A review of the empirical evidence of the value of structuring and coding of clinical information within electronic health records for direct patient care.

KALRA, D., FERNANDO, B., MORRISON, Z. and SHEIKH, A.

2013

Refereed paper

A review of the empirical evidence of the value of structuring and coding of clinical information within electronic health records for direct patient care

Dipak Kalra PhD FRCGP FBCS
Clinical Professor of Health Informatics, Centre for Health Informatics and Multiprofessional Education, University College London, UK

Bernard Fernando MBBS MRCS LRCP MSc MBCS
Clinical Research Fellow

Zoe Morrison MSc MCIM FHEA
Research Associate

Aziz Sheikh MD MSc FRCGP FRCP
Professor of Primary Care Research & Development

eHealth Research Group, Centre for Population Health Sciences, The University of Edinburgh, UK

ABSTRACT

Background The case has historically been presented that structured and/or coded electronic health records (EHRs) benefit direct patient care, but the evidence base for this is not well documented.

Methods We searched for evidence of direct patient care value from the use of structured and/or coded information within EHRs. We interrogated nine international databases from 1990 to 2011. Value was defined using the Institute of Medicine's six areas for improvement for healthcare systems: effectiveness, safety, patient-centredness, timeliness, efficiency and equitability. We included studies satisfying the Cochrane Effective Practice and Organisation of Care (EPOC) group criteria.

Results Of 5016 potentially eligible papers, 13 studies satisfied our criteria: 10 focused on effectiveness, with eight demonstrating potential for improved proxy and actual clinical outcomes if a structured and/or coded EHR was combined with alerting or advisory systems in a focused clinical domain. Three studies demonstrated improvement in safety outcomes. No studies were found reporting value in relation to patient-centredness, timeliness, efficiency or equitability.

Conclusions We conclude that, to date, there has been patchy effort to investigate empirically the value from structuring and coding EHRs for direct patient care. Future investments in structuring and coding of EHRs should be informed by robust evidence as to the clinical scenarios in which patient care benefits may be realised.

Keywords: clinical coding, clinical outcomes, electronic health records, health information technology, structured data entry

Many of the intended benefits of electronic health records (EHRs) rely upon computers automatically processing the information in them. Such benefits may include: practitioner-level outcomes such as more consistent and complete clinical documentation; improved patient outcomes and better quality health care derived from evidence-based and guideline-oriented health care;[1,2] more efficient, effective healthcare systems as a result of greater use of computerised decision support (CDS); enhanced workflow management;

enhanced interoperability between EHR systems; better informed planning of health services;[3,4] and the re-use of data for research.[5]

There are currently major limitations in the extent and reliability with which computers can interpret free-text clinical notes, whereas structured forms and the coding of clinical entries permit computer interpretation and automated analysis for purposes such as decision support.[6,7] The case has therefore historically been presented that the use of structure and coding within EHRs benefits direct patient care beyond computerised physician order entry (CPOE). Many national eHealth programmes include a structured EHR underpinned by interoperability, clinical modelling and terminology standards. The recent specification of 'meaningful use' in the USA,[8] and the USA Certification Commission for Health Information Technology (CCHIT) and European (EuroRec) criteria for the certification of EHR systems are important examples.

However, there are concerns that clinical systems are not yet usable enough for physicians to structure and/or code all aspects of documentation, resulting in most computerised records still being free-text. Challenges in relation to the professional education and behaviour change implications of adopting standardised EHRs are significant.[9] Previous work has found clinician behaviours to have led to significant volumes of coding errors.[10] The process of recording new information does not adequately include learning from existing EHR data,[11] and there are concerns that the move away from narrative recording might depersonalise health care.[12]

Given these challenges, investments in promoting structured EHRs should prioritise those aspects of documentation that bring maximum and near-term value. Some benefits of structuring and/or coding that are well-established, and have been prioritised, include secondary uses such as clinical audit, clinical research, epidemiology, public health, health services research and billing.

However, the evidence for direct care benefits from structuring and/or coding EHRs, and potential harms, has hitherto not been well-documented, making it difficult for eHealth programmes to set appropriate priorities for clinical documentation standards. Building on a recent review of the benefits and risks of structuring and/or coding the presenting patient history,[13] we sought to examine the evidence of structuring and/or coding clinical information within EHRs for value to direct patient care. In so doing, we defined value using the six aims of improvement for 21st century healthcare systems in the Institute of Medicine's (IoM's) *Crossing the Quality Chasm* report, i.e. improvements in safety, effectiveness, patient-centeredness, timeliness, efficiency or equitability of the care delivered to patients.[14]

Methods

The search strategy was developed by iteratively scoping the literature, through discussion with experts and from previously published search strategies. Nine databases were systematically searched for published, unpublished and in-progress research: MEDLINE, EMBASE, CINHAL, PsycINFO, IndMED, LILACS, Paklit, NIHR and Google Scholar. Hand searches of specialist journals and the authors' personal libraries were undertaken in parallel, including snowballing and consultation with other specialists.

To maximise the sensitivity of electronic search terms, an extensive set of keywords and subject headings (MeSH) was developed in three key topic areas:

- EHRs[7]
- tools and techniques for structuring health records (e.g. templates, terminology browsers and pick lists)
- structuring or coding.[15]

These were all combined using the 'AND' operator.

Keywords relating to the category of evidence[16] or to the IoM's six dimensions of quality[14] were not included within search strategies as it was found during a pilot study that these were not reliably stated in publications, hence the risk of missing important studies. These criteria were applied manually during title and abstract screening. The final search strategy for MEDLINE, as an example, is given in Box 1.

Title and abstract screening was undertaken on the basis of the criteria defined in Box 2.

Full paper screening applied these same criteria. Some publications were excluded if only a conference abstract existed with no follow-up full paper to adequately assess the intervention, evidence or outcome. Data from empirical studies were abstracted into an evidence table; findings were then first descriptively summarised and then thematically synthesised.

Results

Initial searches resulted in 6766 papers for consideration, reduced to 5016 after removal of duplicates. Thirteen papers satisfied our inclusion criteria (see Figure 1 for the PRISMA diagram).[17–29] These papers, 12 from the USA and one from Spain, are summarised in Table 1 and grouped below according to the principal quality dimension for which improvement was evaluated.[14]

Box 1 Example search strategy for MEDLINE and numbers of hits returned

1. Tools and techniques search records returned = 12 558
(tool OR tools OR technique OR techniques OR questionnaire* OR computer based questionnaire* OR patient-completed history questionnaire* OR computer-administered patient interview* OR form OR forms OR structured form* OR problem-specific report form* OR self-report form* OR structured registration form* OR *template* OR template-generated medical documentation OR documentation template* OR documentation system* OR case histor* OR standardised interview question* OR structured data collection OR medical history-taking device* OR history-taking system OR computer history taking system* OR patient-driven health information OR data entry kiosk* OR pro forma* OR proforma* coded chief complaints OR structured encounter forms OR encounter note OR diary OR diaries OR 'automated speech recognition' OR automated health assessment)
2. Structuring and coding records returned = 1 820 787
(clinical coding [MeSH] OR code* OR encode* OR read code* OR diagnosis related group* OR international classification of diseases OR medical subject headings OR icd OR snomed OR hrg OR drg OR mesh OR language* OR ontolog* OR systematised nomenclature OR controlled vocab* OR structur* OR metadata OR template* OR form)
3. Electronic health records returned = 15 227
(computerised decision support OR medication decision support OR ePrescribing OR electronic prescribing) OR (electronic health records [MeSH] OR electronic patient record) OR (ehealth OR telehealth OR telecare OR telehealthcare or mhealth)
(1 OR 2) AND 3 published after 1990
records returned = 3276

Effectiveness

The majority of relevant publications focused on improved clinical effectiveness (normally assessed through improved adherence to a clinical guideline).[17–26] These are subgrouped below by disease area. Two studies introduced a structured format as the only intervention: almost all made use of structured data to present prompts as the influential intervention, or evaluated the use of an EHR system as a whole. These studies, however, demonstrate improvements in actual or proxy outcomes when a structured EHR was combined with simple alerts. Studies that referred to the use of coded information offered users a non-hierarchical list of terms (e.g. a pick list) to standardise data entry. No studies employed a hierarchical terminology, in which terms of varying granularity were organised to permit aggregated analysis.

Diabetes

Lobach and Hammond demonstrated that a diabetes clinical guideline could be successfully tailored for specific patients, based on prior information in each patient's EHR.[17] The EHR system at Duke Family Medical Centre was modified to generate a patient-tailored encounter form for each diabetes review. Thirty clinical staff were randomised to receive either this tailored form or a generic form covering the whole guideline. The study examined 884 diabetes review encounters. Clinician compliance rates were calculated as the number of recommendations followed over the number of recommendations due for each patient during an encounter. Median compliance for the group receiving the tailored recommendations was 32.0 versus 15.6% for the control group ($P = 0.01$). Despite this improvement, guideline compliance was lower than the authors had expected, which they attributed to the increased workload that would be required for full compliance and to patient-specific factors that had not been taken into account.

O'Connor *et al* undertook a controlled study investigating the impact of introducing an EHR system on diabetes care by comparing two community clinics of the HealthPartners Medical Group.[18] Both practices had achieved similar standards of care, including HbA1c control, prior to the study. One practice adopted an EHR system that collected structured diabetes reviews and prompted clinicians if: (a) a patient had no HbA1c test within six months, or (b) if the patient's HbA1c levels were $\geq$ 8%. The other practice used existing paper charts. Frequency of HbA1c tests increased at the EHR clinic compared with the non-EHR clinic ($P < 0.001$). However, HbA1c levels improved in both clinics ($P < 0.05$) with no significant differences between clinics after two years ($P = 0.10$) or four years ($P = 0.27$).

More recently, Cebul *et al* demonstrated that intermediate outcomes for diabetes are significantly better in practices using an EHR than those using paper records.[19] Their study included 46 primary care prac-

Box 2 Inclusion and exclusion criteria applied during title and abstract screening

Inclusion criteria:
- a specified introduction of a structured and/or coded format for capturing and/or analysing EHR data as the primary intervention of the research
- AND deployment in at least one healthcare setting
- AND an empirical evaluation reported of additional benefit obtained from the structured and/or coded EHR data meeting the Cochrane's EPOC Group criteria, namely: a randomised controlled trial, controlled clinical trial, controlled before-and-after study or interrupted-time-series (15)
- AND the evaluation could be related to one or more of the six IoM dimensions of quality of patient care.

Exclusion criteria:
- ublications describing relevant new or in-progress projects for which evaluations had not yet been performed
- descriptions (without evaluation) of novel eHealth solutions to deliver EHRs or supporting applications or to automatically encode or analyse EHR data
- feasibility or proof of concept studies demonstrating technical success and/or usability and acceptance of an EHR or clinical application
- feasibility or quality assessments of the potential for EHR data to support a quality improvement or clinical outcome, which did not demonstrate a concrete outcome
- feasibility assessments or actual secondary uses of EHR data for: clinical audit, clinical research, epidemiology, public health, health services research, clinical guideline development, health service evaluations or reimbursements
- the use of an electronic documentation or communication system in which the format of the data was not reported or considered material (i.e. the level of structuring and/or coding was not relevant to the intervention, only that the record is electronic or networked or that a tele-communications channel is used)
- benefits from patient diaries in which the format of the data was not material (i.e. the act of keeping a diary is the intervention and the electronic tool simply enhances acceptance over paper diaries, and/or its contents are simply read irrespective of the format)
- evidence of increase in data quantity and completeness of data collection or data quality without any evidence of a benefit derived from those additional data
- complex interventions in which impact from changes to the capture of EHR data was not capable of being isolated from other causes of the impact (e.g. educational programmes and service model changes in parallel to the introduction of a new EHR template or guideline).
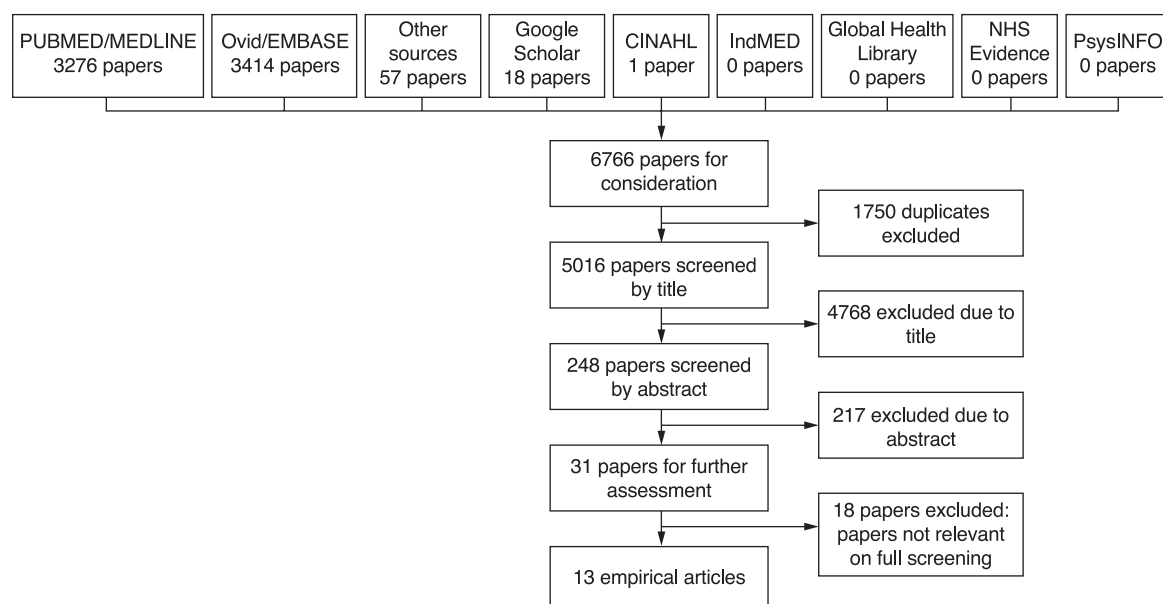

Figure 1 PRISMA flow diagram

Table 1 Key study characteristics and main findings

Author, year (ref)	Setting	Population	Intervention	Outcomes
Lobach and Hammond, 1997 (17)	Duke Family Medicine Center, USA	Diabetes patients	A patient-tailored encounter form printed before each diabetes review	The tailored printout significantly increased adherence to the guideline, from a mean of 15 to 32%, without extending the consultation length
O'Connor et al, 2005 (18)	Two of the 18 community clinics run by the HealthPartners Medical Group	Diabetes patients	The EPIC EMR system, with a prompt if a patient had no HbA1c test within six months or no urine microalbuminuria test within one year	Greater improvement in HbA1c if a prompt is provided that with the EMR alone
Calvert et al, 2009 (17)	147 general practices in England, UK	Diabetes patients	Before and after introduction of the Quality and Outcomes Framework	Better glycaemic control in people with type 2 diabetes for the more stringent target (HbA1c level $\leq$ 7.5%)
Cebul et al, 2011 (19)	46 primary care practices in Ohio, USA	Diabetes patients	Comparison of EHR and paper-based practices	Improvement of care process standards and intermediate outcome standards (e.g. HbA1c) in EHR practices compared with paper-based practices
Lecumberri et al, 2011 (20)	University Clinic of Navarra, Spain	All hospitalised patients	Targeted alert within the EHR system for patients at risk of VTE	Use of VTE prophylaxis in at-risk patients increased from 27 to 60% following introduction of the alert, and VTE incidence during hospitalisation decreased by 50%
Galanter et al, 2010 (21)	University of Illinois Hospital, USA	All inpatients	VTE prophylaxis risk assessment form completion required when making a new CPOE order	Percentage of patients receiving prophylaxis increased from 25.9 to 36.8%, and significant reduction in VTE within the medical unit
Bell et al, 2010 (22)	12 primary care practices across Philadelphia, USA	Asthma patients	Prompts added to a structured EHR	Improved peak flow and increased use of controlling medication such as inhaled steroids

Table 1 Continued

Author, year (ref)	Setting	Population	Intervention	Outcomes
Davis *et al*, 2010 (23)	Center for Family Medicine, Spartanburg, USA	Asthma patients	Introduction of a template to capture routine monitoring visits	Increased appropriate use of inhaled corticosteroids
Körner *et al*, 1998 (23)	Regional hospital in Stavanger, Norway	All adults presenting with suspected acute appendicitis	A structured pro forma for documenting the clinical encounter and diagnosis	Significantly improved diagnostic accuracy and thereby reduced the number of unnecessary operations
Linder *et al*, 2009 (24)	27 primary care clinics in Massachusetts, USA	Patients presenting with acute respiratory infections	A template for managing acute respiratory infections, pre-populated from the EHR	Marginal but non-significant reductions in antibiotic prescribing, particularly for acute bronchitis
Bourgeois *et al*, 2010 (25)	Children's Hospital, Boston, USA	Children and adolescents presenting with acute respiratory infections	An electronic template to advise on antibiotic use in paediatric acute respiratory illness	No difference in total antibiotic prescriptions between control and intervention clinics
Ledwich *et al*, 2009 (26)	A hospital-based and a community based practice in Danville, PA, USA	Patients taking immuno-suppressive drugs for rheumatoid conditions	Alert triggered by opening an EHR if that patient should be offered influenza or pneumococcal vaccination, based on underlying EHR data	More than doubling rates of both vaccination rates
Bates *et al*, 1998 (27)	Brigham and Women's Hospital, Boston, USA	All adults admitted to medical and surgical units involved in the study	Integration of allergy and interaction alerts with a medication ordering system (CPOE), and the co-presentation of salient laboratory values	Reduced serious medication errors by 55%, especially dose errors and known allergy errors
Evans *et al*, 1998 (28)	12-bed intensive care unit at the LDS Hospital, Salt Lake City, USA	All patients admitted to the unit between July 1992 and June 1995	Antibiotic advisory system using structured data within the EHR for diagnosis, medication, microbiology and renal function to provide clinicians with tailored anti-biotic recommendations	Significantly reduced the frequency of allergies, the duration of the antibiotic course and length of stay
Longhurst *et al*, 2010 (29)	Lucile Packard Children's Hospital, Stanford University, USA	Patients admitted between 1 January 2001 and 30 April 2009	Implementation of a commercial CPOE system	A significant 20% reduction in hospital-wide mortality

tices in Ohio (33 computerised and 13 paper-based) and follow-up of 27 000 patients over a year. Outcomes were defined as composite quality of care standards derived from outcome measures defined by the American Diabetic Association. Achievement of composite standards for process of diabetes care (e.g. measurement of HbA1c) was 35.1% higher at EHR sites than at paper-based sites ($P < 0.001$), and achievement of composite standards for outcomes (e.g. HbA1c < 8%) was 15.2% higher ($P = 0.005$). However, the authors pointed out that improvement in quality could not be attributed to the implementation of EHRs alone due to a number of confounding variables, such as differences in patient populations and known variations in quality standards across practices prior to the study.

Venous thromboembolism

Lecumberri et al demonstrated that significant costs in the hospital management of venouse thromboembolism (VTE) could be avoided through alerts to prompt clinicians to use prophylaxis in high-risk patients.[20] They studied over 25 000 patients before and after introducing the alert. At-risk patients were identified computationally, according to American College of Chest Physicians' guidelines, through pre-existing routinely collected EHR data from medical orders, daily nursing reports, surgery registries and laboratory results. Use of VTE prophylaxis in at-risk patients increased significantly from 27 to 60% following introduction of the alert, and hospital VTE incidence decreased by 50% (95% confidence interval [CI] 0.29–0.84). Accounting for the costs of the system and the savings from each prevented episode of VTE, the alerts resulted in an average saving of $8.92 (€6.54) per hospitalised patient.

At the University of Illinois Hospital, Galanter et al demonstrated that the introduction of a structured risk assessment form for VTE prophylaxis significantly increased the use of prophylaxis from 25.9 to 36.8% ($P < 0.001$), and reduced the incidence of VTE.[21] A structured (tick box) form, linked to alert-generating decision support, was presented via the CPOE system prior to ordering for every new inpatient. This approach did not require the pre-existence of relevant data items within the hospital's EHR system, but the data items captured via this form were re-used whenever fresh orders were made for each patient.

Asthma

Bell et al demonstrated that a computerised asthma care plan linked to an EHR system improved measurement of peak expiratory flow rate (8–14%, $P = 0.003$) and increased the use of controlling medication such as inhaled steroids (from 1 to 7%, $P = 0.006$).[22] This cluster randomised trial involved 12 Philadelphia primary care practices and almost 20 000 patients. Because the control group of practices had access to the same EHR system, clinical guidelines and educational sessions, the intervention effect could be attributed to the CDS alerts. As this study did not change the way in which clinical data were captured, it is an example of the way in which structured EHR information can be exploited by CDS to improve adherence to guidelines and thereby improve proxy clinical outcomes.

Davis et al found that a template to capture routine asthma monitoring in primary care increased the appropriate use of inhaled corticosteroids.[23] Their template included checkboxes for documenting the number of days per week that the patient had symptoms, nights per month with symptoms, FEV1, recent exacerbations and use of rescue $\beta 2$ agonists. This study involved 180 records of patients attending the Center for Family Medicine, Spartanburg over two 6-month periods before and after introduction of the template. Use of inhaled steroids increased significantly from 39.4 to 51.1% ($P = 0.017$). Unfortunately the study did not track other outcomes such as emergency department attendances and hospital admissions.

Antibiotic prescribing

Linder et al evaluated a 'Smart Form' for managing acute respiratory infections in primary care, in Massachusetts. The Smart Form was integrated within the EHR system, pre-populated relevant fields from a patient's record when opened, supported the clinical encounter with structured fields (tick boxes and drop-down lists), and simplified the generation of prescriptions and letters.[24] The system advised on whether and which antibiotics were indicated (using published guidelines), advised on streptococcal testing, and checked for drug interactions and allergies. The system therefore combined features of a structured EHR (supporting data entry) with decision support (supporting appropriate prescribing). The evaluation, involving 27 primary care clinics randomly assigned to use Smart Forms or the unmodified EHR system for six months, showed marginal, but non-significant increase in appropriate and reduction in inappropriate antibiotic prescribing, particularly for acute respiratory infections. Using the Smart Form antibiotic prescribing for clinically appropriate acute respiratory diagnoses (e.g. sinusitis) occurred in 88% of encounters compared with 59% in the control group (OR = 5.0; 95% CI 2.9–8.6), and for antibiotic-inappropriate diagnoses (e.g. influenza) occurred in 27% compared with 34% in the control group (OR = 0.7; 95% CI 0.5–1.0). The authors proposed that this limited effect was

due to the low frequency of use of the form, which had to be deliberately invoked rather than being automatically triggered by a symptom or diagnosis.

A study by Bourgeois *et al* in Boston illustrated how the adoption of a new tool to support better quality prescribing, in their case an electronic template to advise on antibiotic use in acute respiratory illness in children, can prove challenging and limit the potential benefits to patients.[25]

Immunisations

Ledwich *et al* demonstrated that an alert, triggered by opening a patient's EHR, indicating whether that patient ought to be offered influenza or pneumococcal vaccination, can more than double vaccination rates (19–41%; $P < 0.001$, for pneumococcal vaccine).[26] The study of over 750 patients was performed over two consecutive years at a hospital and at a community based practice in Danville, Pennsylvania.

Safety

As no studies were found that specifically demonstrated improved safety from the use of structured or coded data within EHRs it may be concluded that neither the act of entering data via a structured proforma or the review of previously entered structured data have been evaluated from a safety perspective. Whilst there is an established body of work considering the use of CDS within CPOE systems, we found only three papers in which pre-existing structured clinical information within an EHR was the focus of investigation. These three studies are summarised below. Each uses structured data within an EHR to enable relevant alerts to be generated, thereby demonstrating improvements in safety or mortality.

In 1998, Bates *et al* demonstrated at the Brigham and Women's Hospital, Boston, that the integration of allergy and interaction alerts with a medication ordering system, and the co-presentation of salient laboratory values, reduced serious medication errors by 55%.[27] The impact was primarily on dosing errors and known allergy errors, both of which required structured and computable data entry and the retrieval of relevant data within each patient's EHR. The primary success factor was the use of pre-existing structured EHR data (medication lists and allergy lists), combined with a knowledge base (such as drug–drug interactions), to enable the generation of alerts.

Evans *et al* demonstrated at the LDS Hospital in Salt Lake City that an antibiotic advisory system can use structured EHR data for diagnosis, medication, microbiology and renal function to provide tailored antibiotic recommendations.[28] A before-and-after evaluation revealed that the system significantly reduced

the frequency of allergies, the duration of antibiotic courses and length of stay, thereby also reducing costs.

Implementation of a commercial (locally modified) CPOE system in an academic children's hospital was associated with a significant 20% reduction (95% CI 0.8–40%) in hospital-wide mortality.[29] This observational study of 17 432 hospital inpatient episodes, compared with 80 063 historical pre-implementation controls, sought to account for trends or other factors that might have influenced this rate. The authors concluded that the success factors included the standardisation of the information used to create orders, shared EHRs including vital signs and medication records, and the consequent better support of team-based care. The authors did not specify the data items that contributed to this improvement, and it is therefore difficult to infer the value gained specifically from structuring or coding parts of the record.

Patient-centredness, timeliness, efficiency and equitability

No studies were found that investigated these quality dimensions. Two of the studies summarised above[20,28] included an estimate of cost savings from the quality improvement, but no formal economic evaluations of the impact of introducing structured and/or coded EHRs were identified.

Discussion

Main findings

The majority of studies we identified focused on effectiveness, demonstrating that proxy, and in some cases, actual clinical outcome can be improved if a structured EHR is combined with prompting or advisory systems in targeted areas: the management of a long-term condition, a preventive intervention, or appropriate choice of therapy. Prescribing was the only example found of improvement to safety (as defined by the IoM).[14] No studies were found reporting value for patient-centredness, timeliness, efficiency or equitability.

Our review focused on studies reporting the structuring or coding of EHRs as the primary intervention, although many of the EHR systems included an alert-generating component. Other published reviews have focused on studies primarily implementing CDS systems and their impact on patient outcomes.[6,7] CDS systems inevitably rely upon computable EHR data, which must therefore be structured and/or coded. Our reading of the CPOE/CDS systematic

review literature indicates that where carefully designed these can translate into improvements in practitioner performance, but these signals are relatively weak and high up in the causal chain, with limited opportunities to have substantial impact on practitioner and patient-level outcomes. In addition, many outcomes of interest (e.g. anaphylaxis to a drug) are relatively uncommon such that the sample size/length of follow-up needed to demonstrate an improvement in outcomes is often prohibitive.

Strengths and limitations

This review used components of previously validated search strategies, a well-accepted definition of quality and a standard definition of evidence to investigate a research area that has not hitherto been well-documented. Despite searching widely, we found only a small number of publications meeting our review criteria. Some possible reasons for this are: (a) it is difficult to locate the relevant studies due to the way literature is indexed; (b) the papers, if any, which describe added value describe the intervention as the introduction or modification of an EHR system (comprising clinical applications, CDS, clinical workflow support as well as an EHR) where the effect of structuring and/or coding the record is not independently assessed.

Implications for policy, practice and research

Our findings suggest that structuring and coding of EHR information will usually form part of a broader reorganisation and systematisation of a particular aspect of clinical practice, for which the intervention is more holistic, and the health record information effect is difficult to isolate. The findings suggest that the use of structured and/or coded information should be isolated for study as part of a deeper understanding of the implications and imperatives of adopting EHRs, and that these studies should be evaluated using criteria directly related to the delivery of direct patient care.

Conclusions

This review indicates that there has been patchy effort to date to empirically evidence the value from structured and/or coded EHRs for direct patient care, as opposed to secondary use benefits or improved

healthcare systems. Structuring and/or coding information is expensive and effortful, and a business case for its promotion should not be made without more robust evidence indicating the priority areas in which patient care benefits are most likely to be realised.

AUTHORS' CONTRIBUTIONS

BF, DK, ZM and AS conceived the idea for this review and developed the methods. BF and ZM undertook the searches, and DK undertook study selection, critical appraisal and data extraction. DK and AS led the drafting of the manuscript, with BF and ZM commenting on and editing several drafts. AS was the PI. All authors approved the final manuscript.

REFERENCES

1 Mitka M. Data-based risk calculators becoming more sophisticated – and more popular. *Journal of the American Medical Association* 2009;302(7):730–1.

2 Hersh WR. Medical informatics: improving health care through information. *Journal of the American Medical Association* 2002;288(16):1955–8.

3 Lurie N and Fremont A. Building bridges between medical care and public health. *Journal of the American Medical Association* 2009;302(1):84–6.

4 Kuehn BM. CDC links data on health and environment. *Journal of the American Medical Association* 2009; 302(10):1049.

5 Delaney B and Taweel A. *TRANSFoRm: translational medicine and patient safety in Europe.* AMIA 2010 Annual Symposium.

6 Jaspers M, Smeulers M, Vermeulen H and Peute L. Effects of clinical decision-support systems on practitioner performance and patient outcomes: a synthesis of high-quality systematic review findings. *Journal of the American Medical Association* 2011;18:327–34. doi: 10.1136/amiajnl-2011–000094.

7 Black AD, Car J, Pagliari C *et al*. The impact of ehealth on the quality and safety of health care: a systematic overview. *PLoS Medicine* 2011;8:e1000387.

8 Blumenthal D and Taverna M. The 'meaningful use' regulation for electronic health records. *New England Journal of Medicine* 2010;363:501–4.

9 Sittig DF and Singh H. Eight rights of safe electronic health record use. *Journal of the American Medical Association* 2009;302(10):1111–3.

10 Lloyd SS and Rissing JP. Physician and coding errors in patient records. *Journal of the American Medical Association* 1985;254(10):1330–6.

11 D'Avolio LW. Electronic medical records at a crossroads: impetus for change or missed opportunity? *Journal of the American Medical Association* 2009; 302(10):1109–11.

12 Wilkinson TM. Human information processing, health information technology, and medical outcomes. *Journal of the American Medical Association* 2009; 302(13):1417.

13 Fernando B, Kalra D, Morrison Z, Byrne E and Sheikh A. Benefits and risks of structuring and/or coding the presenting patient history in the electronic health record: systematic review. *BMJ Quality and Safety* 2012. doi:10.1136/bmjqs-2011–000450.

14 Institute of Medicine. *Crossing the Quality Chasm: a new health system for the 21st Century*. National Academy Press: Washington, DC, 2001.

15 Byrne E, Fernando B, Kalra D and Sheikh A. The benefits and risks of structuring and coding of patient histories in the electronic clinical record: protocol for a systematic review. *Informatics in Primary Care* 2011;18:197–203.

16 Cochrane Effective Practice and Organisation of Care Group. http://epoc.cochrane.org

17 Lobach DF and Hammond WE. Computerized decision support based on a clinical practice guideline improves compliance with care standards. *American Journal of Medicine* 1997;102(1):89–98.

18 O'Connor PJ, Cram AL, Rush W *et al*. Impact of an electronic medical record on diabetes quality of care. *Annals of Family Medicine* 2005;3(4):300–6.

19 Cebul R, Love T, Jain A and Hebert C. Electronic health records and quality of diabetes care. *New England Journal of Medicine* 2011;365:825–33.

20 Lecumberri R, Panizo E, Gomez-Guik A *et al*. Economic impact of an electronic alert system to prevent venous thromboembolism in hospitalised patients. *Journal of Thrombosis and Haemostasis* 2011;9(6):1108–15.

21 Galanter, WL, Thambi M, Rosencranz H *et al*. Effects of clinical decision support on venous thromboembolism risk assessment, prophylaxis, and prevention at a university teaching hospital. *American Journal of Health-System Pharmacy* 2010;67(15):1265–73.

22 Bell LM, Grundmeier R, Localio R *et al*. Electronic health record based decision support to improve asthma care: a cluster-randomized trial. *Pediatrics* 2010;125(4):e770–7.

23 Davis AM, Cannon M, Ables AZ *et al*. Using the electronic medical record to improve asthma severity documentation and treatment among family medicine residents. *Family Medicine* 2010;42(5):334–7.

24 Linder JA, Schnipper JL, Tsurikova R *et al*. Documentation-based clinical decision support to improve antibiotic prescribing for acute respiratory infections in primary care: a cluster randomised controlled trial. *Informatics in Primary Care* 2009;17(4):231–40.

25 Bourgeois FC, Linder J, Johnson S *et al*. Impact of a computerized template on antibiotic prescribing for acute respiratory infections in children and adolescents. *Clinical Pediatrics* 2010;49(10):976–83.

26 Ledwich LJ, Harrington TM, Ayoub WT *et al*. Improved influenza and pneumococcal vaccination in rheumatology patients taking immunosuppressants using an electronic health record best practice alert. *Arthritis Care and Research* 2009;61(11):1505–10.

27 Bates DW, Lapelly Cullen DL *et al*. Effect of computerized physician order entry and a team intervention on prevention of serious medication errors. *Journal of the American Medical Association* 1998;280: 1311–16.

28 Evans RS, Pestonik SL, Classen DL *et al*. A computer-assisted management program for antibiotics and other anti-infective agents. *New England Journal of Medicine* 1998;338:232–8.

29 Longhurst CA, Parast L, Sandborg CI *et al*. Decrease in hospital-wide mortality rate after implementation of a commercially sold computerized physician order entry system. *Pediatrics* 2010;126(1):14–21.

CONFLICTS OF INTEREST

None known.

ADDRESS FOR CORRESPONDENCE

Dipak Kalra PhD FRCGP FBCS
Clinical Professor of Health Informatics
Centre for Health Informatics and Multiprofessional Education
University College London
London N19 5LW
UK
Email: d.kalra@ucl.ac.uk