BMJ Health & Care Informatics

Interventions to improve the use of EMRs in primary health care: a systematic review and meta-analysis

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To cite: Hamade N, Terry A, Malvankar-Mehta M. Interventions to improve the use of EMRs in primary health care: a systematic review and meta-analysis. *BMJ Health & Care Informatics* 2019;**26**:e000023. doi:10.1136/bmjhci-2019-000023

Received 05 December 2018
Revised 08 March 2019
Accepted 23 March 2019

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ABSTRACT

Background Electronic medical record (EMR) adoption in primary care has grown exponentially since their introduction in the 1970s. However, without their proper *use* benefits cannot be achieved. This includes: 1) the complete and safe documentation of patient information; 2) improved coordination of care; 3) reduced errors and 4) more involved patients. The *use* of EMRs is defined by practitioners using EMRs and their features to perform daily practice functions.

Objective The purpose of this systematic review was to identify interventions aimed at improving EMR use in primary healthcare settings.

Methods Ten online databases were searched to identify studies conducted in primary healthcare settings aimed at implementing interventions to observe the use of EMRs and directly measure the use of EMR functions or outcomes effected by the use of EMR functions.

Results Of 2098 identified studies, 12 were included in the review. Results showed that interventions focused on the use of EMR functions, including referrals, electronic communication, reminders, use of clinical decision support systems and workflow management support functions, were five times more likely to show improvements in EMR use compared with controls. Interventions focused on data quality were five and a half times more likely to show improvements in EMR use compared with controls.

Conclusions Individuals in primary healthcare settings aiming to improve EMR use would benefit from implementing interventions focused on EMR feature add-ons such as clinical decision support systems and customised referral templates, and provisions of educational materials, or financial incentives targeted at improving the use of EMR functions and data quality.

Summary

What is already known?

- The electronic medical record (EMR) system was developed originally in the early 1970's as a means to store patient health information. Over time, and with the improvements in technology, EMRs are now capable of using stored patient health information to assist in the daily care provisions primary health care personnel provide to patients. This is done with the hopes of improving patient health care through creating higher quality patient data and improving primary health care center processes.
- However, whether EMR use has been successful in improving the provision of patient care has not been made clear in the literature. Due to the importance of improving the use of EMRs with regard to patient outcomes, there has been recent interest on the part of organizations and governments to provide guidelines to improve EMR use. Improving EMR use requires targeted interventions aimed at the areas in which EMRs were created to function. There have only been a few studies in the literature that have been aimed at studying the effect of certain types of intervention on EMR use.

What does this paper add?

- However, due to the high heterogeneity between those studies a meaningful meta-analysis was not feasible until this point where the synthesis of the results was possible through: the categorization of interventions using the EPOC taxonomy of interventions and the identification of possible intervention target areas to improve EMR use. This allowed for the meaningful grouping of the studies resulting in the ability to conduct the first meta-analysis in this field. This increases the power of the results and conclusions drawn from those results giving us a better understanding of the types of interventions that could be used to improve the use of EMRs.

INTRODUCTION

The past few decades have seen an expansion in the role of technology in healthcare reflected in the introduction of information technologies into the healthcare system. Electronic medical records (EMRs) are one form of information technology which can impact patient health outcomes.[1 2] EMRs are computerised patient records introduced in the early 1970s as a way to organise, secure, complete and improve the quality of patient healthcare records.[3] Around the turn of the century, EMRs gained attention because of the perceived and expected benefits they could offer the healthcare system which included: organisation of patient healthcare information, improving coordination of care as well as easier electronic access to medical information and expert opinion.[4 5] With their creation and introduction into primary

healthcare, EMRs were expected to have a positive impact on the quality of healthcare. This was expected to be realised through the use of EMRs to improve data quality through the recording of patient information and perform primary healthcare functions. This drove organisations and governments to create programme to promote the adoption of EMRs into the healthcare system.[4]

The distinction between EMR adoption and use is not clearly defined in the literature. However, for the purposes of this review, *adoption* of EMRs is defined as simply the introduction of EMRs into primary healthcare practice. The *use* of EMRs is the second step following adoption, involving practitioners using EMRs and their features to perform daily primary healthcare practice functions. A national survey in 2015 showed that the adoption of EMRs into primary healthcare practices is on the rise in Canada while EMR use is still low in comparison.[6 7] The US Centers for Medicare and Medicaid Services (CMS) defined meaningful use as: 'Using (EMRs) to: improve quality, safety, efficiency, and reduce health disparities. Engage patients and family. Improve care coordination, and population and public health. Maintain privacy and security of patient health information'.[8] For the purposes of this review, improved EMR use is defined as using EMRs according to the above definition. Some studies suggest that to achieve noticeable improvements in patient health outcomes following adoption, improving the use of EMRs is necessary.[9–12] Therefore, improving the use of EMRs to achieve desirable health outcomes has attracted recent attention.[13] The mechanisms to improving EMR use however, have not yet been determined. Therefore, this systematic review aims to review the literature to identify interventions and their effect on improving EMR use in primary healthcare settings in hopes of bridging the gap between adoption and use of EMRs.

METHODS

Search strategy

The search strategy was developed with limits to only include studies with human subjects conducted after 1970, the following databases were searched: MEDLINE Ovid, EMBASE Ovid, CINAHL, Cochrane Library and Web of Science. The grey literature was also searched through the following databases: Clinical Trials, NDLTD, CADTH, International Clinical Trials Registry, AHRQ. Finally, after applying the search strategy to all the mentioned databases and collecting the identified studies, snowballing was used as a supplementary search strategy. The full search strategy for all databases is listed in online supplementary appendix A.

Inclusion criteria

Research articles conducted after 1970 and published in the English language regardless of the location of the study. In addition, the following eligibility criteria were used to identify studies for inclusion:

1. *Study focus*: included studies were those that specifically focused on actual use of EMRs in primary healthcare, not simply earlier stages of implementation.
2. *Intervention*: studies with a clear intervention that was implemented or observed for the purpose of studying use or use patterns of EMRs were included.
3. *Setting*: included studies were only those conducted in a primary healthcare setting.
4. *Outcome of interest*: included studies had to have an outcome of interest related to measurements of use of EMR functions (number of uses, duration of use) as well as outcomes effected by EMR use such as number of referrals and completeness of patient records.

No restrictions based on study design or comparator groups were used. Opinion pieces, editorials and publications without an abstract were excluded, along with conference abstracts. After conducting the database searches, EPPI Reviewer V.4.0 (by EPPI-Centre, Social Science Research Unit, the Institute of Education, the University of London, UK) was used to automatically remove duplicates; subsequently, a manual search was conducted to remove any missed duplicates.[14] The abstracts were screened independently by two reviewers, NH and MH, based on a list of screening questions derived from the eligibility criteria described above. Two reviewers, NH and AT, then independently conducted the full-text screening of the included studies. All screening questions are listed in online supplementary appendix B.

Data extraction

The first author's name, year of the study and setting (location and country) were extracted to be used as study citation information. Information on the study population and participant composition was also extracted. In addition, extracted from each study were: intervention name, intervention type and a brief description of the intervention. In terms of outcomes, the outcome measured and a description of the outcome were also extracted. Lastly, information was extracted to allow for assessment of individual study bias.

Details of study interventions

A system was adopted in this review to categorise the wide variety of possible interventions that could be implemented to improve EMR use. Interventions for this systematic review were categorised using the Effective Practice and Organisation of Care (EPOC) taxonomy of interventions, which was published in the Cochrane Review by the EPOC Group in 2015.[15] Interventions included in this review were placed into one of the following categories and are shown in figure 1:

1. *Professional interventions*: defined by EPOC as an intervention implemented with the goal of educating or furthering the knowledge of the target group in a specific area with the purpose of creating change.
2. *Organisational interventions*: defined by EPOC as interventions that target workflow, as well as those that create changes in an organisation's framework. There-

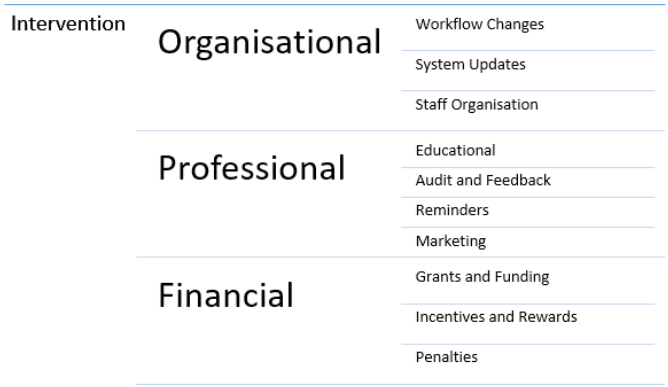

Figure 1 Possible categories of interventions identified in this review. Recreated from: Effective Practice and Organisation of Care (EPOC), EPOC taxonomy, 2015. Available at: https://epoc.cochrane.org/epoc-taxonomy

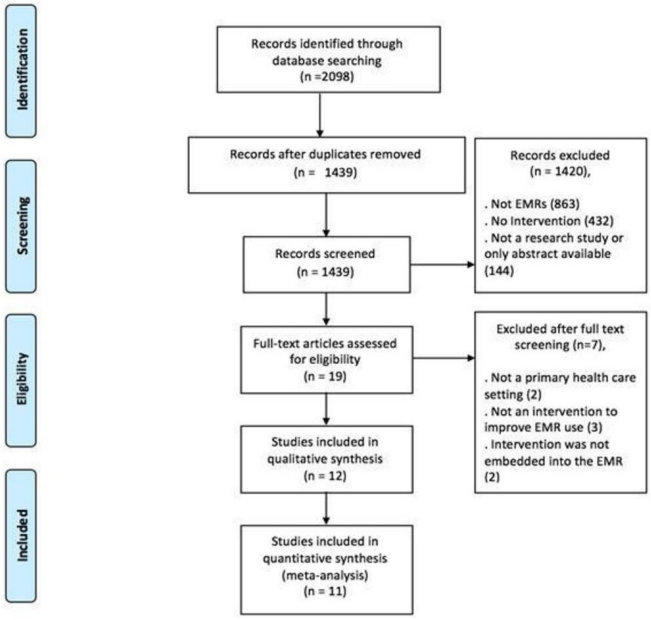

Figure 2 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart of study selection. EMR, electronic medical record.

fore, included are any interventions that cause changes to the workflow of the primary healthcare practice through the healthcare professionals or structurally through changes to the EMR such as feature add-ons would be included.

3. *Financial interventions*: according to the EPOC definition, interventions were considered to be financial interventions if they provided an incentive for action.

Intervention target areas

This study is the first of its kind in this area of research (the first meta-analysis to study the effect of interventions on the use of EMRs). Outcomes for this study were grouped into target areas identified from the definition of EMR use which focuses on the importance of practitioners using EMRs and their features to carry out daily practice function and to maintain a level of patient record quality. These outcomes were measured in a similar population with similar interventions at similar settings and due to those similarities were grouped into target areas using a technique aimed at combining units of the outcomes.[16 17] This technique has been used to group complex interventions in the literature and was adopted to be used in this review.[17 18] For the purposes of this study, the areas targeted for change were called *target areas* and were made up of the identified units based on the defined purpose of EMRs to create a logical and meaningful way to group the complex outcomes identified from the included studies. Two target areas were identified in the included studies:

1. *Use of EMR functions*: describes the use of EMR functions directly in relation to duration and frequency of use. Examples of the functions include referrals, electronic communication, reminders triggered, use of clinical decision support systems as well as workflow management support functions.
2. *Data quality*: studies that described the level of data completeness for basic patient information including diagnostic, laboratory and prescription management information were included in this group.

The outcomes presented in the included studies were grouped by the target area of the intervention into either: 1) use of EMR functions or 2) data quality.

Statistical analysis

Using the above target areas as a guide, the effect sizes from individual studies were combined to create a summary effect size. Studies in which the interventions were aimed at the use of EMR functions all measured the use of those functions through reporting durations and frequency of use allowing for a meaningful summary effect estimate to be created. Similarly, studies with interventions aimed at improving data quality all described the levels of patient data completeness and were therefore grouped to create a single summary effect size. The outcome measures in each individual study were transformed into ORs to be included in the analysis using the data presented by the studies to generate 2-by-2 tables. Studies with multiple outcomes related to the same intervention target area were combined to be included into the analysis. Following that, the studies were separated by intervention target area into two different forest plots to create a meaningful meta-analysis. The statistical analysis including forest and funnel plots was completed using STATA V.13.0 (STATA, College Station, Texas, USA).[19] All results were presented in forest plots and expressed in log-ORs because of the categorical nature of the outcomes of interest, using 95% CIs. Frequencies of outcomes along with the total number of participants were extracted. Some studies presented outcomes using regression coefficients. In this case, these coefficients were converted to ORs using the ln function.[20] In addition, the ORs of the included studies were presented with their SEs in funnel plots to assess publication bias.

The random-effects model was used to conduct the meta-analysis due to its ability to account for in between study variation that arises from differences in study target population,

study intervention and presentation of outcomes. It does that by assuming the true effect estimate varies between studies. Therefore, the random-effects model using the DerSimonian and Laird methods was used in STATA to create the forest plots.[21]

Risk of bias assessment

The Downs and Black tool was used to assesses risk of bias for individual studies included in this review. It is made up of 27 questions divided into subsections based on reporting, external validity, internal validity (bias and confounding) and power.[22] The breakdown of the four subsections and a brief explanation of their importance are listed in online supplementary appendix C. The Downs and Black assessment scale was applied to the selected studies to determine the reliability, validity and power of the study. The Downs and Black checklist for bias assessment is presented in online supplementary appendix D. Scores were then calculated and combined into a risk of bias bar graph, as suggested by the Cochrane Handbook for Systematic Reviews, used to indicate the level of bias in each study.[16]

RESULTS

After searching the databases in October 2015, 2098 abstracts were identified. From these 2098 abstracts, 659 duplicates were removed. This left 1439 titles for abstract screening. Following abstract screening, 19 studies were identified for full-text screening. Full-text screening was performed on the 19 retrieved studies. Twelve were identified that fit the previously specified inclusion criteria.[23–34] The PreferredReporting Items for Systematic Reviews and Meta-Analyses flow chart was used to map out the study selection process as shown in figure 2. [35]All 12 studies identified in this review were identified from initial electronic database screening.

Study characteristics

Of the identified studies more than half (n=7) were conducted in the USA.[23 26–28 30 31 33] The remaining five were set in the UK (n=2),[24 25] Finland (n=2)[29 34] and Canada (n=1).[32] All the included studies were conducted in a primary healthcare setting. In terms of study population size, the 12 included studies targeted 1564 primary care providers in 132 primary healthcare practices and included 578 071 patients. The characteristics of the included studies and the target population are listed in table 1. Of the 12 included studies, 4 were classified as purely organisational interventions[27–30] and 5 were classified as professional interventions.[23 24 32 34] The remaining three studies implemented mixed interventions, including at least two of the following: organisational, professional and financial.[24 30 33] The studies, interventions and a brief description are listed in table 2. Eight of the included studies reported on the use of EMR functions, a more in-depth description of the EMR function and the outcome reported, along with an outcome measurement description is presented in table 3. All the studies in the data quality group focused on the effect of an intervention on improving the recorded data using an EMR.[24–27 30 33 34] The completeness and accuracy of patient information are some of the markers used to measure data quality and were the areas most targeted by the included studies.[35] A more in-depth description of the data quality area reported on and the outcome along with an outcome measurement description is presented in table 4.

The study by de Lusignan *et al*[24] was excluded from the meta-analysis because the results of the study were presented using regression coefficients and were not consistent with the other included studies.[24] In addition, Kruse *et al*[30] did not present preintervention scores and was therefore excluded from the meta-analysis.[31] All other studies included in the analysis presented enough data to calculate ORs and SEs to assess publication bias.

Two forest plots were generated by STATA using the ORs. The first forest plot represents studies focused on the *use of EMR functions* as the intervention target area, displayed in figure 3. The overall effect estimate was a significant log-odds of 1.66 (95% CI 1.43 to 1.88; absolute OR=$e^{1.66}$=5.26, rounded to 5). Therefore, personal, organisational and financial interventions directed at the use of EMR functions had a significant and favourable effect on improving EMR use. More specifically, interventions targeted at the use of EMR functions were five times more likely to show improvements in EMR use compared with the controls (figure 3). The second forest plot represents studies focused on *data quality* as the intervention target area and is presented in figure 4. All the studies depicted in this forest plot favoured the intervention. The overall effect estimate was a significant log-odds of 1.71 (95% CI 0.01 to 3.41; absolute OR=$e^{1.71}$=5.53, rounded to 5.5). Therefore, personal, organisational and financial interventions directed at data quality had a significant and favourable effect on improving EMR use five and a half times more than the controls.

To evaluate the publication bias, two separate funnel plots for the use of EMR functions and data quality were produced using STATA (see figures 5 and 6, respectively) and then visually assessed for symmetry. Both funnel plots showed that studies were clustered at the top with only one each at the base of the funnel plot. This asymmetry in the funnel plot could be the result of publication bias. However, due to the small number of studies it is difficult to confidently exclude the presence of publication bias.

The risk of bias for individual studies showed a high reporting of results scores and low internal validity scores. The mean score for risk of bias in individual studies is 64% with an IQR of 60%. This shows a moderate risk of bias in the included studies as expressed in figure 7.

DISCUSSION

The systematic review and meta-analysis were conducted to identify possible interventions focused on improving EMR use in primary healthcare settings. This review indicates that significant improvements in EMR use can be realised in primary healthcare settings where

Table 1 Study characteristics

Author	Setting	Study design	Number of Primary Care Providers (PCPs)	Composition	Number of patients
Jerome *et al*[40]	1 primary healthcare centre Country: USA	Prospective observational	137	Attending and resident physicians	*
de Lusignan *et al*[23]	*Primary healthcare centres Country: UK	Retrospective observational	576	*	*
de Lusignan *et al*[24]	84 primary healthcare centres Country: UK	Quasi-experimental	252	84 physicians 84 nurses 84 managers	~20 000 19 470 preintervention 19 784 postintervention
Pan *et al*[25]	2 family medicine residency training clinics Country: USA	Quasi-experimental	8	4 certified medical assistants 4 nurses	525 patients 279 preintervention 246 postintervention
Baer *et al*[26]	5 primary healthcare centres Country: USA	Quasi-experimental	*	*	15 495
Mavigilia *et al*[27]	18 outpatient clinics Country: USA	Quasi-experimental	359	187 physicians 108 nurses 64 other	413 417
Kortteisto *et al*[28]	1 primary healthcare centre Country: Finland	Randomised controlled trial	48	15 physicians 24 nurses 9 other	13 588
Nemeth *et al*[29]	8 primary healthcare centres Country: USA	Mixed methods	74	*	66 104
Kruse *et al*[30]	2 primary healthcare centres Country: USA	Mixed methods	36	21 physicians 3 nurses 12 physician trainees	2894
Maddocks *et al*[31]	9 primary healthcare centres Country: Canada	Randomised controlled trial	24	Physicians	23 688
Davis *et al*[32]	1 primary healthcare centre Country: USA	Retrospective observational	36	Residents	360 patients 180 preintervention 180 postintervention
Sweeney *et al*[33]	1 primary healthcare centre Country: Ireland	Randomised controlled trial	16	10 physicians 6 nurses	22 000

*Represent missing data.

interventions targeting the use of EMR functions or data quality have been implemented. However, due to the possibility of publication bias, these results should be interpreted with caution. The findings of this review draw attention to four main themes in this area of study. Those themes are listed and discussed below.

Number of identified studies

In this review, only 12 studies of interventions focused on improving EMR use in primary healthcare were identified. Primary healthcare settings directly influence the majority of Canadians' health outcomes.[36] The importance of a well-functioning primary healthcare system was not reflected in the literature. Compared with the impact of this area on the health of the general population, the number of identified studies is surprisingly lacking. The deficiency in studies in the area of EMR use is possibly due to the focus in the field being on the adoption of EMRs. Even though studies have shown that adoption alone is not enough to access the EMR's full potential, the shift to focus on improving EMR use is slow.[8 11 12 36] In conclusion, one of the main hopes of this review is to draw attention to this gap in the literature. There should be a greater focus in the area of studies that can connect EMR availability to positive patient outcomes through improving EMR use with targeted interventions.

Lack of consistency

The area of EMR use is deficient in terms of available literature, and in the usability of this literature due to its lack of consistency in the information provided. Studies on the topic of EMR use vary in terms of interventions and approaches to assessing EMR use. Due to this being a relatively new field of study, there has been no standardisation

Table 2 Interventions and intervention description

Author	Intervention	Intervention description
Baer *et al*[26]	Organisational intervention: web-based appraisal tool	► Web-based appraisal tool used to generate reminders with the help of an electronic decision support system. ► Self-administered by patients to collect family history information.
Mavigilia *et al*[27]	Organisational intervention: KnowledgeLink	► A medication 'look-up' button. ► Allowed physicians with questions about a patient's medication to access that information with one click from the EMR.
Kortteisto *et al*[28]	Organisational intervention: computer-based decision support system EBMeDS	► The EBMeDS collects diagnosis information entered in the EMR and runs it against studies done on the base population generating reminders pertaining to treatment triggered by the data. ► Presented reminders triggered by accessing the EMR.
Kruse *et al*[30]	Organisational intervention: electronic one-click referral button to tobacco use control centre	► Clicking the button sends an automatically generated email to the internal tobacco care coordinator (TTC) centre.
Jerome *et al*[40]	Professional intervention: focus groups driven by customised educational strategies	► The EBM worked to directly link evidence expertise to the clinical work flow facilitating easy and direct communication. ► The EBM was marketed to clinicians at the start of the study. ► A focus group was conducted at the midway point of the study to discuss strategies to improve use and visibility of the Evidence-Based Medicine (EMB) feature.
de Lusignan *et al*[24]	Professional Intervention: Primary Care Data Quality (PCDQ) Programme	► An educational intervention that targeted primary healthcare providers to improve data recording while monitoring and assessing data quality. 1. Three-step intervention:1 hour introductory meeting at baseline. 2. Every 6 months workshops that lasted 2–3 hours were held. 3. The PCDQ included a Morbidity, Information Query and Export System (MIQUEST) programme. which extracted data to be used in the workshops and produced guidelines on how to code information in the EMR.
Pan *et al*[25]	Professional intervention: feedback and education	► First a focus group to get a better understanding of EMR use to appropriate data entry was conducted. 1. Using the focus group data, a 5-component intervention to improve EMR data entry was developed:Motivational feedback; 2. Academic detailing: a personalised educational programme, which highlighted the importance of recording patient information; 3. Improved efficiency of data entry: training on how to correctly use EMR data entry templates; 4. Post-test feedback; 5. Awards based on aggregate improvement in data entry.
Maddocks *et al*[31]	Professional intervention: 2-hour educational session	► Hands-on training to teach physicians how to manipulate the EMR to generate a list of patients eligible for preventive testing. ► Provided was also an instructional material tool kit. ► Feedback on current levels of preventive care in Ontario were provided for comparison.
Sweeney *et al*[33]	Professional intervention: data management strategy	► Provided information and training on data recording to create protected, logical and unified levels of coded patient information. ► Coding was then monitored to provide feedback to primary healthcare providers and management reports.
de Lusignan *et al*[24]	Mixed interventions: feedback of data quality markers and financial incentives	► 10 data quality markers were examined for completion, calculated and feedback to the physicians every 3 months to determine if feedback caused an improvement in data quality. ► A small financial incentive was also given to physicians to reach intended levels of quality scores.
Nemeth *et al*[29]	Mixed interventions: electronic standing orders provided by a customised health template	► Customised health maintenance template that provided authorisation to healthcare personnel to carry out medical orders for screening, immunisation and diabetes measures. ► An introductory meeting was conducted explaining the project and guiding participates in using the electronic Standing Orders (SOs) in their primary healthcare practices.
Davis *et al*[32]	Mixed interventions: asthma template along with lectures and tutorials	► Mandatory lecture guidelines for use of the asthma template for proper documentation. ► Reminders to stress the importance of the template use were also posted in patient care areas and on PowerPoint slides before meetings.

Table 3 Outcome measurement description of studies reporting on the use of EMR functions

Author	Outcome	EMR feature	Outcome measurement description
Jerome *et al*[40]	Per cent change in use of EBM literature request	Decision support	▶ Change was measured by obtaining number of literature requests by healthcare providers.
Baer *et al*[26]	Per cent of new EMR generated reminders on colon and breast cancer screening	Decision support	▶ Data entered into the EMR was saved in a firewall-protected server to be used in the study. ▶ Participants were also contacted by phone for an interview.
Mavigilia *et al*[27]	Frequency of use of KnowledgeLink	Decision support	▶ Participants were emailed an online questionnaire after every incident of use of the KnowledgeLink feature along with a more extensive questionnaire at the end of the study. ▶ Data on use was collected by analysing search logs or through patient consent.
Kortteisto *et al*[28]	Change in number of reminders triggered	Alerts and reminders	▶ Reminders were triggered automatically on use. ▶ The EMR system was used to calculate the number of reminders triggered.
Nemeth *et al*[29]	Per cent of nurses and nursing staff using the health maintenance template	Health template	▶ Primary healthcare practices submitted the EMR data electronically on a quarterly basis to the Practice Partner Net. ▶ Data were then used to measure the use of the Health Maintenance Template.
Kruse *et al*[30]	Per cent of referrals through EMR to tobacco use control centre	Exchange of patient healthcare information	▶ Measured through access to EMR records and Tobacco Treatment Coordinator centres.
Maddocks *et al*[31]	Change in provided preventive care testing	Exchange of patient healthcare information	▶ The rate of patients tested was calculated by dividing the number of patients that visit the primary healthcare centres by the number of patients tested per year.
Davis *et al* [32]	Per cent use of asthma template	Health template	▶ Preintervention data were collected by retrospectively reviewing patient records, while post intervention data were collected through a chart review of the patients with asthma seen by residents.

EMR, electronic medical record.

Table 4 Outcome measurement description of studies reporting on data quality

Author	Outcome	Data quality area	Outcome measurement description
de Lusignan *et al*[23]	Change over time in the score of 10 data quality markers	10 data quality markers	▶ Mean quality marker scores were calculated for each general practitioner by year in which they joined the Mediplus Database.
de Lusignan *et al*[24]	Per cent change of completed patient records in blood pressure, cholesterol, smoking habits and patients asked to stop smoking	Completeness of patient information	▶ Data on coding were collected at review meetings throughout the study.
Pan *et al*[25]	Per cent of new patient height, weight and blood pressure records that were complete	Completeness of patient information	▶ Data were collecting through the examination of the EMR of all patients included in the study.
Baer *et al*[26]	Per cent of new coded patient data of family history of cancer	Completeness of patient information	▶ Data entered into the EMR were saved in a firewall-protected server to be used in the study. ▶ Participants were also contacted by phone for an interview.
Nemeth *et al*[29]	Per cent of new coded patient data	Completeness of patient information	▶ Primary healthcare practices submitted the EMR data electronically on a quarterly basis to the Practice Partner Net. ▶ Data were then used to calculate performance measures.
Davis *et al*[32]	Per cent documentation of asthma severity	Completeness of patient information	▶ Preintervention data were collected through retrospectively reviewing patient records, ▶ While postintervention data were collected through a chart review of the patients with asthma seen by residents in the primary healthcare practices.
Sweeney *et al*[33]	Proportion of primary healthcare provider notes that were coded using the International Classification of Primary Care (ICPC-02) system	ICPC-02 coding system	▶ Data extraction on physician and nurse coding levels was done through the general practitioner coding software system at four times points in the 18-month period.

Meta-analysis results.
EMR, electronic medical record.

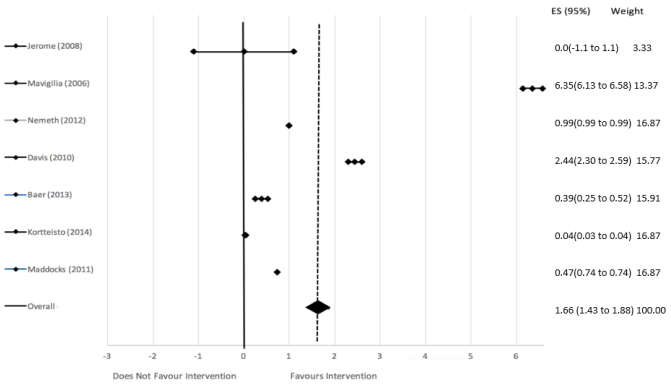

Figure 3 Log odds with associated 95% CIs showing the effect of interventions on use of electronic medical record functions.

of implementing interventions to improve EMR use established. This creates difficulties in synthesising those studies to create a useful meta-analysis.[37] A standardised form of testing interventions to improve EMR use could create studies that are homogeneous enough to provide conclusions with greater power. In addition, there is no generally accepted evaluation method when discussing EMR use. In the future, studies would benefit from standardised interventions and a clearly defined way of evaluating meaningful use of EMRs.

Nature of the interventions

The predominant intervention type identified in this review used educational material, seminars and guidelines to target EMR use (professional interventions), which were identified in 8 of the 12 studies. This focus on professional interventions was found to be consistent with the literature given that the only other systematic review in this area,[37] only included studies with educational interventions.[37] However, perceived barriers to EMR use include lack of both financial incentives and useful EMR features.[38 39] To address those barriers, the implementation of financial and organisational interventions is required. Therefore, there is a need for future studies to consider the other categories of interventions (organisational and financial) in the area of improving EMR use.

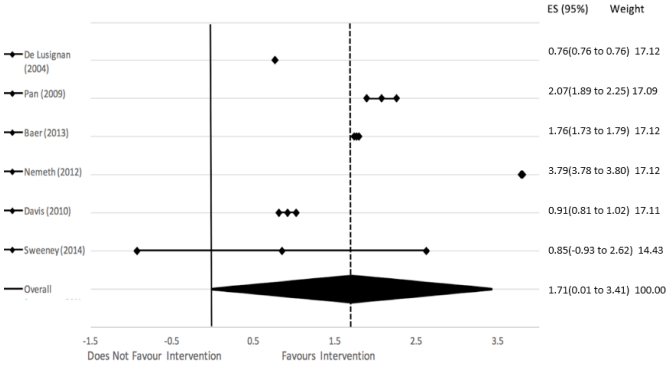

Figure 4 Log odds with associated 95% CIs showing the effect of interventions on data quality.

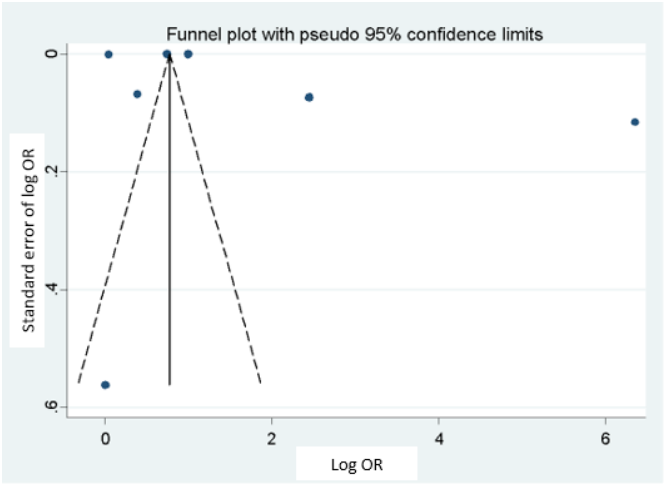

Figure 5 Funnel plot showing the spread of included studies targeted at use of electronic medical record.

Focus of interventions

Both use of EMR functions and data quality received equal attention as target areas for interventions to improve EMR use. Even though the studies collected for this review represent two important areas for interventions to target in order to improve EMR use, the literature was found to be lacking in other areas that could be targeted to improve use areas such as: communication, workflow, knowledge/skills and technological support. The field of interventions and intervention target areas aimed at improving EMR use is still lacking in well-designed studies that cover all areas that effect EMR function and use.

Strengths and limitations

This review is aimed at a new and developing field. This is one of only two systematic reviews conducted in the area of improving EMR use.[37] However, due to high heterogeneity in this area, previous reviews were unable to conduct a meaningful meta-analysis.[37] In this review, a synthesis of the results was possible through: the categorisation of interventions using the EPOC taxonomy of

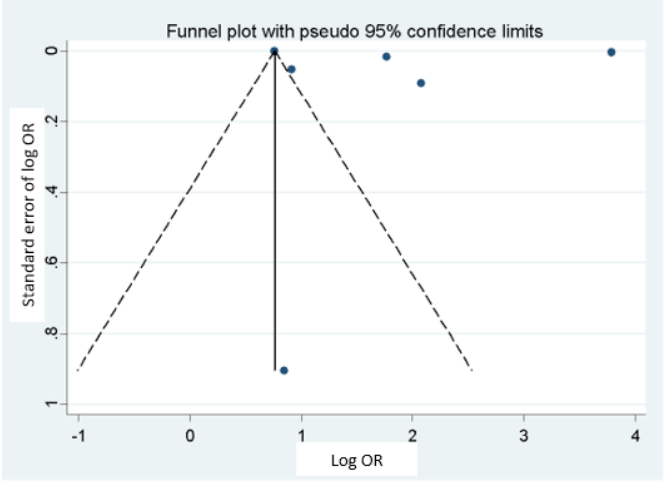

Figure 6 Funnel plot showing the spread of included studies targeted at data quality.

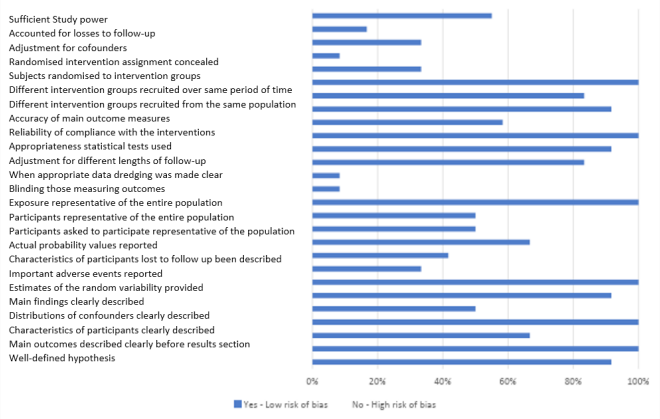

Figure 7 Risk of bias assessment of individual studies.

interventions and the identification of possible intervention target areas to improve EMR use. A limitation of this study was that due to the new and wide geographic spread of information technology use in the health field, EMRs are identified differently in different countries, making it impossible to identify all the studies with one search term. In an attempt to learn all the possible terms that are used to refer to an EMR, a search was performed prior to the creation of the search strategies. Using those newly found terms, a search strategy was then created to be as inclusive as possible without straying from the inclusion/exclusion criteria.

CONCLUSION

This review reveals a lack of attention given to interventions aimed at improving EMR use in primary healthcare. This is also reflected in the absence of a generalised method to evaluate EMR use, as well as guidelines to implement interventions to improve this use. After an intensive and inclusive search of the literature, this systematic review found a relatively small number of included studies with high heterogeneity. However, it is still worth noting that the results of this meta-analysis indicate that it is beneficial for primary healthcare practice to implement organisational, professional and financial interventions. This can be achieved through investing in EMR feature add-ons, educational materials and financial incentives to improving EMR use.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

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Appendix A: Complete Search Strategies

Medline- Ovid

#	Search	Results
1	exp Medical Records Systems, Computerized/	29129
2	((electronic or computer* or online) adj2 (medical or health or patient) adj2 (record or records)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]	22037
3	1 or 2	37459
4	Primary Health Care/ or Physicians, Primary Care/ or Family Practice/ or General Practice/ or General Practitioners/ or Nurse Practitioners/	135663
5	(Primary health care or Primary healthcare or Primary medical care or Family practi* or Family medicine or General practi* or Family physician* or Family Doctor* or Nurse Practition*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]	207800
6	4 or 5	208329
7	Intervention Studies/ or Feedback/ or Health Knowledge, Attitudes, Practice/ or Computer User Training/ or workflow/ or Office Management/ or Practice Management, Medical/ or Decision Making, Computer-Assisted/ or "quality of health care"/ or exp quality improvement /	200385
8	(Intervention Stud* or Computer user training or Work Flow or Office Management or Medical Practice Management or Computer assisted Decision making or Computer assisted Diagnosis or "meaningful use" or feedback or quality improvement).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]	162119
9	7 or 8	309976
10	3 and 6 and 9	823
11	limit 10 to (english language and yr="1970 -Current")	709

EMBASE

#	Search	Results
1	exp electronic medical record/	32147
2	((electronic or computer* or online) adj2 (medical or health or patient) adj2 (record or records)).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	40575
3	1 or 2	40738
4	primary health care/ or general practice/ or general practitioner/ or nurse practitioner/ or family nurse practitioner/	188427
5	(Primary health care or Primary healthcare or Primary medical care or Family practi* or Family medicine or General practi* or Family physician* or Primary care physician* or Family Doctor* or Nurse	295406

	Practition*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	
6	4 or 5	295406
7	intervention study/ or attitude to health/ or exp knowledge management/ or "meaningful use criteria"/ or workflow/ or computer assisted diagnosis/	158262
8	(Intervention Stud* or Computer user training or Work Flow or Office Management or Medical Practice Management or Computer assisted Decision making or Computer assisted Diagnosis or "meaningful use" or feedback or quality improvement).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	243833
9	7 or 8	336743
10	3 and 6 and 9	887
11	limit 10 to (english language and yr="1970 -Current")	791

CINAHL

#	Search	Results
1	(MH "Medical Records, Personal") OR (MH "Computerized Patient Record")	11,234
2	(electronic OR computer* OR online) N2 (medical OR health OR patient) N2 (record OR records)	13,390
3	(S1 OR S2)	13,719
4	(MH "Family Nurse Practitioners") OR (MH "Nurse Practitioners") OR (MH "Family Practice") OR (MH "Physicians, Family") OR (MH "Primary Health Care")	57,922
5	Primary health care or Primary healthcare or Primary medical care or Family practi* or Family medicine or General practi* or Family physician* or Family Doctor* or Nurse Practition*	82,062
6	(S4 OR S5)	82,062
7	(MH "Knowledge Management+") OR (MH "Meaningful Use") OR (MH "Computer User Training")OR (MH "Decision Support Systems, Clinical") OR (MH "Decision Making, Computer Assisted") OR (MH "Attitude to Health")	1,688
8	Intervention Stud* or Computer user training or Work Flow or Office Management or Medical Practice Management or Computer assisted Decision making or Computer assisted Diagnosis or “meaningful use” or feedback or quality improvement	61,868
9	(S7 OR S8)	63,268
10	(S3 AND S6 AND S9)	322

Web of Science

#	Search	Results
1	TS=(“Electronic medical record*”) OR TS=(“Electronic health record*”) OR TS=(“Computerized patient record*”) *Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years*	12,811

2	TS=("Primary Health Care") or TS=("Primary Care Physicians") or TS=("Family Practice") or TS=("General Practice") or TS=("General Practitioners") or TS=("Nurse Practitioners") *Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years*	79,091
3	TS=("Intervention Studies") or TS=(Feedback) or TS=("Computer User Training") or TS=(workflow) or TS=("Office Management") or TS=("Practice Management") or TS=("Computer Assisted Decision Making") or TS=("meaningful use") or TS=("quality improvement") or TS=("Computer assisted Diagnosis") *Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years*	350,825
4	#3 AND #2 AND #1 *Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years*	141
5	(#4) *AND* LANGUAGE: (English) *Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=1970-2015*	140

Cochrane Library

#	Search	Results
1	MeSH descriptor: [Medical Records Systems, Computerized] explode all trees	439
2	MeSH descriptor: [Primary Health Care] explode all trees	4022
3	MeSH descriptor: [General Practice] this term only	209
4	MeSH descriptor: [General Practitioners] explode all trees	95
5	MeSH descriptor: [Nurse Practitioners] this term only	316
6	MeSH descriptor: [Intervention Studies] this term only	2306
7	MeSH descriptor: [Feedback] this term only	979
8	MeSH descriptor: [Health Knowledge, Attitudes, Practice] this term only	3916
9	MeSH descriptor: [Computer User Training] explode all trees	47
10	MeSH descriptor: [Workflow] explode all trees	13
11	MeSH descriptor: [Office Management] explode all trees	70
12	MeSH descriptor: [Decision Making, Computer-Assisted] explode all trees	3751
13	MeSH descriptor: [Quality Improvement] 1 tree(s) exploded	49
14	Enter terms for search #2 or #3 or #4 or #5	4485

15	Enter terms for search #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13	10975
16	Enter terms for search "electronic medical records"	183
17	Enter terms for search "electronic health records"	213
18	Enter terms for search "computerized medical records"	21
19	Enter terms for search "electronic patient records"	28
20	Enter terms for search "primary health care"	4725
21	Enter terms for search "primary healthcare"	341
22	Enter terms for search "Primary medical care"	1879
23	Enter terms for search "Family practice"	3579
24	Enter terms for search "Family medicine"	1807
25	Enter terms for search "General practice"	5345
26	Enter terms for search "Family physician"	612
27	Enter terms for search "Family Doctor"	179
28	Enter terms for search "Nurse Practitioner"	544
29	Enter terms for search "Intervention Study"	5584
30	Enter terms for search "Computer user training"	48
31	Enter terms for search "Work Flow"	25
32	Enter terms for search "Office Management"	16
33	Enter terms for search "Medical Practice Management"	3
34	Enter terms for search "Computer assisted Decision making"	5
35	Enter terms for search "Computer assisted Diagnosis"	108
36	Enter terms for search "meaningful use"	21
37	Enter terms for search "feedback"	8445
38	Enter terms for search "quality improvement"	1287
39	Enter terms for search #1 or #16 or #17 or #18 or #19	417
40	Enter terms for search #14 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28	15661
41	Enter terms for search #15 or #29 or #30 or #31 or #32 or #33 or #34 or #35 or #36 or #37 or #38	23975
42	Enter terms for search #40 and #41 and #42	80

Appendix B: Screening Questions

Level 1 Screening Questions

1. Is the study focused on Information Technologies (IT) in relation to electronic or computerized patient records and not just as a data source? (could include but is not limited to Electronic Health Records, Electronic Patient Records, Computerized Patient Records, Computerized Medical Records, Computerized Health Records along with proper names for programs being used)
    a. Yes
    b. No
    c. Don't know
2. Does the study focus on EMR use (not the adoption or implementation of EMRs)?
    a. Yes
    b. No
    c. Don't know
3. Is it a study that either implements or observes an intervention with the intent of observing its effect on EMR use? (interventions could include but are not limited to: Educational Interventions, Computer Training, feedback, Work Flow, Practice Management, Office Management, Computer Assisted Diagnosis, Practice Guidelines, Guideline adherence or Training Support)
    a. Yes
    b. No
    c. Don't know
4. Was the study conducted in a primary health care setting? (such as patients' homes, physicians' clinics, physicians' offices, chronic health and primary health units)
    a. Yes
    b. No
    c. Don't know
5. Is it a research study (not an editorial, opinion, case report)?
    a. Yes
    b. No
    c. Don't know

Level 2 Screening Questions

1. Does the study target primary health care settings or personnel?
    a. Yes
    b. No
    c. Don't know
2. Is there a planned intervention implemented or observed with the intention of improving EMR use?
    a. Yes
    b. No
    c. Don't know
3. Does the study report measurements of use (the frequency of use, level of use or variety of use) of EMRs?
    a. Yes
    b. No
    c. Don't know

Appendix C: Further Explanation of the Downs and Black Bias Assessment Tool

The Downs and Black scale is made of 27 questions divided in to sub-sections:

1. **Reporting:** Assess whether the information provided allows for an unbiased assessment of the study outcomes. Consists of nine items all scored from 0 to 1 except for the question on listing confounding variables which scored from 0 to 2 contributing a maximum of ten points to the final score.

2. **External Validity:** Examines whether the findings of the study can be generalized to the intended population. Consists of three items all scored from 0 to 1 contributing a maximum of three points to the final score.

3. **Internal Validity:**

    a. **Bias:** Examines the presence of any bias in the measurements of the intervention and outcome. Consists of seven items all scored from 0 to 1 contributing a maximum of seven points to the final score.

    b. **Confounding:** Asses the bias of studies in the selection of study participants. Consists of six items all scored from 0 to 1 contributing a maximum of six points to the final score.

4. **Power**: Examines the possibility that the study findings could be due to chance. Consists of one item and is scored from 0 to 5 contributing a maximum of five points to the final score.

Therefore, studies could score a maximum of 31 points for assessing risk of bias of individual studies.[86]

Appendix D: The Downs and Black Checklist for Risk of Bias Assessment

Reporting

1. *Is the hypothesis/aim/objective of the study clearly described?*

yes 1

no 0

2. *Are the main outcomes to be measured clearly described in the Introduction or Methods section?* If the main outcomes are first mentioned in the Results section, the question should be answered no.

yes 1

no 0

3. *Are the characteristics of the patients included in the study clearly described?* In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given.

yes 1

no 0

4. *Are the interventions of interest clearly described?* Treatments and placebo (where relevant) that are to be compared should be clearly described.

yes 1

no 0

5. *Are the distributions of principal confounders in each group of subjects to be compared clearly described?* A list of principal confounders is provided.

yes 2

partially 1

no 0

6. *Are the main findings of the study clearly described?* Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions.

yes 1

no 0

7. *Does the study provide estimates of the random variability in the data for the main outcomes?* In non-normally distributed data the inter-quartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.

yes 1

no 0

8. *Have all important adverse events that may be a consequence of the intervention been reported?* This should be answered yes if the study demonstrates that there was a comprehensive attempt to measure adverse events.

yes 1

no 0

9. *Have the characteristics of patients lost to follow-up been described?* This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered 'no' where a study does not report the number of patients lost to follow-up.

yes 1

no 0

10. *Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?*

yes 1

no 0

External validity

All the following criteria attempt to address the representativeness of the findings of the study and whether they may be generalized to the population from which the study subjects were derived.

11. *Were the subjects asked to participate in the study representative of the entire population from which they were recruited?* The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not

report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.

yes 1

no 0

unable to determine 0

12. Were those subjects who were prepared to participate representative of the entire population from which they were recruited? The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.

yes

no 0

unable to determine 0

13. *Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive?* For the question to be answered yes the study should demonstrate that the intervention was representative of that in use in the source population. The question should be answered no if, for example, the intervention was undertaken in a specialist center unrepresentative of the hospitals most of the source population would attend.

yes

no 0

unable to determine 0

Internal validity - bias

14. *Was an attempt made to blind study subjects to the intervention they have received ?*

For studies where the patients would have no way of knowing which intervention they received, this should be answered yes.

yes 1

no 0

unable to determine 0

15. *Was an attempt made to blind those measuring the main outcomes of the intervention?*

yes 1

no 0

unable to determine 0

16. *If any of the results of the study were based on "data dredging", was this made clear?* Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.

yes 1

no 0

unable to determine 0

17. *In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls?* Where follow-up was the same for all study patients the answer should yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. (Studies where differences in follow-up are ignored should be answered no).

yes 1

no 0

unable to determine 0

18. *Were the statistical tests used to assess the main outcomes appropriate?* The statistical techniques used must be appropriate to the data. For example, non- parametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.

yes 1

no 0

unable to determine 0

19. Was compliance with the interventions reliable? Where there was noncompliance with the allocated treatment or where there was contamination of one group, the question should be answered no. For studies where the effect of any misclassification was likely to bias any association to the null, the question should be answered yes.

yes 1

no 0

unable to determine 0

20. *Were the main outcome measures used accurate (valid and reliable)?* For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.

yes 1

no 0

unable to determine 0

Internal validity - confounding (selection bias)

21. *Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population?*

For example, patients for all comparison groups should be selected from the same hospital. The question should be answered unable to determine for cohort and case- control studies where there is no information concerning the source of patients included in the study.

yes 1

no 0

unable to determine 0

22. Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time? For a study which does not specify the time period over which patients were recruited, the question should be answered as unable to determine.

yes 1

no 0

unable to determine 0

23. *Were study subjects randomized to intervention groups?*

Studies which state that subjects were randomized should be answered yes except where method of randomization would not ensure random allocation. For example, alternate allocation would score no because it is predictable.

yes 1

no 0

unable to determine 0

24. *Was the randomized intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?* All non-randomized studies should be answered no. If assignment was concealed from patients but not from staff, it should be answered no.
yes 1
no 0
unable to determine 0

25. *Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?* This question should be answered no for trials if: the main conclusions of the study were based on analyses of treatment rather than intention to treat; the distribution of known confounders in the different treatment groups was not described; or the distribution of known confounders differed between the treatment groups but was not taken into account in the analyses. In non-randomized studies if the effect of the main confounders was not investigated or confounding was demonstrated but no adjustment was made in the final analyses the question should be answered as no.
yes 1
no 0
unable to determine 0

26. *Were losses of patients to follow-up taken into account?* If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.
yes 1
no 0
unable to determine 0

Power

27. *Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?* Sample sizes have been calculated to detect a difference of x% and y%.

	Size of *smallest* intervention group	
A	$<n_1$	0
B	n_1–n_2	1
C	n_3–n_4	2
D	n_5–n_6	3
E	n_7–n_8	4
F	n_8+	5

Source: Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health*. 1998;52(6):377-384.