropoietin for patients with haemoglobin < 120 g/dL
Outcomes	Process adherence (prescribing)
Notes	System for delivery of reminder: EMR with link to CPOE

Plaza 2005

Methods	
Participants	
Interventions	
Outcomes	
Notes	

Roumie 2006 - classified, excluded

Methods	Cluster-RCT
Participants	2 hospitals, 8 ambulatory clinics, Nashville, USA (Vanderbilt University) 871 patients, 116 providers
Interventions	Alert in electronic medical record displaying recent blood pressure value and outlining national recommendations for hypertension treatment and blood pressure goals
Outcomes	Process adherence (prescribing), clinical outcomes
Notes	System for delivery of reminder: EMR Additional interventions delivered to intervention and control groups: provider education (printed materials delivered via e-mail)

Sales 2008

Methods	CCT
Participants	Hospitals in a regional network within the Veterans Health Administration, USA (Rocky Mountain Network) 5438 patients, 199 providers, 6 hospitals
Interventions	Reminders at the point of care to improve lipid measurement and treatment in patients with ischemic heart disease
Outcomes	Process adherence (tests, prescribing)
Notes	

Tape 1993

Methods	Cluster-CCT
Participants	Internal medicine teaching clinic, Omaha, USA (University of Nebraska) 1809 patients, 2 clinics

Tape 1993 *(Continued)*

Interventions	Drawing attention to deficiencies in preventive care measures for a given patient
Outcomes	Process adherence (test ordering, vaccination)
Notes	System for delivery of reminder: EMR Additional interventions delivered to intervention and control groups: provider education (conferences), paper reminders to providers

Study published in Spanish - awaiting translation. Expected to be eligible for inclusion.

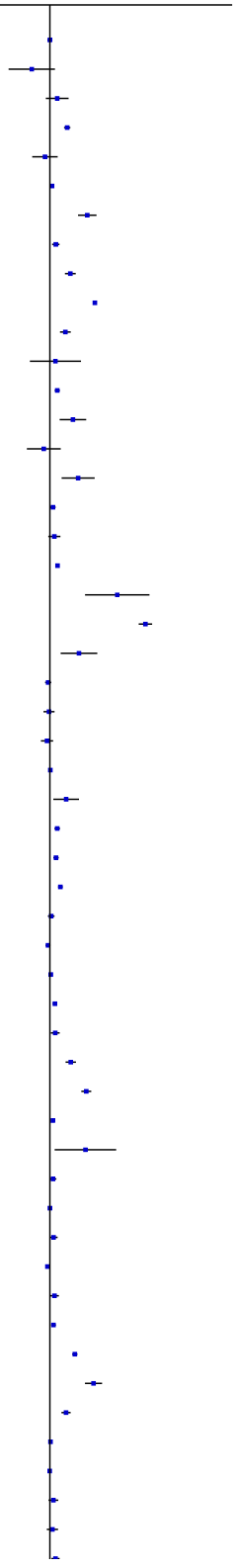
DATA AND ANALYSES

Comparison 1. CDSS (+/- co-intervention) vs. Usual care (+/- co-intervention)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1.1 All	114	935192	Risk Difference (M-H, Random, 95% CI)	0.07 [0.06, 0.09]
1.2 Prescription	64	276410	Risk Ratio (M-H, Random, 95% CI)	1.16 [1.12, 1.20]
1.3 Vaccination	11	66725	Risk Ratio (M-H, Random, 95% CI)	1.51 [1.29, 1.77]
1.4 Testing	30	212791	Risk Ratio (M-H, Random, 95% CI)	1.20 [1.12, 1.29]
1.5 Documentation	25	539528	Risk Ratio (M-H, Random, 95% CI)	1.75 [1.48, 2.07]
1.7 Other	32	300114	Risk Ratio (M-H, Random, 95% CI)	1.63 [1.47, 1.81]

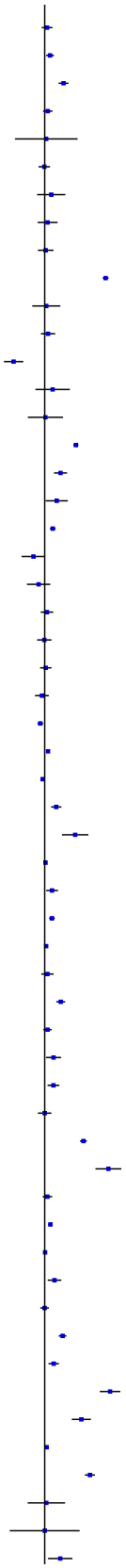
Analysis 1.1. Comparison 1: CDSS (+/- co-intervention) vs. Usual care (+/- co-intervention), Outcome 1: All

Study or Subgroup	CDSS Events	CDSS Total	Usual care Events	Usual care Total	Weight	Risk Difference M-H, Random, 95% CI
Abdel-Kader 2011	145	145	103	103	1.0%	0.00 [-0.02 , 0.02]
Ansari 2003	10	64	14	51	0.5%	-0.12 [-0.27 , 0.03]
Arts 2017	287	522	130	259	0.8%	0.05 [-0.03 , 0.12]
Awdishu 2016	268	1579	141	2489	1.0%	0.11 [0.09 , 0.13]
Baandrup 2010	110	216	209	386	0.7%	-0.03 [-0.12 , 0.05]
Baer 2013	193	9647	34	5848	1.0%	0.01 [0.01 , 0.02]
Bates 1999	320	437	245	502	0.8%	0.24 [0.18 , 0.30]
Beeler 2014	1730	2555	2210	3462	1.0%	0.04 [0.01 , 0.06]
Bell 2010	67	464	2	185	0.9%	0.13 [0.10 , 0.17]
Bernstein 2017	1584	5391	0	5548	1.0%	0.29 [0.28 , 0.31]
Beste 2015	218	790	366	2094	0.9%	0.10 [0.07 , 0.14]
Boustani 2012	9	40	10	53	0.4%	0.04 [-0.13 , 0.20]
Chak 2018	119	1484	48	1503	1.0%	0.05 [0.03 , 0.06]
Co 2010	161	206	130	206	0.7%	0.15 [0.06 , 0.24]
Cote 2008a	52	134	74	173	0.6%	-0.04 [-0.15 , 0.07]
Cote 2008b	90	147	74	173	0.6%	0.18 [0.08 , 0.29]
Davis 2007	2654	6318	2351	5877	1.0%	0.02 [0.00 , 0.04]
Dean 2015	686	817	509	628	0.9%	0.03 [-0.01 , 0.07]
Dexter 2001	270	4995	20	5070	1.0%	0.05 [0.04 , 0.06]
Diaz 2018	24	25	13	25	0.3%	0.44 [0.23 , 0.65]
Diaz 2019	292	468	0	583	0.9%	0.62 [0.58 , 0.67]
Downs 2006	32	107	6	55	0.6%	0.19 [0.07 , 0.31]
Dregan 2014	2590	3336	2474	3141	1.0%	-0.01 [-0.03 , 0.01]
Eccles 2002a	300	1117	334	1218	0.9%	-0.01 [-0.04 , 0.03]
Eccles 2002b	511	1200	517	1163	0.9%	-0.02 [-0.06 , 0.02]
Feder 2011	223	70521	12	73347	1.0%	0.00 [0.00 , 0.00]
Field 2009	172	274	134	257	0.7%	0.11 [0.02 , 0.19]
Fiks 2009	3238	6110	2800	5809	1.0%	0.05 [0.03 , 0.07]
Fiks 2013	3723	5557	3583	5688	1.0%	0.04 [0.02 , 0.06]
Filippi 2003	3012	8030	2242	7313	1.0%	0.07 [0.05 , 0.08]
Flottorp 2002a	458	2318	533	2822	1.0%	0.01 [-0.01 , 0.03]
Flottorp 2002b	612	4751	417	2956	1.0%	-0.01 [-0.03 , 0.00]
Frank 2004	343	4387	348	4833	1.0%	0.01 [-0.00 , 0.02]
Gill 2009	4444	5473	5048	6480	1.0%	0.03 [0.02 , 0.05]
Gill 2011	394	1470	477	2047	1.0%	0.04 [0.01 , 0.06]
Gonzales 2013	400	1017	764	2974	0.9%	0.14 [0.10 , 0.17]
Goud 2009	1411	1610	709	1110	1.0%	0.24 [0.21 , 0.27]
Guiriguet 2016	9539	21619	8196	19423	1.0%	0.02 [0.01 , 0.03]
Gupta 2014	31	46	19	43	0.3%	0.23 [0.03 , 0.43]
Hicks 2008	55	786	52	1048	1.0%	0.02 [-0.00 , 0.04]
Holt 2010	59	18021	56	18071	1.0%	0.00 [-0.00 , 0.00]
Holt 2017	1647	2484	1558	2438	1.0%	0.02 [-0.00 , 0.05]
Hoye 2013	11216	12435	4972	5416	1.0%	-0.02 [-0.03 , -0.01]
Judge 2006	606	1982	513	1861	1.0%	0.03 [0.00 , 0.06]
Karlsson 2018	5734	7861	4346	6156	1.0%	0.02 [0.01 , 0.04]
Kenealy 2005	1434	4509	877	5656	1.0%	0.16 [0.15 , 0.18]
Krall 2004	315	580	128	496	0.9%	0.29 [0.23 , 0.34]
Kucher 2005	296	1255	163	1251	1.0%	0.11 [0.08 , 0.14]
Linder 2009-1	5957	104052	4727	88887	1.0%	0.00 [0.00 , 0.01]
Linder 2009-2	98	5154	136	6729	1.0%	-0.00 [-0.01 , 0.00]
Lo 2009	689	1685	767	1988	1.0%	0.02 [-0.01 , 0.05]
Locatelli 2009	277	289	243	258	0.9%	0.02 [-0.02 , 0.05]
Loo 2011a	259	1336	303	1930	1.0%	0.04 [0.01 , 0.06]



Analysis 1.1. (Continued)

Locatelli 2009	277	289	243	258	0.9%	0.02 [-0.02 , 0.05]
Loo 2011a	259	1336	303	1930	1.0%	0.04 [0.01 , 0.06]
Loo 2011b	832	1394	903	1930	0.9%	0.13 [0.09 , 0.16]
Martins 2017	613	679	641	727	1.0%	0.02 [-0.01 , 0.05]
Matheny 2008	22	38	25	44	0.3%	0.01 [-0.20 , 0.23]
Mazzaglia 2016	766	1059	676	931	0.9%	-0.00 [-0.04 , 0.04]
McCowan 2001	77	147	158	330	0.7%	0.05 [-0.05 , 0.14]
McGinn 2013	298	374	174	224	0.8%	0.02 [-0.05 , 0.09]
Meigs 2003	269	307	253	291	0.9%	0.01 [-0.05 , 0.06]
Mertens 2015	1381	3108	30	1132	1.0%	0.42 [0.40 , 0.44]
Murray 2004	56	181	51	171	0.7%	0.01 [-0.08 , 0.11]
Myers 2011a	288	324	317	366	0.9%	0.02 [-0.03 , 0.07]
Myers 2011b	177	271	317	366	0.8%	-0.21 [-0.28 , -0.15]
Nendaz 2010	73	130	73	144	0.6%	0.05 [-0.06 , 0.17]
Overhage 1996	10	70	8	58	0.6%	0.00 [-0.12 , 0.13]
Overhage 1997	2874	5702	1654	5702	1.0%	0.21 [0.20 , 0.23]
Palen 2010	703	861	424	599	0.9%	0.11 [0.06 , 0.15]
Paul 2006	216	297	176	273	0.8%	0.08 [0.01 , 0.16]
Peiris 2015	3030	5335	2483	4846	1.0%	0.06 [0.04 , 0.07]
Persell 2016a	62	70	131	136	0.8%	-0.08 [-0.16 , 0.00]
Persell 2016b	47	51	131	136	0.8%	-0.04 [-0.12 , 0.04]
Persell 2016c	93	95	131	136	0.9%	0.02 [-0.03 , 0.06]
Persell 2016d	98	102	131	136	0.9%	-0.00 [-0.05 , 0.05]
Persell 2016e	200	206	131	136	0.9%	0.01 [-0.03 , 0.05]
Persell 2016f	153	162	131	136	0.9%	-0.02 [-0.07 , 0.03]
Peterson 2007	3007	4556	3143	4555	1.0%	-0.03 [-0.05 , -0.01]
Player 2010	119	2532	89	3725	1.0%	0.02 [0.01 , 0.03]
Price 2017	17900	18668	5635	5792	1.0%	-0.01 [-0.02 , -0.01]
Rothschild 2007	546	1350	503	1546	0.9%	0.08 [0.04 , 0.11]
Safran 1995	162	191	101	158	0.7%	0.21 [0.12 , 0.30]
Schnipper 2010	67	3649	48	3831	1.0%	0.01 [0.00 , 0.01]
Schriefer 2009	46	379	33	467	0.9%	0.05 [0.01 , 0.09]
Sequist 2005	643	2924	564	3319	1.0%	0.05 [0.03 , 0.07]
Sequist 2009	650	10912	540	10948	1.0%	0.01 [0.00 , 0.02]
Sequist 2011	143	717	110	610	0.9%	0.02 [-0.02 , 0.06]
Sequist 2018a	909	2020	655	1927	1.0%	0.11 [0.08 , 0.14]
Sequist 2018b	1363	1893	1296	1851	1.0%	0.02 [-0.01 , 0.05]
Silbernagel 2016	100	455	69	434	0.9%	0.06 [0.01 , 0.11]
Smith 2012	421	457	391	454	0.9%	0.06 [0.02 , 0.10]
Spirk 2017	536	804	526	789	0.9%	0.00 [-0.05 , 0.05]
Stockwell 2015	2179	3199	1409	3394	1.0%	0.27 [0.24 , 0.29]
Strom 2010	111	194	20	148	0.7%	0.44 [0.35 , 0.53]
Szilagyi 2015	736	1760	703	1760	1.0%	0.02 [-0.01 , 0.05]
Tamblyn 2003	4012	4767	3694	4603	1.0%	0.04 [0.02 , 0.05]
Tamblyn 2010	27	1166	23	1127	1.0%	0.00 [-0.01 , 0.01]
Tamblyn 2018a	166	625	126	636	0.9%	0.07 [0.02 , 0.11]
Tamblyn 2018b	200	1289	162	1042	1.0%	-0.00 [-0.03 , 0.03]
Tang 2012	163	958	55	1156	1.0%	0.12 [0.10 , 0.15]
Taveras 2014	12	194	0	184	0.9%	0.06 [0.03 , 0.10]
Taveras 2015a	87	194	0	184	0.8%	0.45 [0.38 , 0.52]
Taveras 2015b	43	171	0	184	0.8%	0.25 [0.19 , 0.32]
Terrell 2009	2578	2647	2416	2515	1.0%	0.01 [0.00 , 0.02]
Terrell 2010	851	1493	335	1290	0.9%	0.31 [0.28 , 0.34]
Tierney 2003	41	109	39	107	0.5%	0.01 [-0.12 , 0.14]
Tierney 2005	26	39	16	24	0.3%	0.00 [-0.24 , 0.24]
Trick 2009	8	66	1	69	0.7%	0.11 [0.02 , 0.19]



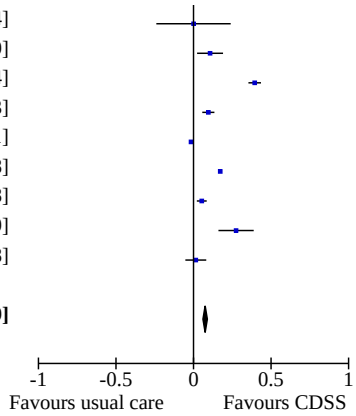
Analysis 1.1. (Continued)

Tierney 2005	26	39	16	24	0.3%	0.00 [-0.24 , 0.24]
Trick 2009	8	66	1	69	0.7%	0.11 [0.02 , 0.19]
Van Wyk 2008a	701	1079	225	882	0.9%	0.39 [0.35 , 0.44]
Van Wyk 2008b	438	1249	225	882	0.9%	0.10 [0.06 , 0.13]
Walker 2010	1370	12925	1476	12098	1.0%	-0.02 [-0.02 , -0.01]
Wright 2012	10016	38025	3739	41039	1.0%	0.17 [0.17 , 0.18]
Wu 2018	42	467	15	408	1.0%	0.05 [0.02 , 0.08]
Zanetti 2003	93	137	55	136	0.6%	0.27 [0.16 , 0.39]
Zera 2015	265	471	206	376	0.8%	0.01 [-0.05 , 0.08]
Total (95% CI)		**483510**		**451682**	**100.0%**	**0.07 [0.06 , 0.09]**
Total events:	132479		91929			

Heterogeneity: Tau² = 0.01; Chi² = 50268.39, df = 113 (P < 0.00001); I² = 100%

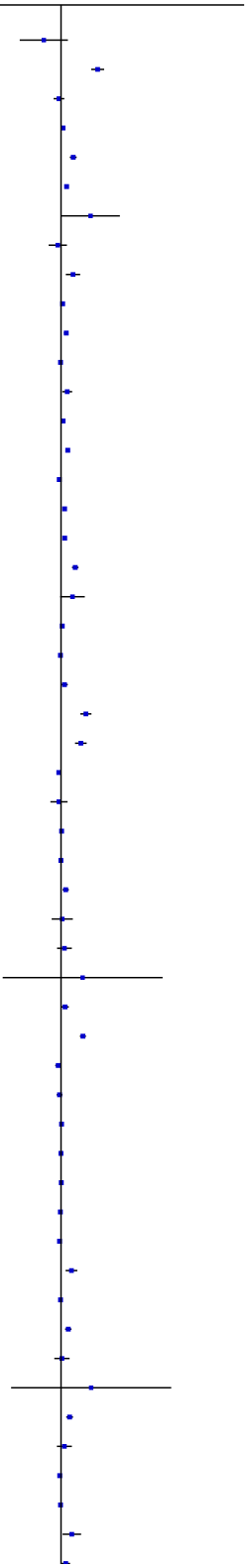
Test for overall effect: Z = 10.39 (P < 0.00001)

Test for subgroup differences: Not applicable



Analysis 1.2. Comparison 1: CDSS (+/- co-intervention) vs. Usual care (+/- co-intervention), Outcome 2: Prescription

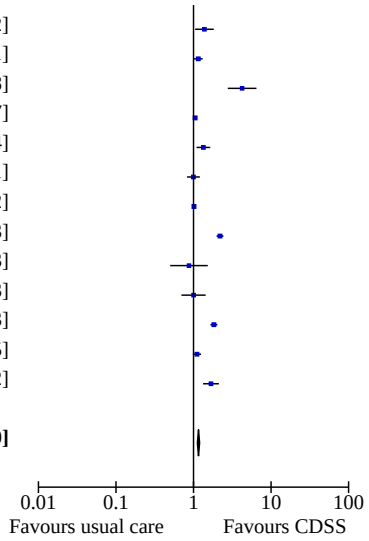
Study or Subgroup	CDSS Events	CDSS Total	Usual care Events	Usual care Total	Weight	Risk Ratio M-H, Random, 95% CI
Ansari 2003	10	61	14	51	0.2%	0.60 [0.29 , 1.23]
Awdishu 2016	268	1579	141	2489	1.2%	3.00 [2.47 , 3.64]
Baandrup 2010	110	216	209	386	1.4%	0.94 [0.80 , 1.10]
Beeler 2014	1730	2555	2210	3462	2.1%	1.06 [1.02 , 1.10]
Bell 2010	682	926	209	409	1.8%	1.44 [1.30 , 1.60]
Bernstein 2017	1827	5391	1591	5548	2.1%	1.18 [1.12 , 1.25]
Boustani 2012	15	199	7	225	0.1%	2.42 [1.01 , 5.82]
Cote 2008a	52	134	74	173	0.9%	0.91 [0.69 , 1.19]
Cote 2008b	90	147	74	173	1.1%	1.43 [1.15 , 1.77]
Davis 2007	2654	6318	2351	5877	2.1%	1.05 [1.01 , 1.10]
Dexter 2001	1484	4995	1288	5070	2.0%	1.17 [1.10 , 1.25]
Dregan 2014	2590	3336	2474	3141	2.2%	0.99 [0.96 , 1.01]
Field 2009	172	274	134	257	1.5%	1.20 [1.04 , 1.40]
Fiks 2013	3723	5557	3583	5688	2.2%	1.06 [1.04 , 1.09]
Filippi 2003	3012	8030	2242	7313	2.1%	1.22 [1.17 , 1.28]
Flottorp 2002a	1354	2522	1676	2961	2.1%	0.95 [0.90 , 1.00]
Flottorp 2002b	2827	5031	1583	3135	2.1%	1.11 [1.07 , 1.16]
Gill 2009	3837	5473	4069	6479	2.2%	1.12 [1.09 , 1.15]
Gonzales 2013	400	1017	764	2974	1.8%	1.53 [1.39 , 1.69]
Hicks 2008	55	786	52	1048	0.6%	1.41 [0.98 , 2.04]
Holt 2017	1647	2484	1558	2438	2.1%	1.04 [1.00 , 1.08]
Hoye 2013	11216	12435	4972	5416	2.2%	0.98 [0.97 , 0.99]
Judge 2006	606	1982	513	1861	1.8%	1.11 [1.00 , 1.22]
Krall 2004	315	580	128	496	1.4%	2.10 [1.78 , 2.49]
Kucher 2005	296	1255	163	1251	1.3%	1.81 [1.52 , 2.16]
Linder 2009-1	2601	8218	2108	6236	2.1%	0.94 [0.89 , 0.98]
Linder 2009-2	98	5154	136	6729	0.9%	0.94 [0.73 , 1.22]
Locatelli 2009	277	289	243	258	2.1%	1.02 [0.98 , 1.06]
Mazzaglia 2016	766	1059	676	931	2.1%	1.00 [0.94 , 1.05]
McGinn 2013	415	586	245	398	1.9%	1.15 [1.05 , 1.26]
Murray 2004	56	181	51	171	0.7%	1.04 [0.76 , 1.42]
Nendaz 2010	73	130	73	144	1.1%	1.11 [0.89 , 1.38]
Overhage 1996	2	243	1	232	0.0%	1.91 [0.17 , 20.92]
Paul 2006	216	297	176	273	1.7%	1.13 [1.01 , 1.26]
Peiris 2015	1243	5335	586	4846	1.9%	1.93 [1.76 , 2.11]
Persell 2016a	62	70	131	136	1.9%	0.92 [0.84 , 1.01]
Persell 2016b	47	51	131	136	1.9%	0.96 [0.88 , 1.04]
Persell 2016c	93	95	131	136	2.1%	1.02 [0.97 , 1.06]
Persell 2016d	98	102	131	136	2.1%	1.00 [0.95 , 1.05]
Persell 2016e	200	206	131	136	2.1%	1.01 [0.97 , 1.05]
Persell 2016f	153	162	131	136	2.1%	0.98 [0.93 , 1.03]
Peterson 2007	3007	4556	3143	4555	2.2%	0.96 [0.93 , 0.98]
Player 2010	223	2532	240	3725	1.3%	1.37 [1.15 , 1.63]
Price 2017	17900	18668	5635	5792	2.2%	0.99 [0.98 , 0.99]
Rothschild 2007	546	1350	503	1546	1.8%	1.24 [1.13 , 1.37]
Schnipper 2010	136	2650	143	2865	1.0%	1.03 [0.82 , 1.29]
Schriefer 2009	2	379	1	467	0.0%	2.46 [0.22 , 27.07]
Sequist 2005	643	2924	564	3319	1.8%	1.29 [1.17 , 1.43]
Sequist 2011	143	717	110	610	1.1%	1.11 [0.88 , 1.38]
Sequist 2018a	1535	2020	1522	1927	2.1%	0.96 [0.93 , 1.00]
Sequist 2018b	1212	1893	1203	1851	2.1%	0.99 [0.94 , 1.03]
Silbernagel 2016	100	455	69	434	0.8%	1.38 [1.05 , 1.82]
Smith 2012	247	457	213	454	1.6%	1.15 [1.01 , 1.31]



Analysis 1.2. (Continued)

Silbernagel 2016	100	455	69	434	0.8%	1.38 [1.05 , 1.82]
Smith 2012	247	457	213	454	1.6%	1.15 [1.01 , 1.31]
Strom 2010	111	194	20	148	0.5%	4.23 [2.77 , 6.48]
Tamblyn 2003	4012	4767	3694	4603	2.2%	1.05 [1.03 , 1.07]
Tamblyn 2018a	166	625	126	636	1.2%	1.34 [1.09 , 1.64]
Tamblyn 2018b	200	1289	162	1042	1.2%	1.00 [0.82 , 1.21]
Terrell 2009	2578	2647	2416	2515	2.2%	1.01 [1.00 , 1.02]
Terrell 2010	851	1493	335	1290	1.8%	2.19 [1.98 , 2.43]
Tierney 2003	17	71	20	73	0.3%	0.87 [0.50 , 1.53]
Tierney 2005	26	39	16	24	0.6%	1.00 [0.70 , 1.43]
Van Wyk 2008a	801	1218	275	766	1.8%	1.83 [1.65 , 2.03]
Van Wyk 2008b	385	969	275	766	1.7%	1.11 [0.98 , 1.25]
Zanetti 2003	93	137	55	136	1.0%	1.68 [1.33 , 2.12]
Total (95% CI)		**147511**		**128899**	**100.0%**	**1.16 [1.12 , 1.20]**
Total events:	82306		57900			

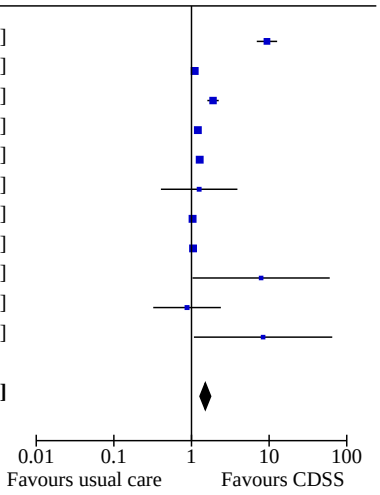
Heterogeneity: Tau² = 0.01; Chi² = 2671.67, df = 63 (P < 0.00001); I² = 98%
Test for overall effect: Z = 8.97 (P < 0.00001)
Test for subgroup differences: Not applicable



Analysis 1.3. Comparison 1: CDSS (+/- co-intervention) vs. Usual care (+/- co-intervention), Outcome 3: Vaccination

	CDSS		Usual care			Risk Ratio	Risk Ratio
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**M-H, Random, 95% CI**
Dexter 2001	425	4995	46	5070	9.6%	9.38 [6.94 , 12.68]	
Fiks 2009	3238	6110	2800	5809	14.7%	1.10 [1.06 , 1.14]	
Frank 2004	333	11947	222	15089	12.7%	1.89 [1.60 , 2.24]	
Loo 2011a	755	1336	903	1930	14.4%	1.21 [1.13 , 1.29]	
Loo 2011b	832	1394	903	1930	14.5%	1.28 [1.20 , 1.36]	
Overhage 1996	7	271	5	243	1.7%	1.26 [0.40 , 3.90]	
Stockwell 2015	2438	3199	2505	3394	14.7%	1.03 [1.00 , 1.06]	
Szilagyi 2015	736	1760	703	1760	14.3%	1.05 [0.97 , 1.13]	
Tierney 2003	10	104	1	82	0.6%	7.88 [1.03 , 60.34]	
Tierney 2005	7	89	7	78	2.1%	0.88 [0.32 , 2.39]	
Trick 2009	8	66	1	69	0.6%	8.36 [1.08 , 65.05]	
Total (95% CI)		**31271**		**35454**	**100.0%**	**1.51 [1.29 , 1.77]**	
Total events:	8789		8096				

Heterogeneity: Tau² = 0.04; Chi² = 327.90, df = 10 (P < 0.00001); I² = 97%
Test for overall effect: Z = 5.07 (P < 0.00001)
Test for subgroup differences: Not applicable



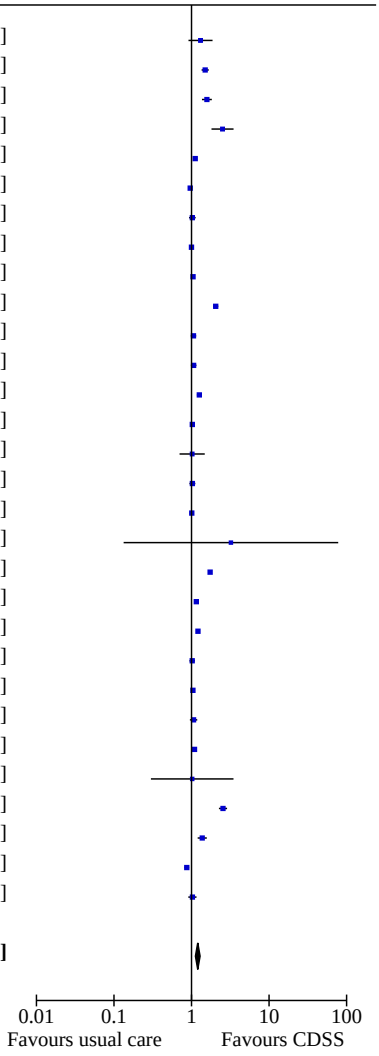
Analysis 1.4. Comparison 1: CDSS (+/- co-intervention) vs. Usual care (+/- co-intervention), Outcome 4: Testing

	CDSS		Usual care			Risk Ratio	Risk Ratio
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**M-H, Random, 95% CI**
Abdel-Kader 2011	57	145	31	103	1.9%	1.31 [0.91 , 1.87]	
Bates 1999	320	437	245	502	3.6%	1.50 [1.35 , 1.67]	
Beste 2015	218	790	366	2094	3.4%	1.58 [1.36 , 1.83]	
Chak 2018	119	1484	48	1503	2.1%	2.51 [1.81 , 3.48]	
Flottorp 2002a	1266	2522	1332	2961	3.9%	1.12 [1.06 , 1.18]	
Flottorp 2002b	2918	5031	1890	3135	3.9%	0.96 [0.93 , 1.00]	
Frank 2004	677	4370	666	4404	3.7%	1.02 [0.93 , 1.13]	
Gill 2009	4195	4672	5286	5880	3.9%	1.00 [0.99 , 1.01]	
Guiriguet 2016	9539	21619	8196	19423	3.9%	1.05 [1.02 , 1.07]	
Kenealy 2005	1434	4509	877	5656	3.8%	2.05 [1.90 , 2.21]	
Lo 2009	689	1685	767	1988	3.8%	1.06 [0.98 , 1.15]	
Loo 2011a	440	758	576	1056	3.7%	1.06 [0.98 , 1.15]	
Loo 2011b	581	845	576	1056	3.8%	1.26 [1.17 , 1.35]	
Martins 2017	613	679	641	727	3.9%	1.02 [0.99 , 1.06]	
Matheny 2008	22	38	25	44	1.8%	1.02 [0.70 , 1.48]	
McGinn 2013	298	374	174	224	3.7%	1.03 [0.94 , 1.12]	
Meigs 2003	269	307	253	291	3.8%	1.01 [0.95 , 1.07]	
Overhage 1996	1	80	0	86	0.0%	3.22 [0.13 , 77.97]	
Overhage 1997	2874	5702	1654	5702	3.9%	1.74 [1.66 , 1.82]	
Palen 2010	703	861	424	599	3.8%	1.15 [1.09 , 1.23]	
Peiris 2015	5196	19385	4281	19340	3.9%	1.21 [1.17 , 1.25]	
Schnipper 2010	616	1284	650	1383	3.8%	1.02 [0.94 , 1.11]	
Sequist 2009	4572	10912	4401	10948	3.9%	1.04 [1.01 , 1.08]	
Sequist 2011	366	717	293	610	3.6%	1.06 [0.95 , 1.19]	
Sequist 2018b	1117	1893	1000	1852	3.9%	1.09 [1.03 , 1.16]	
Tierney 2005	6	97	4	66	0.3%	1.02 [0.30 , 3.48]	
Van Wyk 2008a	701	1079	225	882	3.5%	2.55 [2.26 , 2.87]	
Van Wyk 2008b	438	1249	225	882	3.4%	1.37 [1.20 , 1.57]	
Walker 2010	1370	12925	1476	12098	3.8%	0.87 [0.81 , 0.93]	
Zera 2015	265	471	206	376	3.5%	1.03 [0.91 , 1.16]	
Total (95% CI)		**106920**		**105871**	**100.0%**	**1.20 [1.12 , 1.29]**	
Total events:	41880		36788				

Heterogeneity: Tau² = 0.03; Chi² = 1425.91, df = 29 (P < 0.00001); I² = 98%

Test for overall effect: Z = 5.27 (P < 0.00001)

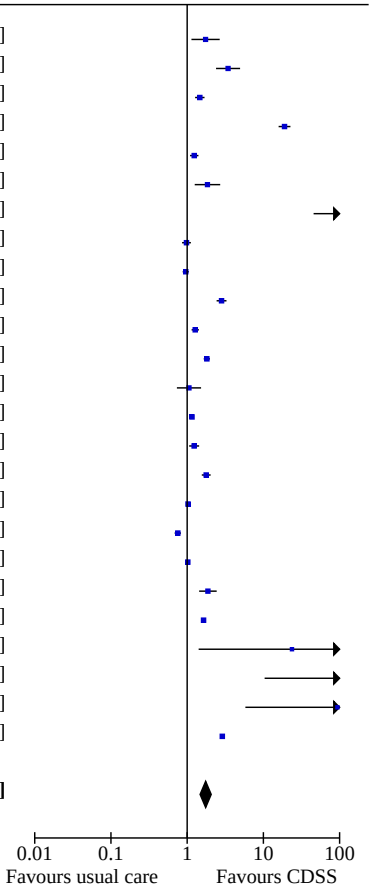
Test for subgroup differences: Not applicable



Analysis 1.5. Comparison 1: CDSS (+/- co-intervention) vs. Usual care (+/- co-intervention), Outcome 5: Documentation

Study or Subgroup	CDSS Events	CDSS Total	Usual care Events	Usual care Total	Weight	Risk Ratio M-H, Random, 95% CI
Abdel-Kader 2011	54	145	22	103	3.8%	1.74 [1.14 , 2.67]
Baer 2013	193	9647	34	5848	4.0%	3.44 [2.39 , 4.95]
Bell 2010	491	926	148	409	4.8%	1.47 [1.27 , 1.69]
Bernstein 2017	2245	5391	122	5548	4.7%	18.94 [15.84 , 22.63]
Co 2010	161	206	130	206	4.9%	1.24 [1.09 , 1.41]
Diaz 2018	24	25	13	25	4.0%	1.85 [1.26 , 2.71]
Diaz 2019	292	468	0	583	0.3%	728.44 [45.58 , 11642.56]
Eccles 2002a	300	1117	334	1218	4.9%	0.98 [0.86 , 1.12]
Eccles 2002b	511	1200	517	1163	4.9%	0.96 [0.87 , 1.05]
Feder 2011	641	70521	236	73347	4.8%	2.82 [2.43 , 3.28]
Frank 2004	654	10476	567	11592	4.9%	1.28 [1.14 , 1.42]
Gupta 2014	991	10991	682	13713	4.9%	1.81 [1.65 , 1.99]
Holt 2010	59	18021	56	18071	4.0%	1.06 [0.73 , 1.52]
Linder 2009-2	34443	64321	31620	68309	5.0%	1.16 [1.14 , 1.17]
Loo 2011a	259	1336	303	1930	4.8%	1.23 [1.06 , 1.44]
Loo 2011b	389	1394	303	1930	4.8%	1.78 [1.56 , 2.03]
Myers 2011a	288	324	317	366	5.0%	1.03 [0.97 , 1.09]
Myers 2011b	177	271	317	366	4.9%	0.75 [0.69 , 0.83]
Peiris 2015	17596	19385	17227	19340	5.0%	1.02 [1.01 , 1.03]
Schnipper 2010	147	6017	85	6511	4.4%	1.87 [1.44 , 2.44]
Stockwell 2015	2179	3199	1409	3394	5.0%	1.64 [1.57 , 1.72]
Taveras 2014	12	194	0	184	0.3%	23.72 [1.41 , 397.73]
Taveras 2015a	87	194	0	184	0.3%	166.03 [10.38 , 2655.98]
Taveras 2015b	43	171	0	184	0.3%	93.58 [5.81 , 1508.27]
Wright 2012	10016	38025	3739	41039	5.0%	2.89 [2.79 , 2.99]
Total (95% CI)		**263965**		**275563**	**100.0%**	**1.75 [1.48 , 2.07]**
Total events:	72252		58181			

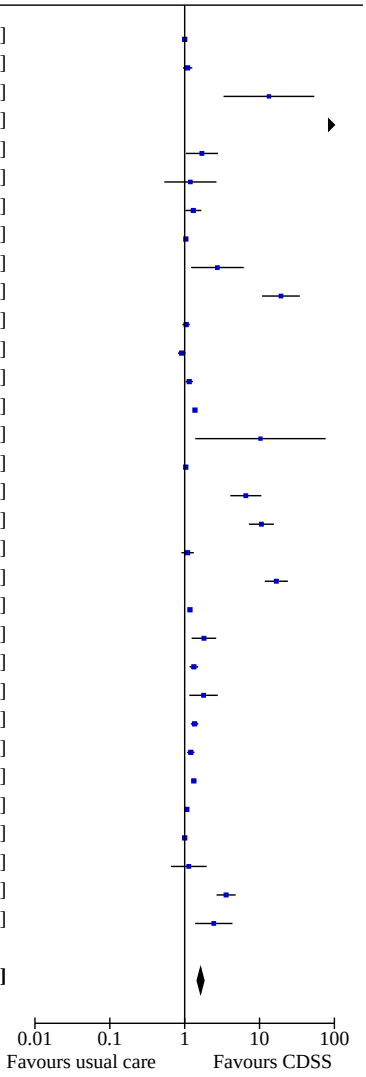
Heterogeneity: Tau² = 0.15; Chi² = 9032.57, df = 24 (P < 0.00001); I² = 100%
Test for overall effect: Z = 6.54 (P < 0.00001)
Test for subgroup differences: Not applicable



Analysis 1.7. Comparison 1: CDSS (+/- co-intervention) vs. Usual care (+/- co-intervention), Outcome 7: Other

Study or Subgroup	CDSS Events	CDSS Total	Usual care Events	Usual care Total	Weight	Risk Ratio M-H, Random, 95% CI
Abdel-Kader 2011	145	145	103	103	4.4%	1.00 [0.98 , 1.02]
Arts 2017	287	522	130	259	4.1%	1.10 [0.95 , 1.27]
Bell 2010	67	464	2	185	0.5%	13.36 [3.31 , 53.95]
Bernstein 2017	1584	5391	0	5548	0.1%	3261.27 [203.95 , 52149.21]
Beste 2015	25	790	39	2094	2.2%	1.70 [1.04 , 2.79]
Boustani 2012	9	40	10	53	1.2%	1.19 [0.54 , 2.66]
Co 2010	90	206	69	206	3.6%	1.30 [1.02 , 1.67]
Dean 2015	686	817	509	628	4.4%	1.04 [0.99 , 1.09]
Downs 2006	32	107	6	55	1.2%	2.74 [1.22 , 6.16]
Feder 2011	223	70521	12	73347	1.9%	19.33 [10.81 , 34.55]
Flottorp 2002a	458	2318	533	2822	4.2%	1.05 [0.94 , 1.17]
Flottorp 2002b	612	4751	417	2956	4.2%	0.91 [0.81 , 1.03]
Gill 2009	394	1470	477	2047	4.2%	1.15 [1.02 , 1.29]
Goud 2009	1411	1610	709	1110	4.4%	1.37 [1.31 , 1.44]
Gupta 2014	11	46	1	43	0.3%	10.28 [1.39 , 76.32]
Karlsson 2018	5734	7861	4346	6156	4.4%	1.03 [1.01 , 1.06]
Kucher 2005	125	1255	19	1251	2.3%	6.56 [4.07 , 10.56]
Linder 2009-2	235	5292	29	6915	2.8%	10.59 [7.21 , 15.55]
McCowan 2001	77	147	158	330	3.9%	1.09 [0.90 , 1.32]
Mertens 2015	1381	3108	30	1132	2.9%	16.77 [11.75 , 23.92]
Peiris 2015	12164	19385	10317	19340	4.4%	1.18 [1.16 , 1.20]
Player 2010	59	2532	48	3725	2.8%	1.81 [1.24 , 2.64]
Safran 1995	162	191	101	158	4.2%	1.33 [1.16 , 1.51]
Schriefer 2009	45	379	31	467	2.5%	1.79 [1.16 , 2.77]
Sequist 2005	556	2924	465	3319	4.2%	1.36 [1.21 , 1.52]
Sequist 2009	650	10912	540	10948	4.2%	1.21 [1.08 , 1.35]
Sequist 2018a	909	2020	655	1927	4.3%	1.32 [1.22 , 1.43]
Smith 2012	375	457	349	454	4.4%	1.07 [1.00 , 1.14]
Spirk 2017	536	804	526	789	4.4%	1.00 [0.93 , 1.07]
Tamblyn 2010	27	1166	23	1127	2.0%	1.13 [0.65 , 1.97]
Tang 2012	163	958	55	1156	3.3%	3.58 [2.67 , 4.80]
Wu 2018	42	467	15	408	1.9%	2.45 [1.38 , 4.34]
Total (95% CI)		**149056**		**151058**	**100.0%**	**1.63 [1.47 , 1.81]**
Total events:	29274		20724			

Heterogeneity: Tau² = 0.06; Chi² = 2187.00, df = 31 (P < 0.00001); I² = 99%
Test for overall effect: Z = 9.16 (P < 0.00001)
Test for subgroup differences: Not applicable



ADDITIONAL TABLES

Table 1. Median improvements in process adherence across included studies

Dichotomous outcomes (number of intervention vs. control comparisons)	Median absolute improvement (Interquartile range)	
	Using median outcome from each study	Using best outcome from each study
All process outcomes	4.2%	5.6%
(N = 32)	(0.8% to 18.8%)	(2.0% to 19.2%)
Prescription of medications	3.30%	6.2%

Table 1. Median improvements in process adherence across included studies *(Continued)*

(N = 21)	(0.5% to 10.6%)	(3.0% to 28.0%)
Prescription of recommended vaccines	3.8%	4.8%
(N = 6)	(0.5% to 6.6%)	(0.5% to 7.8%)
Test ordering	3.8%	9.6%
(N = 13)	(0.4% to 16.30%)	(0.6% to 24.0%)
Elements of recommended documentation	0.0%	2.0%
(N = 3)	(-1.0% to 1.3%)	(2.0% to 4.0%)
Other process outcomes	1.0%	4.0%
(N = 7)	(0.8% to 8.5%)	(0.8% to 8.5%)

The Table shows average improvements (expressed as the median and interquartile range) across included comparisons for different types of process outcomes. All process outcomes were defined so that higher values always represent an improvement. For example, data from a study aimed at reducing the percentage of patients receiving inappropriate medications would be captured as the complementary percentage of patients receiving appropriate medications, so that an increase in process adherence would represent an improvement. Most studies reported multiple endpoints but did not specify a primary outcome. For the main analyses, we used the median improvement from each study (that is the median change in adherence to a target guideline or process of care across all such changes reported for the study) as the single representative outcome for that study. We then calculated the median improvements across all included studies for different types of process measures, as shown in the middle column of the table. The column to the far right presents the same results when we used the best improvement from each study as its representative outcome.

APPENDICES

Appendix 1. MEDLINE search strategy

Strategy 1 (OVID)

1 "Forms and Records Control"/
2 exp "Appointments and Schedules"/
3 Medical Records Systems, Computerized/
4 exp Decision Making, Computer-Assisted/
5 exp Artificial Intelligence/
6 or/1-5
7 Reminder Systems/
8 (reminder$ or prompt$ or cue).tw.
9 or/7-8
10 6 and 9
11 7 or 10
12 computer$.tw,hw.
13 11 and 12
14 (computer$ adj3 reminder$).tw.
15 or/13-14
16 randomized controlled trial.pt.
17 controlled clinical trial.pt.
18 randomized controlled trials/
19 random allocation/
20 double blind method/
21 single blind method/
22 clinical trial.pt.
23 exp clinical trials/
24 (clinical adj trial?).tw.
25 ((singl$ or doubl$ or trebl$ or tripl$) adj25 (blind$ or mask$)).tw.

26 (random$ or placebo?).tw.
27 or/16-26
28 animal/
29 human/
30 28 not (28 and 29)
31 27 not 30
32 15 and 31

Strategy 2 (PubMed)

#1 Search Ambulatory Care Information Systems [mh] OR Point-of-Care Systems [mh] OR Medical Order Entry Systems [mh] OR decision support systems, clinical [mh] OR drug therapy, computer-assisted [mh] OR Medical Records Systems, Computerized [mh] OR Reminder Systems [mh] OR ((computer* [ti] OR electronic [ti]) AND (decision* [ti] OR support [ti] OR order* [ti] OR entry [ti] OR reminder* [ti] or prompt* [ti] or cue* [ti] OR alert* [ti]))
#2 Search ((Randomised [ti] OR Randomized [ti] OR Controlled [ti] OR intervention [ti] OR evaluation [ti] OR Comparative [ti] OR effectiveness [ti] OR Evaluation [ti] OR Feasibility [ti]) AND (trial [ti] OR Studies [ti] OR study [ti] OR Program [ti] OR Design [ti])) OR Clinical Trial [pt] OR Randomized Controlled Trial [pt]
#3 Search #1 and #2, Limits: English

Appendix 2. EPOC Register search strategy

[limit to RCT and CCT, 2005 -]

((reminder* or prompt* or cue*) and (computer* or on-screen))

Appendix 3. CINAHL search strategy

1 exp Medical Records/
2 ((form? or record?) adj (medical or control)).tw.
3 "Appointments and Schedules"/
4 exp Patient Records Systems/
5 exp Decision Making, Computer-Assisted/
6 exp Artificial Intelligence/
7 artificial intelligence.tw.
8 natural language processing.tw.
9 or/1-8
10 Reminder System/
11 (reminder$ or prompt$ or cue).tw.
12 or/10-11
13 9 and 12
14 10 or 13
15 computer$.tw,hw.
16 14 and 15
17 (computer$ adj3 reminder$).tw.
18 16 or 17
19 exp clinical trials/
20 comparative studies/
21 (clinical adj trial?).tw.
22 (random$ or placebo?).tw.
23 ((singl$ or doubl$ or trebl$ or tripl$) adj25 (blind$ or mask$)).tw.
24 exp quasi-experimental studies/
25 or/19-24
26 18 and 25

Appendix 4. EMBASE search strategy

1 Medical Record/
2 ((form? or record?) adj (medical or control)).tw.
3 (patient? adj3 (schedul$ or appointment?)).tw.
4 (computer$ adj (medical or record?)).tw.
5 Computer Analysis/
6 (decision? adj2 computer-assisted).tw.
7 exp Artificial Intelligence/
8 artificial intelligence.tw.
9 natural language processing.tw.

10 or/1-9
11 Reminder System/
12 (reminder$ or prompt$ or cue).tw.
13 or/11-12
14 10 and 13
15 11 or 14
16 computer$.tw,hw.
17 15 and 16
18 (computer$ adj3 reminder$).tw.
19 17 or 18
20 Randomized Controlled Trial/
21 (random$ or placebo?).tw.
22 clinical trial/
23 (clinical adj trial?).tw.
24 ((singl$ or doubl$ or trebl$ or tripl$) adj25 (blind$ or mask$)).tw.
25 or/20-24
26 19 and 25

WHAT'S NEW

Date	Event	Description
15 June 2021	Review declared as stable	A related systematic review was published in September 2020 (https://doi.org/10.1136/bmj.m3216) and consequently there are no current plans to update this Cochrane Review.

HISTORY

Protocol first published: Issue 2, 1998
Review first published: Issue 3, 2009

Date	Event	Description
7 December 2010	Amended	Minor typo change to title
11 November 2009	Amended	Minor changes to figures

CONTRIBUTIONS OF AUTHORS

KS led the project, including preparing the data abstraction form, screening and dealing with consensus issues, and led the analysis.

AJ participated in screening, data extraction and data analysis.

AM participated in data extraction and screening.

CRR provided support for the analysis.

MPE provided input into overall structure of the review.

JG was involved in the protocol publication and also provided input into the overall structure of the review.

DECLARATIONS OF INTEREST

ME and JG are authors on one included study and three excluded studies in this review. Four authors (AM, ME, CRR, JG) are editors or staff within the Cochrane EPOC Review Group. Editors and staff are required to conduct at least one Cochrane review. This requirement ensures that editors are aware of the processes and commitment needed to conduct reviews. This involvement does not seem to be a source of

conflict of interest in the Cochrane EPOC Review Group. Any editor or staff who is a review author is excluded from editorial decisions on the review in which they are contributors.

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Internal sources

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- Canadian Institutes of Health Research, Canada
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- CIHR Institute of Musculoskeletal Health and Arthritis, Canada
- CIHR Institute of Gender and Health, Canada
- CIHR Institute of Human Development, Child and Youth Health, Canada
- CIHR Institute of Nutrition, Metabolism and Diabetes, Canada
- CIHR Institute of Infection and Immunity, Canada
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INDEX TERMS

Medical Subject Headings (MeSH)

Decision Making, Computer-Assisted; *Decision Support Systems, Clinical; *Outcome and Process Assessment, Health Care; *Point-of-Care Systems; *Reminder Systems

MeSH check words

Humans