How do inter-organisational electronic health records affect hospital physician and pharmacist decisions? A scoping review.

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Philip Scott, Haythem Nakkas, Paul Roderick

Abstract

Objective

To provide an overview of the effects of inter-organisational electronic health records on inpatient diagnosis and treatment decisions by hospital physicians and pharmacists.

Materials and Methods

Five-stage scoping review, using distributed cognition and the information value chain as guiding conceptual models. Eligibility criteria: empirical studies addressing how shared health records were used in inpatient clinical decision-making, published 2008-18. Sources: Healthcare Databases Advanced Search, covering nine sources including PubMed. Charting methods: data extraction form completed by one author, with inter-rater reliability assessment at title and abstract review.

Results

Quantitative studies (n=14) often reported relatively low usage of shared records (6.8% to 37.1% of cases). Usage is associated with reduction in diagnostic testing and readmission and variable effects on admissions and overall costs. Qualitative studies (n=6) reported avoidance of duplicate diagnostics, changing clinical decisions, the value of historical laboratory results and optimising the timeliness of care. We found no explicit use of explanatory theoretical models, but there is implicit evidence of an information value chain. We found only one study specifically about pharmacists.

Discussion

Relatively low usage is due to clinical judgement whether “extra” data is needed, given current knowledge of the presenting condition and relative complexity. We suggest that extensive EHRs need recommender systems to highlight (sometimes unexpected) relevant content, in parallel with professional guidance on indications for consulting shared records.

Conclusions

Clinicians only consult shared health records when they must. Mixed effects on process outcomes are due to the hidden variables of patient complexity, clinician judgement and organisational context.

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BACKGROUND

The adoption of electronic health records (EHRs) is foundational in the shift to "digital health".[1] This basic step is necessary to achieve higher-level aspirations such as computerised clinical decision support,[2] precision medicine[3] and Learning Health Systems.[4] Often, electronic health records are limited in scope to a single healthcare provider organisation in a particular care sector, such as hospital, primary care or community care. However, there is also widespread interest in sharing data between primary, secondary, tertiary and social care across large geographical areas to support unscheduled care and services for patients who are treated by multiple healthcare provider organisations.[5, 6] This is often called "Health Information Exchange" (HIE), which has been variously defined,[7] but we use the simple definition that it is technology that "allows doctors, nurses, pharmacists, other health care providers and patients to appropriately access and securely share a patient's vital medical information electronically".[8] Unfortunately, it has remained unclear when or how such HIE or an extensive inter-organisational health record is more helpful than local records or a patient summary.[9-11]

The authors were commissioned to conduct an evaluation of a regional inter-organisational health record developed by the NHS in southern England. This shared record, created in the early 2000s, was originally called the Hampshire Health Record[12] but has since expanded in geographical scope and content so is now called the Care and Health Information Exchange (CHIE).[13] Regional shared records have fairly recently become national policy for the NHS in England.[5] One of the specified objectives in the study protocol was "To produce a scoping review of the literature that identifies, appraises and synthesises knowledge about the mechanisms of action of inter-organisational electronic health records on clinical decision-making". As the scope of our primary research was to evaluate the impact of CHIE on decisions about inpatient diagnosis and treatment, we limited this scoping review to hospital physicians and pharmacists. In this review, the terms "inter-organisational health records", "shared EHRs" and "Health Information Exchange" (HIE) are generally used interchangeably. This scoping review aimed to inform our primary research by providing an overview of how inter-organisational EHRs can support improvements in direct patient care.

MATERIALS AND METHODS

We have previously reported our protocol[14] but summarise the key elements here for convenience. The study followed the five-stage Arksey and O'Malley framework for scoping reviews:[15] (1) identifying the initial research questions, (2) identifying relevant studies, (3)

study selection, (4) charting the data, and (5) collating, summarising and reporting the results. Stages 3-5 are reported in the Results section. We have followed the PRISMA-ScR checklist for reporting scoping reviews.[16] We adopted sociotechnical systems thinking[17] and in particular the notion of distributed cognition[18] as the guiding conceptual models for the review. Specifically, we used the Distributed Cognition for Teamwork – Concentric Layers model (DiCoT-CL)[19] (**Figure 1**) and the information value chain concept (**Figure 2**).[20] We particularly wanted to see if there was evidence in the literature relating the sharing of data between organisations with the notion of "team cognition" or with the chain of events from patient interactions to decisions to outcomes.

[Insert Figure 1 here]

Figure 1. Distributed Cognition for Teamwork – Concentric Layers (adapted from Ref. 19 with permission). EHR, electronic health record.

[Insert Figure 2 here]

Figure 2. Information value chain (reproduced from Ref. 20 with permission).

The ambiguity of terminology mentioned above is one reason why we chose to conduct a scoping review rather than a systematic review. It has been suggested that the indications for choosing the scoping review methodology include clarification of key concepts and definitions in the literature and determining key characteristics or factors related to a concept.[21] Although we formulated specific research questions (as recommended in the framework and PRISMA-ScR checklist), our aim was fundamentally to provide an overview of knowledge in this field as background for our primary research rather than to synthesise evidence-based guidelines for clinical practice.

A patient and public involvement (PPI) group was set up to advise the development of the project, including this scoping review. The review methods were discussed with the project PPI group and with a regional Young Adults PPI group organised by the South Central Research Design Service of the National Institute for Health Research. These discussions confirmed that the proposed scope was important and relevant to patients and that the approach was satisfactory.

We used the Healthcare Databases Advanced Search (HDAS) resource, provided by the National Institute for Care Excellence and Health Education England, as it enables search of nine relevant databases including PubMed[14]. Articles were included if they were empirical studies or systematic reviews that addressed how inter-organisational electronic health records or health information exchanges were used in inpatient clinical decision-making.

Studies were excluded if they were discussing solely technical aspects or if they addressed only electronic health records within a single organisation. The date range in our search strategy was from April 2008 until April 2018, as both inter-organisational electronic health records and health information exchanges are relatively new innovations.

To chart the results, we developed a data extraction form which was completed by one author, with independent review of a sample of 200 papers at both title and abstract review stages to determine inter-rater reliability.

In stage 1, we identified the research questions. The main research question was: (RQ1) “How do inter-organisational electronic health and care records affect decision-making by hospital physicians and pharmacists?” We also defined secondary research questions: (RQ2) “When are rich electronic health records more useful than summary records?” and (RQ3) “What specific pathways or protocols demonstrate cost reduction or quality improvement (QI) from inter-organisational electronic health records?”

Stage 2 defined the search terms and inclusion/exclusion criteria. We used the following search terms to capture a broad range of relevant literature: (("Decision-making" OR "Clinical decision-making" OR "Computer-assisted decision-making" OR "clinical decision support systems") AND ("Medical Records Systems, Computerized" OR "Electronic Health Records" OR "Hospital Information Systems" OR "Health Information Exchange")). We also hand-searched using the reference lists of the included studies in order to identify additional relevant articles. In addition to our search strategy, we adopted a highly relevant review by Bowden & Coiera as a supplementary source.[22] We also included other systematic reviews that we found in our search, so that we could compare their scope and conclusions with this review.

RESULTS

Stage 3 was the search execution. Using the search terms specified in stage 2, 2196 articles were identified from PubMed and 563 from other HDAS sources. Based on title and abstract review, we excluded the majority of these, but a further 14 articles were identified from the Bowden & Coiera review. Search results were downloaded and imported into Microsoft Excel for further analysis. Guided by the inclusion and exclusion criteria, 22 studies were identified as being pertinent to the review. Two extra snowball references were located. Full text versions of the articles were obtained, with each article being reviewed and confirmed as appropriate by all authors. In total, 24 studies were included in the review. **Figure 3** below shows the PRISMA diagram.

The inter-rater reliability assessment at title and abstract review stage, based in each case on a sample of 200 papers, resulted in Cohen’s kappa = 0.71 showing substantial agreement.[23]

We re-assessed the papers where we had variant conclusions and agreed on all final inclusion and exclusion decisions. At the full text review stage, we jointly assessed all papers and so did not calculate inter-rater reliability.

[Insert Figure 3 here]

Figure 3. PRISMA diagram for study selection.

In stage 4 we charted the data. This search strategy yielded 3 systematic reviews and 21 articles from five countries. Thirteen of the studies were primarily quantitative, 6 were primarily qualitative and one used mixed methods. The quantitative studies were from the USA (n=9) and Israel (n=6). The qualitative studies were from the USA (n=4), UK (n=2) and Canada (n=1).

Table 1 summarises the findings of the 3 systematic reviews. **Table 2** presents the results of the 14 quantitative studies and the quantitative results of the mixed methods study. **Table 3** gives the key conclusions of the 6 qualitative studies and the qualitative results of the mixed methods study.

Ref	Authors	Scope	Date range	N studies included	Findings
[24]	Rudin et al., 2014	Use and effect of HIE on clinical care.	2003-2014	12 hypothesis-testing studies 12 studies of HIE usage 17 studies of financial sustainability 38 studies of attitudes and barriers	Low-quality evidence of cost savings in ED Wide variation in usage levels: typically, 2-10%, but one site achieved 60% 25% claim to have sustainable business model HIE considered valuable but barriers remain: costs, privacy concerns, technical and workflow issues
[22]	Bowden & Coiera, 2017	Impact on accessing primary care records in unscheduled care.	No limit	22	Shared EHRs poorly evaluated. Heterogeneity of systems and populations make it difficult to generalise. No studies used any theoretical model. Evidence for shared EHR benefits is weak.
[25]	Hersh et al., 2015.	HIE outcomes.	1990-2015	34	No studies reported on clinical outcomes or identified harms. Low-quality evidence generally finds that HIE reduces duplicate laboratory and radiology testing, emergency department costs, hospital admissions and improves public health reporting, ambulatory quality of

					care and disability claims processing. Most clinicians attributed positive changes in care coordination, communication and knowledge about patients to HIE.

Table 1. Key findings of the systematic reviews

Ref	Lead author & year	Period	Design	Comparison	Country	Study setting	Population	Sample size	Outcome variable	Result
[26]	Bailey, 2013	2 years	RC	Use of HIE versus non use (concurrent)	USA	15 EDs	Adult repeat visit after headache	1252 adults	HIE usage Neuroimaging volume Guideline adherence Cost	21.8% Lower (OR 0.38, CI 0.29-0.50) Higher (OR 1.33, CI 1.02-1.73) Overall NSD Higher for physician and nurse practitioner usage ($36/visit, p<0.05)
[27]	Ben-Assuli, 2012	4 years	RC	Use of HMO-wide EHR versus non use (concurrent)	Israel	7 EDs	All encounters	3,219,910 ED referrals	ED admission ED single-day admission	Higher when history viewed (OR 1.43, CI 1.42-1.44) Lower when ED crowded (OR 0.97, CI 0.96-0.97) Lower when history viewed (OR 0.84, CI 0.83-0.85) Higher when ED crowded (OR 1.07, CI 1.06-1.08)
[28]	Ben-Assuli, 2013a	4 years	RC	Use of HMO-wide EHR versus non use (concurrent)	Israel	7 EDs	All encounters	281,750 ED referrals	EHR usage ED 7-day readmission ED single day admission	31.2% all patients (4.3% views of external data) Lower when external data used (OR 0.52, p<0.001). NSD for CP and PO differential diagnoses Lower when external data used (OR 0.76, p<0.001). NSD for UTI and PO differential diagnoses
[29]	Ben-Assuli, 2013b	4 years	RC	Use of HMO-wide EHR versus non use (concurrent)	Israel	7 EDs	All encounters	3,219,910 ED referrals	EHR usage ED admission by EHR component viewed ED single-day admission by EHR component viewed	n=519,132 (16.1%) referrals to ED Higher: Past admissions OR 1.52 (CI 1.48-1.56); Surgical history OR 1.62 (CI 1.55-1.70); Pathology OR 1.13 (CI 1.08-1.19) Lower: Lab results OR 0.93 (CI 0.92-0.94) Lower: Past admissions OR 0.88 (CI 0.83-0.92); Surgical history OR 0.83 (CI 0.75-0.91); Lab results OR 0.80 (CI 0.78-0.81)
[30]	Ben-Assuli, 2014	4 years	RC	Use of HMO-wide EHR versus non use (concurrent)	Israel	7 EDs	All encounters	3.2m encounters	EHR usage (all patients) EHR usage (ED admission) EHR component usage by differential diagnosis ED admission by differential diagnosis ED readmission by differential diagnosis	16.1% 23.7% Summary history usage: 20.7% (GE), 27.7% (AP), 32.3% (UTI), 36.8% (CP). Only other components over 10% usage: blood pressure (11.5%, CP), community records (10.7%, CP), surgical history (11.0%, AP) OR > 1 associated with viewing admission history (CP, AP, GE), blood pressure (CP), community records (CP), surgical history (AP) (p<0.01). OR < 1 associated with viewing lab results (all) and imaging (CP, AP, UTI) (p<0.01). OR < 1 associated with viewing lab results (all) and imaging (AP) (p<0.01).
[31]	Ben-Assuli, 2015	4 years	RC	Use of HMO-wide EHR versus non use (concurrent)	Israel	7 EDs	All encounters	815,114 ED patients who had serum creatinine test	EHR usage ED admission ED single-day admission ED 7-day readmission Creatinine result	n=302,127 (37.1%) Higher when EHR used (OR 1.09, CI 1.08-1.10) Lower when EHR used (OR 0.93, CI 0.91-0.96) Lower when EHR used (OR 0.92, CI 0.90-0.94) Single unit increase associated with: Increased likelihood of admission (OR 1.22, CI 1.22-1.23) Decreased likelihood of single-day admission (OR 0.98, CI 0.97-0.99) Increased likelihood of 7-day readmission (OR 1.14, CI 1.13-1.15)
[32]	Daniel, 2010	6 mo pre-EHR, 5 mo post-EHR	RC	Before and after payer-based EHR introduced	USA	1 ED	All encounters	EHR use 779 encounters. Pre-EHR 1509 encounters	ED LOS (not admitted) ED LOS (admitted patients) Cost (discharged patients) Cost (admitted patients)	Lower (19 min, CI 5-33 min) Lower (77 min, CI 28-126 min) NSD Lower ($2,294/patient, p=0.03)

Ref	Lead author & year	Period	Design	Comparison	Country	Study setting	Population	Sample size	Outcome variable	Result
[33]	Frisse, 2011	13 mo	RC	Use of HIE versus non use (concurrent)	USA	12 EDs	All encounters	31,596 ED visits	HIE usage Admissions Estimated cost saving	6.8% all encounters Lower (OR 0.27, CI 0.21-0.35) $1.07m/year
[34]	Lammers, 2014	4 years	RC	EDs using HIE versus EDs not using HIE (concurrent)	USA	447 EDs	All encounters	37 EDs using HIE 410 EDs not using HIE	Repeat imaging in ED	Lower (CT -8.7%, US -9.1%, CXR -13%)
[35]	Johnson, 2011	6 mo	RC	HIE usage versus non-usage	USA	12 EDs and 2 ambulatory clinic groups	All encounters	38,428 ED visits 12,773 clinic visits	HIE usage	6.8% all encounters (6.9% ED, 5.8% clinics) 14.6% at repeat ED visits within 30 days 18.7% at repeat clinic visits 28% for comorbid patients
[36]	Politi, 2015	3 years	RC	Use of HIE versus non use (concurrent)	Israel	1 ED	ED patients sent to resuscitation room	611 patients 639 encounters	HIE usage patterns (type of session, number and % of total) ICU admission	A: quick and basic (n=300, 46.9%), B: moderately basic (n=205, 32.1%), C: moderately elaborate (n=88, 13.8%), D: slow and basic (n=25, 3.9%), E: broad and deep (n=21, 3.3%). OR 1.31 ($p<0.05$) per additional HIE view of the patient record. Higher OR for each HIE usage pattern: B 1.98, C 2.11, D 2.59, E 5.89 ($p<0.05$).
[37]	Jung, 2015	1 year	RC	Use of HIE versus non use (concurrent)	USA	Diagnostic imaging	2 health plans covering 60% regional population	12,620 propensity score-matched patients	HIE usage Repeat imaging Estimated cost saving	30.5% (n=3,843) Lower (OR 0.81, CI 0.69-0.96) $32,460/year ($2.57/patient/year)
[38]	Vest, 2014	6 mo	RC	Use of HIE versus non use (concurrent)	USA	11 hospitals	All discharges	6,807 discharges	30-day same-cause readmission Estimated cost saving	Lower (OR 0.43, CI 0.27-0.70) $605,472/year
[39]	Yaraghi, 2015	2 mo	Non-random control group	Use of HIE versus non use (different ED shifts)	USA	1 ED	All encounters	698 patients using HIE, 1,275 control	Lab test volume Radiology exam volume	Lower in HIE group (52%) Lower in HIE group (36%)
[40]	Boockvar, 2017	2 years 7 mo	Cluster RCT	Access to HIE versus non access for medicines reconciliation	USA	4 inpatient units in a VA hospital	Patients admitted > 24h who had received care outside VA	381 admissions (n=186 with HIE, n=195 control)	Identified risk-weighted discrepancies between preadmission and inpatient medication regimens	HIE group: mean=8.0 Non-HIE group: mean=5.7 (p=0.038)

Table 2. Key quantitative results

Key: RC=retrospective cohort; OR=odds ratio; CI=95% confidence interval; NSD=no significant difference; RCT=randomised controlled trial; ED=emergency department; HIE=health information exchange; EHR=electronic health record; LOS=length of stay; HMO=Health Maintenance Organization; VA=Veterans Administration; AP=abdominal pain; CP= chest pain; UTI=urinary tract infection; GE=gastroenteritis; PO=pneumonia; US=ultrasound; CXR=chest x-ray; ED admission=hospital admission following ED visit; ED single-day admission=ED admission where LOS=1; external data=data from other hospitals.

Ref	Authors	Country	Objectives	Methods	Participants	Findings
[41]	Greenhalgh et al. 2008	England	Explore introduction of SCR and draw wider lessons about large-scale HIT	Multi-site mixed methods case study using DoI	Four early adopter SCR sites 250 interviews 1500 hours observation	Key interacting influences: SCR immaturity and lack of interoperability; concerns about workload and confidentiality; influence of champions; organizational background and readiness; implementation process; programme coherence; political context.
[42]	Hincapie et al. 2011	USA	Evaluate physician perceptions of Arizona Medical Info Exchange	Focus groups	29 clinicians	Benefits: identification of “doctor shopping”, avoiding duplicate tests, efficiency of information gathering. Limited by data availability.
[10]	Morris et al., 2012	Scotland	Improve safety of unscheduled care when usual primary care record unavailable	Survey	113 clinicians in NHS24 call centres	81% said ECS helpful Clinical management changed in 20% of cases
[43]	Gordon et al., 2015	USA	Understand utility of HIE to ED physicians	Interviews	40 interviews with 29 physicians	Themes: importance of unexpected information; historical lab results as reference points; context for admission/discharge decisions; improved confidence; changing decisions for diagnostic imaging
[44]	Alexander et al., 2017	Canada	Explain how value of shared EHRs is captured	Collaborative inquiry	3 case studies	Value of patient focus in mental health service, not merely process efficiency. Improved information access by stroke team increased number of patients served and optimised referrals of urgent cases. EHR data enabled risk stratification and targeted pharmacy advice.
[35]	Johnson et al., 2011	USA	Explore characteristics of HIE use and users.	Semi-structured interviews and observation	369 clinician interviews in EDs and ambulatory clinics	19.8% said repeat tests avoided 12.5% said extra communication avoided 9.8% said helpful to have prior lab results 6.0% said patient seen faster 5.2% said social data helpful 4.9% said treatment plan changed 3.0% said admissions avoided

Table 3. Key qualitative results

Stage 5: Collating, summarising and reporting the results. We found six recurring themes related to our research questions from the quantitative results given in **Table 2**. We define themes as similar findings in three or more studies. The derived themes are shown in **Table 4**. Overall, low usage was the most frequently reported finding, with a minimum of 6.8% of encounters, a maximum of 37.1% and mean 20.8%. This is relevant as it relates to the prior decision about when HIE usage is required. There were superficially contradictory effects on admission decisions. Each of these six themes is at least implicitly related to some impact of inter-organisational health records upon clinical decision-making.

Theme	Relationship to research questions	No. papers (%) (Total n=14)	References
Low HIE usage	RQ1: common factor is clinical judgement about whether extra information is needed	9 (64%)	26, 28, 29, 30, 31, 33, 35, 36, 37
Reduced ED admission	RQ1: shared record has implicit effect on admission decision	5 (36%)	28, 29, 30, 31, 33
Increased ED admission	RQ1: shared record has implicit effect on admission decision	4 (29%)	27, 29, 30, 31
Reduced costs	RQ3: shared record reduces cost in some cases	4 (29%)	32, 33, 37, 38
Reduced diagnostic tests and imaging examinations	RQ3: shared record reduces perceived need for further diagnostics	3 (21%)	34, 37, 39
Reduced ED readmission	RQ1: implies shared record has implicit effect on readmission decision	3 (21%)	28, 29, 38

Table 4 – Recurring themes in the 14 quantitative studies

Other interesting findings that only featured in one or two quantitative studies, but relevant to our research questions, were: improved guideline adherence,[26] reduced ED length of stay,[32] increased detection of medication discrepancies,[40] costs unchanged,[26 32] variation in the EHR components used according to differential diagnosis[30] and the existence of distinct patterns of usage (ranging from “quick and basic” to “broad and deep”).[36]

These findings are consistent with four qualitative findings: avoiding duplicate diagnostics,[35, 42] changing clinical decisions,[10,35,43] the value of historical laboratory results,[35,43] and optimising the timeliness of care.[35,44]

DISCUSSION

RQ1: How do inter-organisational electronic health and care records affect decision-making by hospital physicians and pharmacists?

The mixture of positive and negative results about admission rates from ED, ED length-of-stay and diagnostic volumes illustrate the multifaceted interplay of factors at work here. Variance is inferred to arise from the collective impact of richer knowledge about each patient in a particular population. The various net financial impacts reported are consequences of that set of effects. It is not a simple linear relationship of "more data reduces admissions and length-of-stay and therefore cost". As noted in our protocol, this is a complex socio-technical phenomenon. However, in this scoping review, we found only passing references to socio-technical impacts where the theoretical lens of the DiCoT-CL model[19] would be directly applicable. This probably reflects more about how studies were framed than the actual causal factors at work, given that many benefits described as linear effects in fact require multiple team interactions (for example, avoiding readmission or reducing length-of-stay). Bowden & Coiera[22] also noted the absence of theoretical framing in the evaluation of inter-organisational health records. One qualitative study[41] did take an explicitly socio-technical perspective, but concentrated on factors related to adoption rather than effects on clinical decisions.

One qualitative study[43] specifically explored the impact of HIE upon clinical decision-making in the emergency department. Clinicians reported that using HIE changed their decision-making in 12/37 (32%) of the patient encounters studied. Notably, in 34/37 (92%) of the encounters, the clinician was looking for a specific "known unknown", but in 14/37 (38%) cases found unanticipated useful information. Clinicians reported increased confidence, even when a decision was unchanged, and that more complete information gave context to decisions. In comparison, another qualitative study reported changed clinical decisions in 4.9% of cases[35] and yet another reported 20%.[10]

A cluster of findings suggests that the generally observed low rate of usage of inter-organisational health records is predominantly down to clinical judgement about whether extra information is needed for a particular patient. The literature showed usage variance by differential diagnosis[30], usage patterns ranging from "quick and basic" to "broad and deep",[36] admission rates co-varying with level of ED crowding,[27] association between admission rates and information component usage[29] and searches for specific missing data.[43] In other words, we propose that the low usage rate is largely due to the judgement by the clinician about relative need for more data given what is already known and the nature of the immediate presenting problem. The "hidden variables" in usage levels for inter-organisational health records seem to be patient complexity, clinician judgement and organisational context.

Therefore, there is implicit evidence that an information value chain[20] exists with respect to inter-organisational health records, in that decisions clearly are changed, processes are altered and outcomes are changed. It is quite obvious, for example, that discovering relevant

laboratory test results or imaging examinations simply obviates the need for their repetition. However, the steps in most instances of that chain remain fairly opaque. We have a glimmer of insight from the study which analysed EHR component usage,[29] which showed a relative increase in admissions for emergency patients with chest pain when admission history and blood pressure were viewed and a relative reduction when laboratory results and imaging reports were viewed. It does seem plausible that there would be an association between presenting condition and perceived information need. What we do not know is how each clinician decided which parts of the record were important for which chest pain patients and whether such judgements are consistent professional practice across a clinical team or merely idiosyncratic. This current limited understanding of the information value chain is tentative and solely qualitative, given the heterogeneity of the quantitative results.

This review found limited data about the impact of inter-organisational health records on pharmacist decisions. We know anecdotally that shared records are frequently used in hospital medicines reconciliation, but we found only one published study of this aspect. There was one other reference to medication, in a study that mentioned shared EHR data enabling risk stratification and targeted pharmacy advice.[44]

RQ2 When are rich electronic health records more useful than summary records?

We cannot answer this question precisely from the literature, but there are some straightforward inferences that can be drawn. Firstly, the overall low usage rate of inter-organisational health records in itself implies that only the minimum necessary set of data is usually wanted. This is supported by the finding[36] that the “quick and basic” use pattern of HIE and the “moderately basic” use pattern between them account for 79% of usage and the observation[43] that in 92% of patient encounters, the clinician was looking for a specific item of missing data. Related earlier work has suggested a very limited “lifetime” of information utility.[16] Secondly, there are some examples of when more than basic data is needed: extant history of previous admissions or surgery[29] or when presenting complaint is chest pain, abdominal pain or gastroenteritis.[28] A prospective evaluation by clinical scenario and regression analysis of usage levels and patient parameters would be needed to make any robust conclusions about this question, but there is an obvious relationship between the complexity of the case and the perceived relative need for rich data. However, there is also the finding[43] that in 38% of cases the clinician found information that was *unexpectedly* useful, so there is also a need to signpost potentially relevant data once there are some decision rules for how to work out what that is.

RQ3 What specific pathways or protocols demonstrate cost reduction or quality improvement from inter-organisational electronic health records?

We found no consistent evidence of particular pathways or protocols where costs were reduced or quality was improved by using inter-organisational electronic health records. There is consistent evidence of reduction in laboratory tests and diagnostic imaging, but the only specific condition where that was shown is adult repeat emergency visit after headache.[26]

Comparison with previous reviews

All three systematic reviews that we considered highlighted the relative weakness of evidence about this topic. The substantial variation in HIE usage levels has been noted,[24] as has the absence of theoretical framing[22] and data about patient outcomes.[25] Two out of three systematic reviews noted that clinicians were generally positive about the value of shared EHRs.[24,25] Two of the systematic reviews mentioned the role of HIE in reducing medication discrepancies.[22,25]

Further work

We suggest that future studies of shared EHRs and clinical decision-making should explicitly address the socio-technical concept of team cognition, as modelled in DiCoT-CL, and the related notion of "collective intelligence".[45]

We hypothesise that it is feasible to estimate a maximum achievable usage level of inter-organisational health records by developing regression models of actual usage and population case-mix. There is the potential to use propensity scoring[46] to model patient populations to control for "confounding by indication",[47] using covariates such as presenting complaint, polypharmacy, comorbidity, surgical history and last admission.

Similarly, we propose that should be possible to develop decision algorithms for information that is potentially useful in a given case but may not be obvious to the clinician from their immediate knowledge. There are significant data analysis and usability design challenges in somehow highlighting the additional unexpected information, but this feature would facilitate targeted quality improvement work that aimed to change clinical judgements about when to use a shared record. This would, in effect, be a form of "recommender system".[23] This could be developed in parallel with professional guidance on indications for consulting shared records, with exemplars of the type of information that can change practice. There should also be consideration of how to bring this kind of awareness into healthcare professional training.

Finally, we suggest a new set of research questions: How many more patients could have reduced diagnostics if inter-organisational health records were used routinely? What is the cost/benefit trade-off of time to find the "extra" data versus cost avoidance and reduced

treatment burden? What are the patient safety benefits especially for people who are confused or unconscious?

Limitations

There is a notable concentration of literature from only a small number of developed countries, presumably reflecting both the nature of their healthcare systems and the relative levels of investment in regional information sharing. As this is a scoping review, we did not make a quality appraisal of the included studies. Our scope included hospital pharmacists, but we found only one study featuring this profession.

We found no follow-up information of longer-term impact on patient clinical outcomes or quality of life. All the studies looked at process outcomes. The study designs were all observational, mostly retrospective cohorts with varying comparisons (mostly concurrent or before-after) and varying adjustments for confounding between patients. There is limited data on what was accessed and how it was used to change decisions.

We note that the specific issues around inter-organisational EHRs may not be intrinsically different from mono-organisational EHRs that contain many years of patient data. There are perhaps questions of provenance and trust and variations in the quality and consistency of both structured and unstructured data, but we did not explore these in detail.

CONCLUSIONS

In the literature that we reviewed, clinicians did not use inter-organisational electronic health records routinely but only when they judged it really necessary. There are mixed effects on admission and costs partly due to confounding by indication and the hidden variables of patient complexity, clinician judgement and organisational context. Health IT programmes should be realistic about what a shared health record can and cannot achieve, what constitutes a satisfactory level of usage and seek to gather data on patient outcomes.

Competing interests

None.

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REFERENCES

1. World Health Organisation. *Global Strategy on Digital Health 2020-2024*. 2019.
2. Middleton, B., D.F. Sittig, and A. Wright, *Clinical Decision Support: a 25 Year Retrospective and a 25 Year Vision.* Yearb Med Inform, 2016. **Suppl 1**: p. S103-16.
3. Sitapati, A., et al., *Integrated precision medicine: the role of electronic health records in delivering personalized treatment.* Wiley Interdiscip Rev Syst Biol Med, 2017. **9**(3).
4. Scott, P., et al., *Learning health systems need to bridge the 'two cultures' of clinical informatics and data science.* J Innov Health Inform, 2018. **25**(2): p. 126-131.
5. NHS England. *Joining up health and care data*. n.d. [cited 2019 June 27]; Available from: https://www.england.nhs.uk/digitaltechnology/connecteddigitalsystems/health-and-care-data/joining-up-health-and-care-data/.
6. Clarke, J.M., et al., *Guiding interoperable electronic health records through patient-sharing networks.* Digital Medicine, 2018. **1**(65).
7. Akhlaq, A., A. Sheikh, and C. Pagliari, *Defining health information exchange: scoping review of published definitions.* BMJ Health & Care Informatics, 2016. **23**(4): p. 684-764.
8. Office of the National Coordinator for Health Information Technology. *What is HIE?* 2019; Available from: https://www.healthit.gov/topic/health-it-and-health-information-exchange-basics/what-hie.
9. HL7. *International Patient Summary*. 2019 [cited 2019 June 27]; Available from: http://international-patient-summary.net/.
10. Morris, L.M., et al., *The Scottish Emergency Care Summary–an evaluation of a national shared record system aiming to improve patient care: technology report.* Journal of Innovation in Health Informatics, 2013. **20**(1): p. 41-49.
11. Whiting-O'Keefe, Q.E., et al., *A computerized summary medical record system can provide more information than the standard medical record.* JAMA, 1985. **254**(9): p. 1185-92.
12. Sanderson, H., et al., *Lessons from the central Hampshire electronic health record pilot project: evaluation of the electronic health record for supporting patient care and secondary analysis.* BMJ, 2004. **328**(7444): p. 875-8.
13. NHS South, C.a.W.C.S.U. *About Us*. 2020 [cited 2020 11 June]; Available from: https://careandhealthinformationexchange.org.uk/about-us/.
14. Scott, P., H. Nakkas, and P. Roderick, *Protocol for a scoping review to understand how interorganisational electronic health records affect hospital physician and pharmacist decisions.* BMJ Open, 2019. **9**(1): p. e023712.
15. Arksey, H. and L. O'Malley, *Scoping studies: towards a methodological framework.* International journal of social research methodology, 2005. **8**(1): p. 19-32.
16. Tricco, A.C., et al., *PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation.* Ann Intern Med, 2018. **169**(7): p. 467-473.
17. Davis, M.C., et al., *Advancing socio-technical systems thinking: A call for bravery.* Applied ergonomics, 2014. **45**(2): p. 171-180.
18. Hazlehurst, B., P.N. Gorman, and C.K. McMullen, *Distributed cognition: an alternative model of cognition for medical informatics.* International journal of medical informatics, 2008. **77**(4): p. 226-234.
19. Furniss, D., et al., *Exploring medical device design and use through layers of distributed cognition: how a glucometer is coupled with its context.* Journal of biomedical informatics, 2015. **53**: p. 330-341.
20. Kim, M.O., E. Coiera, and F. Magrabi, *Problems with health information technology and their effects on care delivery and patient outcomes: a systematic review.* Journal of the American Medical Informatics Association, 2017. **24**(2): p. 246-250.
21. Munn, Z., et al., *Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach.* BMC Med Res Methodol, 2018. **18**(1): p. 143.
22. Bowden, T. and E. Coiera, *The role and benefits of accessing primary care patient records during unscheduled care: a systematic review.* BMC Medical Informatics and Decision Making, 2017. **17**(1): p. 138.

23. Landis, J.R. and G.G. Koch, *The measurement of observer agreement for categorical data.* Biometrics, 1977. **33**(1): p. 159-74.
24. Rudin, R.S., et al., *Usage and effect of health information exchange: a systematic review.* Annals of internal medicine, 2014. **161**(11): p. 803-811.
25. Hersh, W.R., et al., *Outcomes From Health Information Exchange: Systematic Review and Future Research Needs.* JMIR Med Inform, 2015. **3**(4): p. e39.
26. Bailey, J.E., et al., *Does health information exchange reduce unnecessary neuroimaging and improve quality of headache care in the emergency department?* Journal of general internal medicine, 2013. **28**(2): p. 176-183.
27. Ben-Assuli, O., M. Leshno, and I. Shabtai, *Using electronic medical record systems for admission decisions in emergency departments: examining the crowdedness effect.* Journal of medical systems, 2012. **36**(6): p. 3795-3803.
28. Ben-Assuli, O., I. Shabtai, and M. Leshno, *The impact of EHR and HIE on reducing avoidable admissions: controlling main differential diagnoses.* BMC medical informatics and decision making, 2013. **13**(1): p. 49.
29. Ben-Assuli, O., I. Shabtai, and M. Leshno, *The influence of EHR components on admission decisions.* Health and Technology, 2013. **3**(1): p. 29-35.
30. Ben-Assuli, O., et al., *EHR in emergency rooms: exploring the effect of key information components on main complaints.* Journal of Medical Systems, 2014. **38**(4): p. 36.
31. Ben-Assuli, O., I. Shabtai, and M. Leshno, *Using electronic health record systems to optimize admission decisions: the Creatinine case study.* Health Informatics J, 2015. **21**(1): p. 73-88.
32. Daniel, G.W., et al., *Efficiency and Economic Benefits of a Payer-based Electronic Health Record in an Emergency Department.* Academic Emergency Medicine, 2010. **17**(8): p. 824-833.
33. Frisse, M.E., et al., *The financial impact of health information exchange on emergency department care.* Journal of the American Medical Informatics Association, 2011. **19**(3): p. 328-333.
34. Lammers, E.J., J. Adler-Milstein, and K.E. Kocher, *Does health information exchange reduce redundant imaging? Evidence from emergency departments.* Medical care, 2014. **52**(3): p. 227-234.
35. Johnson, K.B., et al., *Health information exchange usage in emergency departments and clinics: the who, what, and why.* Journal of the American Medical Informatics Association, 2011. **18**(5): p. 690-697.
36. Politi, L., et al., *Use patterns of health information exchange systems and admission decisions: Reductionistic and configurational approaches.* Int J Med Inform, 2015. **84**(12): p. 1029-38.
37. Jung, H.-Y., et al., *Use of health information exchange and repeat imaging costs.* Journal of the American College of Radiology, 2015. **12**(12): p. 1364-1370.
38. Vest, J.R., et al., *The potential for community-based health information exchange systems to reduce hospital readmissions.* Journal of the American Medical Informatics Association, 2014. **22**(2): p. 435-442.
39. Yaraghi, N., *An empirical analysis of the financial benefits of health information exchange in emergency departments.* Journal of the American Medical Informatics Association, 2015. **22**(6): p. 1169-1172.
40. Boockvar, K.S., et al., *Effect of health information exchange on recognition of medication discrepancies is interrupted when data charges are introduced: results of a cluster-randomized controlled trial.* J Am Med Inform Assoc, 2017. **24**(6): p. 1095-1101.
41. Greenhalgh, T., et al., *Introduction of shared electronic records: multi-site case study using diffusion of innovation theory.* Bmj, 2008. **337**: p. a1786.
42. Hincapie, A.L., et al., *Physicians' opinions of a health information exchange.* Journal of the American Medical Informatics Association, 2010. **18**(1): p. 60-65.

43. Gordon, B.D., et al., *Impact of Health Information Exchange on Emergency Medicine Clinical Decision Making.* West J Emerg Med, 2015. **16**(7): p. 1047-51.
44. Alexander, T., et al., *The Connecting South West Ontario (cSWO) Benefits Model: An Approach for the Collaborative Capture of Value of Electronic Health Records and Enabling Technology.* Stud Health Technol Inform, 2017. **234**: p. 6-12.
45. Radcliffe, K., et al., *Collective intelligence in medical decision-making: a systematic scoping review.* BMC Med Inform Decis Mak, 2019. **19**(1): p. 158.
46. Austin, P.C., *Optimal caliper widths for propensity-score matching when estimating differences in means and differences in proportions in observational studies.* Pharm Stat, 2011. **10**(2): p. 150-61.
47. Salas, M., A. Hofman, and B.H. Stricker, *Confounding by indication: an example of variation in the use of epidemiologic terminology.* Am J Epidemiol, 1999. **149**(11): p. 981-3.