THE VALUE OF ELECTRONIC HEALTH RECORDS: A LITERATURE REVIEW

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Susan Clamp

Justin Keen

Yorkshire Centre for Health Informatics, University of Leeds

24 Hyde Terrace Leeds LS2 9LN • Tel 0113 3434960 • s.clamp@leeds.ac.uk •

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SECTION 1

INTRODUCTION AND BACKGROUND TO THE STUDY

INTRODUCTION

Electronic health records (EHR) lie at the heart of IT implementation plans in health care systems around the world. This report summarises what we know, and what we don't yet know, about the value of EHR in health care.

This report is presented in two main sections. This first section explains the approach we have taken to assessing the current state of knowledge about EHR, and how to interpret the evidence we present. The second section presents the evidence we have assembled about the value of EHR, and summarises our current understanding. We conclude that we can be confident about the positive effects of EHR in some specific clinical settings, but also that there are many areas where our understanding of costs and effects is at best limited.

OUR APPROACH

We expected, and found, that many papers on EHR were health services research studies. That is, many studies used experimental or quasi-experimental designs. In addition, we found many studies which used observational designs, some employing surveys and other using qualitative methods such as interviews and observation of meetings. Methods for systematic literature reviews of experimental studies are well established (Cochrane Collaboration[1]), but methods that incorporate a range of study types have not been used extensively to date. Our task, therefore, was to identify a strategy for reviewing the literature on EHR which could incorporate studies which used a range of different research methods.

There is currently a great deal of interest in academic circles in strategies for combining different types of evidence in literature reviews. For example, Popay and Roen undertook a study for the Social Care Institute for

Excellence (SCIE) in England, and found a number of different approaches that could be used[2]. In this study we have followed, in broad outline, our University of Leeds colleague Ray Pawson's 'realist synthesis' approach to reviews[3,4]. Pawson et al (2004)[4] contains a helpful four page synopsis of the approach. The main steps are set out below.

An initial sketch of the process of realist synthesis

Define the scope of the review	Identify the question	• What is the nature and content of the intervention? • What are the circumstances or context for its use? • What are the policy intentions or objectives? • What are the nature and form of its outcomes or impacts? • Undertake exploratory searches to inform discussion with review commissioners/decision makers
	Clarify the purpose(s) of the review	• Theory integrity – does the intervention work as predicted? • Theory adjudication – which theories about the intervention seem to fit best? • Comparison – how does the intervention work in different settings, for different groups? • Reality testing – how does the policy intent of the intervention translate into practice?
	Find and articulate the programme theories	• Search for relevant theories in the literature • Draw up 'long list' of programme theories • Group, categorise or synthesise theories • Design a theoretically based evaluative framework to be 'populated' with evidence
Search for and appraise the evidence	Search for the evidence	• Decide and define purposive sampling strategy • Define search sources, terms and methods to be used(including cited reference searching) • Set the thresholds for stopping searching at saturation
	Appraise the evidence	• Test relevance – does the research address the theory under test? • Test rigour – does the research support the conclusions drawn from it by the researchers or the reviewers?
Extract and synthesise findings	Extract the results	• Develop data extraction forms or templates • Extract data to populate the evaluative framework with evidence
	Synthesise findings	• Compare and contrast findings from different studies • Use findings from studies to address purpose(s) of review • Seek both confirmatory and contradictory findings • Refine programme theories in the light of evidence
Draw conclusions and make recommendations		• Involve commissioners/decision makers in review of findings • Draft and test out recommendations and conclusions based on findings with key stakeholders • Disseminate review with findings, conclusions and recommendations

Given the relatively limited time available for the review, and the broad scope of the literature review agreed between Accenture and YCHI – we were to define EHR broadly and seek any relevant evidence – we used a modified version of the approach. Specifically, we:

- Defined the scope of the review. We adopted a very broad view of the definition of EHR, to include clinical images and non-health data, such as data that would typically be held by social services in many countries.

- For practical reasons, we broke down the literature into a number of discrete areas, e.g. evidence about EHR, computerised physician order entry (CPOE) and picture archiving and communication systems (PACS). The literature is effectively compartmentalised under these and other headings, and we found that it was necessary to search within each area separately. (We comment on the use of terms in the literature in Part 2 of this report.)
- In each area, our main focus was on evidence about the impact of EHR on clinical or management processes, and on evidence about the costs and benefits (including patient outcomes) of any observed process changes. We therefore excluded papers which were concerned with technical aspects of the design of EHR, or broader policy issues such as confidentiality of patient data.
- It was apparent early on that there we would find relatively few good papers. Inclusion and exclusion criteria were identified in two stages. In the first stage, papers that appeared to be relevant, and published since 1998, were identified and copies obtained. It was decided that papers published before 2000 would be reports of old-fashioned systems, and would have little relevance to current systems, unless they were general papers. Some 200 papers were identified.
- In the second stage, all of the papers obtained were read closely, to assess the nature and quality of the data presented. Papers with poor evidence were excluded. The usual criteria for high quality evidence were used in each case. That is, we made judgements about the design of experimental studies, or for interview-based studies, using criteria for good experiments and good interview data respectively. This process resulted in a final set of over 70 papers.
- The results of the review were synthesised. The bulk of the work undertaken was focused on ensuring that we had an accurate and complete set of papers.
- In parallel, we have developed a simple framework for our analysis of the available evidence: this is equivalent to the theory development stage in Pawson's process. The main value of the framework lies in

allowing us to identify the places where we have good evidence and where it is weak or missing: it is presented below.

Five Approaches in the Literature

Five distinct approaches were found in the literature:

- experimental methods;
- economic evaluations;
- surveys;
- 'narrative' observational methods (e.g. findings based on a programme of interviews or of regular observations of meetings);
- predictive modelling of cost savings.

A FLEXIBLE CONCEPTUAL FRAMEWORK

In order to make an assessment of our current state of knowledge about EHR, we need to understand the ways in which EHR work – how they impact on clinical and management practices.

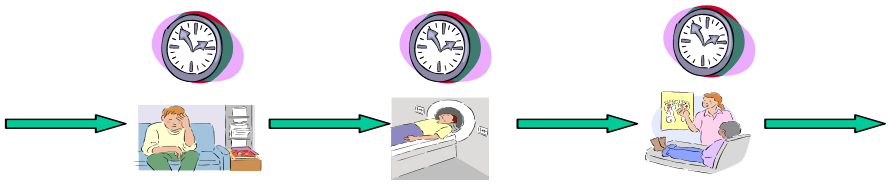
Sensible commentators agree that information technologies can, by their nature, influence behaviour in several different ways. One has only to think of the fact that we communicate in different ways because we have email, order books and CDs in new ways through Amazon, and so on. EHR are the same, in the sense that they might reasonably be expected to change the work patterns of the people who use them. But EHR are different, too. They are unusually complicated technologies, in the sense that they are used by many different people in different ways and in different work contexts. They will be used in one way by a hospital doctor working in A&E/ER, and quite another by a physiotherapist working in the community. Further, there is no single thing called an EHR – there are many different systems on the market already, and no doubt there will be many more in the future.

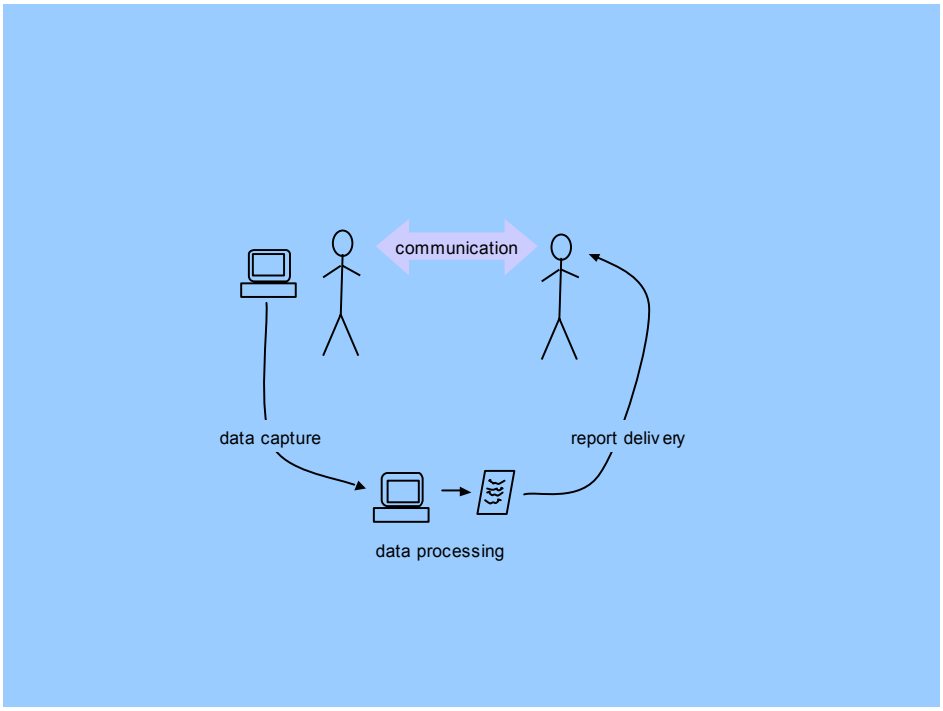
The general literature on the impact of information technologies on organisations suggests several possible causal mechanisms. For the purposes

of discussion here we can separate out two main groups, which we can call micro and macro. At the micro level IT services might influence behaviour in organisations through, for example, improved scheduling, better clinical & administrative communications, and localised structural change. These are three possible 'programme theories' in Ray Pawson's method – theories about the ways in which It services can influence work practices.

- Scheduling: There is ample evidence that health services are not properly integrated, from the point of view of patients or of those who provide and manage services. Systems could be used to ensure that people move 'seamlessly' and efficiently between services (see the first diagram below);
- Communications: the availability of network-based services facilitates new forms of communication between clinicians, as shown in the second diagram below.
- Structural change: the availability of electronic services facilitates new ways of working, as proposed in process redesign and related strategies.

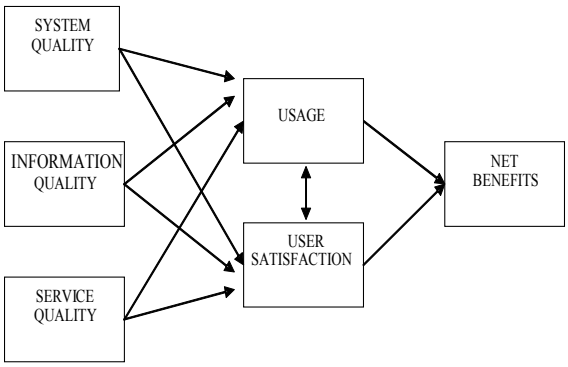
IT may influence work practices through improved scheduling





(Diagram courtesy of Jeremy Wyatt, Dundee University)

These are just three plausible theories of change. Modern electronic services probably work in more subtle ways as well, for example by aiding education and learning 'on the job'. And, there may well be overlaps between the mechanisms: changes in communications may lead to structural changes. To give just one example here, in the review we came across DeLone and McLean's revised success model see Pare et al (2004)[5].



This posits a relationship between an information system and benefits, which is influenced by other factors.

The key general point here is that there is *no agreed set* of mechanisms whereby IT services influence work practices in health or social care settings. It would be wrong to say that there is no evidence available, but fair to say that, at the start of this review, nobody had written about the possible mechanisms in a systematic way.

There were two practical consequences of this point for the literature review. The first was that we made no assumptions about the causal mechanisms that we thought would be, or should be, reported in the literature. We looked for good evidence wherever it occurred. The second consequence was that, in the absence of general agreement about the ways in which electronic network services influence work patterns, we had to adopt a conservative position on some claims. For example, we found several papers which purported to demonstrate the potential for massive future savings following EHR implementation. The problem here is one of causation. These papers tend to make claims of future savings in operating costs, and often also increased revenue, without showing how the new EHR will generate them. Put another way, there must in practice be several steps between the introduction of an EHR and any measurable cost savings but the papers fail to make clear how, exactly, the EHR will generate the savings. As a result we rejected the claims made in these papers and have not included them in this review. More generally, we excluded papers where the causal chains of events were long, and were not substantiated by the evidence presented.

We now turn to macro effects. These are different in kind to micro effects because they are a consequence of the network operating across many sites, rather than just one. Commercial ventures such as Amazon and eBay provide compelling examples of this kind of 'network effect': the effects are due to the ubiquitous nature of the service. The mechanisms whereby network services exert their effects in *organisational* settings have not been extensively researched (Keen 1998)[6], and we did not find any papers on EHR in this review. This said, we have been investigating these network

effects in health care at Leeds for the last three years, and would be happy to discuss our work with Accenture. We believe – though this is difficult to prove – that some of the most important positive effects of modern network services may be due to these 'network effects', and may not be captured in studies of 'micro' effects which currently dominate the literature.

To summarise then, the ways in which information systems – and particularly electronic network services – influence work patterns are not particularly well understood. This does not mean that it is impossible to say anything about them, but it does mean that we have to be careful in our interpretation of the results found in the literature.

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SECTION 2

THE EVIDENCE

INTRODUCTION

This section sets out the results of the literature review, drawing out what we do and do not know about the impact of EHR in health care. The results are presented in the three main areas where we found relevant papers, namely electronic health records (EHR), computerised physician order entry (CPOE) and picture archiving and communication systems (PACS). We were unable to find any relevant papers under any of the other headings we used.

ELECTRONIC HEALTH RECORDS (EHR)

A number of good, recent papers on the impact of EHR were identified. We start with three systematic reviews, which between them provide a useful overview of the literature. We then cover the following topics:

- Patient outcomes
- Activity/work patterns
- Costs and cost savings
- Time costs
- Other points

Three Systematic Reviews

Poissant et al (2005)[1] reviewed evidence of the impact of EHR on the efficiency of time use by physicians and nurses. Based on 23 high quality papers, they concluded that:

> "The use of bedside terminals and central station desktops saved nurses, respectively, 24.5% and 23.5% of their overall time spent documenting during a shift. Using bedside or point-of-care systems increased documentation time of physicians by 17.5%. In comparison, the use of central station desktops for computerised provider order entry (CPOE) was found to be inefficient, increasing the work time from 98.1% to 328.6% of physician's time per working shift (weighted average of CPOE-oriented studies, 238.4%). Studies that conducted their evaluation process relatively soon after implementation of the EHR tended to demonstrate a reduction in documentation time in comparison to the increases observed with those that had a longer time period between implementation and the evaluation process. This review highlighted that a goal of decreased documentation time in an EHR project is not likely to be realised."

In a review of EHR and quality of care, Delpierre et al (2004)[2] found mixed results:

> "A clear positive impact of CBPRS [computer-based patient record systems] on preventive care was noted. This finding is consistent with other systematic reviews. Improvements in medical practice and the adoption of guidelines was less certain. Positive experiences were as frequent as experiences showing no benefit. In studies of arterial hypertension and major depression, there was no improvement in medical practice and compliance with guidelines."

They also found that:

> "Only six studies analysed the impact of the use of CBPRS on patient outcomes and did not show any benefit of CBPRS…. The [complicated] relationship between the process of care and health outcomes might explain why improved outcomes are difficult to relate to the implementation of CBPRS."

Ross and Lin (2003)[3] reviewed evidence about patient access to EHR. They concluded that there were few good studies. There was modest evidence that access might improve processes, e.g. doctor-patient communication, but low statistical power reduced confidence in any positive findings.

Patient outcomes

The one paper that makes strong claims, that appear to be valid, is by Kinn et al (2001)[4] of a system designed to support a lipid clinic. The key results are shown in the Table below, which lists measurable changes in relevant clinical indicators.

Variable (mg/dl)	Control Group (n=764)	EMR (n=1109)	P value
Total cholesterol	184 +/- 1	171 +/- 1	<.0001
HDL	44 +/- 1	44 +/- 1	NS
Triglycerides	159 +/- 3	159 +/- 3	NS
Mean LDL	110 +/- 1	96 +/- 1	<.0001
Median LDL	104	93	-
LDL <= 105	243 (32%)	785 (71%)	<.0001
LDL <= 110	267 (35%)	839 (76%)	<.0001

This was the strongest patient outcome data we found. We should make one important observation which is that the authors were reporting on their own system – but even allowing for this the results are striking.

Activity/Work Patterns

Garrido et al (2005)[5] report striking positive results from a Kaiser Permanente study of the impact of the introduction of EHR on ambulatory care in two regions in the USA (Colorado and Northwest). Again, this paper was written by 'insiders', in this case Kaiser employees – but also again the results are striking. EHR was introduced over a period of a year in both regions. A number of before and after measures were reported. The number of ambulatory visits reduced significantly in both regions. The authors reported that:

> "Two years after electronic health records were fully implemented, age adjusted rates of office visits fell by 9% in both regions. Age adjusted primary care visits decreased by 11% in both regions and specialty care visits decreased by 5% in Colorado and 6% in the Northeast. All these decreases were significant (P<0.0001)."

Over the same period the number of telephone contacts increased, and there were no significant changes in the numbers of laboratory and radiology tests ordered or in the quality of care more generally.

Wager et al (2000)[6] undertook a qualitative study of EHR in five primary care settings in the USA. They concluded that:

> "Physicians and staff indicated that the EMR system has changed not only how they manage patient records but also how they communicate with each other, provide patient care services, and perform job responsibilities."

Cimino et al (2002)[7] also arrived at positive conclusions. Patient access to EHR improved communication with physicians and – possibly – patients' understanding of their own condition.

Makoul et al (2001)[8] found that EHR changed physician-patient communication patterns in an out-patient setting. They concluded that:

> "An EMR system may enhance the ability of physicians to complete information intensive tasks but can make it more difficult to focus attention on other aspects of patient communication."

That is, the overall results were mixed, in the sense that there was positive evidence that physicians were clarifying what patients were telling them – more than in a control group using paper records – but there was also suggestive evidence that the encounter was less patient-centred, e.g. there was less discussion of the patient's wider social and emotional issues and concerns. In more negative studies, Gadd and Penrod (2000)[9] reported that physician concerns about physician-patient rapport increased following EHR implementation, and also physician disenchantment six months post-implementation of an EHR in an out-patient setting in the USA (Gadd and Penrod 2001)[10].

Costs and cost savings

- Barlow et al (2004)[11] reported substantial cost savings associated with the introduction of an EHR into a multi-site, multi-specialty out-patient clinic organisation in the USA. It is difficult to assess the overall claim of combined cost savings and revenue increase of $952,000 in one year. No account was taken of the cost of implementing and operating the EHR, and while some of the savings reported appear to be reliable, others do not look convincing, at least on the basis of the material presented in the paper.
- Zdon and Middleton (1999)[12] claimed of cost savings made through the avoidance of transcription of data from tapes to records following implementation of EHR. Again, no implementation or running cost data were presented so it is difficult to interpret the results.

Time costs

Keshavjee et al (2001)[13] reported significant reduction in administrative staff time costs, increases in physician time costs, and in chart/EHR related activities following implementation of EHR in primary care in Canada. The papers contain a great deal of data, but the most important single Table is reproduced below. As with so many papers, it reports reductions in time costs for some tasks with increases for others. For example, Saarinen et al (2005)[14] found more time spent on patient care and other nursing activities - but also on document management – in intensive care.

Administrative Tasks	Pre EMR	6 months post	18 months post
Prepare day sheet (min)	9.8	4.1	1.2
95% CI	(3.7)	(.36)	(.11)
Pull charts for day visit (#)	29.2	27.4	22.2
95% CI	(4.1)	(4.5)	(6.9)
Pull charts for day visit (min)	46.4	37.1	16.5
95% CI	(11.9)	(11.1)	(6.8)
Pull charts for inquiries (min)	43.5	38.4	20.6
95% CI	(11.8)	(10.3)	(15.1)
Writing in chart – staff (min)	33.0	44.0	71.9
95% CI	(12.3)	(21.4)	(31.6)
Billing tasks (min/month)	441.7	341.9	389.8
95% CI	(174)	(150)	(103)

Physician Tasks	Pre EMR	6 months post	18 months post
Writing in chart (MD) min	101.3	149.3	102.8
95% CI	(24.7)	(50.1)	(18.3)
Paper use (%)	100	52.6	39.0
Script writing and renewals - min	16.2	14.2	21.3
95% CI	(2.5)	(3.0)	(5.8)
Consult reports review - min	14.9	14.6	23.4
95% CI	(3.4)	(2.9)	(6.8)
Lab report review - min	14.3	15.1	12.1
95% CI	(2.47)	(2.7)	(2.3)
Number of patients seen per day	34	-	33.4
Billing tasks (min/month)	4.31	-	3.84

Other papers failed to find significant differences between paper records and EHR:

- The results of the study did not reveal a significant difference in the overall time to complete typical physician tasks. However, on average physicians can perform *viewing* tasks faster, *documenting* tasks slower and *ordering* tasks at about the same speed on the graphical-based system than on the paper based system (Rodriguez et al 2002)[15]
- No difference between paper and EHR in tasks in 5 primary care clinics (Pizziferri et al 2005)[16]
- No significant difference in consultation time compared with paper records – see Table below (Newmark 2004)[17]
- No significant difference between charts and EHR in intensive care setting (Apkon and Singharviranon 2001)[18]

Table from Newmark (2004)[17]

Table 1. Time spent in analysis categories

Analysis Categories	Minutes per Patient: Adjusted Means		Diff
	Pre-EHR (N=20)	Post-EHR (N=20)	
Direct Pt Care	14.29	13.41	-.88
Indirect Pt Care–Read	1.84	2.65	.81
Indirect Pt Care–Write	5.81	5.92	.11
Indirect Pt Care–Other	1.32	1.35	.03
Administration	.45	.88	.43
Miscellaneous	3.86	2.89	-.97
Overall Time Spent	29.47	25.13	-4.34

Note: Overall Time Spent per pt. was calculated independently, not by the sum of time spent in each of the analysis categories.

Patient perceptions of EHR

- In a qualitative study, Ralston et al (2004)[19] reported on the value of access to a diabetes management programme. Patients with diabetes who rated the programme reported a range of both positive and negative experiences.

- Survey results suggest positive user satisfaction with EHR (Hier et al 2004[20]; O'Connell et al 2004)[21]

Other papers

- EHR compare favourably with paper records for completeness and legibility, in a study in England (Hippisley-Cox et al 2003)[22]
- Report of EHR containing significant inaccuracies and missing data in prescribing data (Ernst et al 2001[23], Manley et al 2003)[24]

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Section 2 Electronic Health Records – Benefits Table

1 Systematic Reviews					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Poissant L, Pereira J, Tamblyn R, Kawasumi Y. J Am Med Inf Assoc 12; 506-16, 2005		Systematic Review (23 papers included)	Hospitals	Time costs of physicians and nurses	The use of bedside terminals and central station desktops saved *nurses*, respectively, 24.5% and 23.5% of their overall time spent documenting during a shift. Using bedside or point-of-care systems increased documentation time of *physicians* by 17.5%. In comparison, the use of central station desktops for computerised provider order entry (CPOE) was found to be inefficient, increasing the work time from 98.1% to 328.6% of physician's time per working shift (weighted average of CPOE-oriented studies, 238.4%).
Delpierre C, Cuzin L, Fillaux J, Alvarez M, Massip P, Lang T. Int. J Quality Health Care, 16(5), 407-16, 2004		Systematic review (26 papers included)	Any health care setting – but most studies reported were based in hospitals	User perceptions of the value of EHR in clinical practice	Systems increased user and patient satisfaction. Studies of quality of care and patient outcome (6 studies) were not conclusive. The review results are all qualitative in nature, as different instruments, eg for measuring satisfaction, were used in different studies and the results could not be combined quantitatively.
Ross SE, Lin CT. J Am Med Inf Assoc 10(2); 129-38, 2003		Systematic review (30 papers included)	Any setting	Effects of patient access to medical records on patients, doctor-patient relationships and medical practice	All results were qualitative. Limitations in study designs make it difficult to arrive at clear conclusions. However, the most clear-cut result was that patient access improves doctor-patient communication. Promoting patient access to records does not appear to create excessive demands on staff time, negatively impact documentation, or adversely affect the doctor-patient relationship. Overall, adult medical patients are likely to look upon patient accessible medical records favourably and to employ them reasonably.

2 Patient Outcomes					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Kinn JW, O'Toole MF, Rowley SM, Marek JC, Bufalino VJ, Brown AS. Am J Cardiol, 88; 163-5, July 15 2001	EMR plus Virtual Lipid Clinic software	Observational. Cohort of 1109 patients seen by 3 physicians.	Lipid clinic	Changes in blood cholesterol and other markers	See main text of report for data: evidence of reduction in cholesterol (184 to 171) and increase in numbers of people with low LDL scores, on introduction of EMR and specialist software (Virtual Lipid Clinic). For LDL, 243 (32% of sample) people had <=105 in the control group, compared to 785 (71%) in the intervention group

3 Activity/work patterns					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Garrido T, Jamieson L, Zhou Y, Wiesenthal A, Liang L. BRIT MED J; 330; 581, 2005	EpicCare	Retrospective, before and after, and cross-site study	Two Kaiser Permanente regions (Colorado and Northwest)	Process change measures, including numbers of ambulatory care visits	Two years after EHR were fully implemented, age adjusted rates of office visits fell by 9% in both regions. Age adjusted primary care visits decreased by 11% in both regions and specialty care visits decreased by 5% in Colorado and 6% in the Northeast. All these decreases were significant ($P<0.0001$). The percentage of members making ≥ 3 visits a year decreased by 10% in Colorado and 11% in the Northwest. The percentage of members with ≤ 2 visits a year increased. In the Northwest, scheduled telephone contact increased from a baseline of 1.26 per member per year to 2.09 after two years. Use of clinical laboratory and radiology services did not change conclusively. Intermediate measures of quality of health care remained unchanged or improved slightly.
Wager KA, Lee FW, White AW, Ward DM, Ornstein SM. J Am Board Fam Pract 13(5); 333-48, 2000	Practice Partner Patient Record (see www.pmsi.com)	Qualitative: interview and non-participant observation	5 primary care practices in the USA	Impact of EHR on work practices	Effective leadership, the presence of a system champion, availability of technical training and support, and adequate resources are essential elements to the success of the EMR. The EMR system changed not only how physicians manage patient records but also how they communicate with each other, provide patient care services, and perform job responsibilities.

Cimino JJ, Patel VL, Kushniruk AW. Int J Med Inf 68; 113-27, 2002	Patient Clinical Information (PatCIS), interfaced with hospital's clinical data system	Multi method study: analysis of system log of usage over 36 months, questionnaires, telephone interviews	Patients and physicians at New York Presbyterian Hospital	36 patients' use of system, patient and physician perceptions of the effect of the system on understanding of own condition, quality of communication with physicians, etc.	Patients primarily used system for viewing laboratory results. Both patients and physicians believed that access improved patient understanding of own condition and quality of communication between the two parties. No adverse events were encountered during the study.
Makoul G, Curry RH, Tang PC. J Am Med Inf Asoc . 8:610-5, 2001	EpicCare	Exploratory multi-method study: videotaped physician-patient encounters, questionnaires, reviews of medical records. Comparison of 3 physicians using EHR with 3 without EHR.	Internal medicine service at an academic medical centre in Chicago	Effects of EHR on physician-patient communication in an examination room	Initial clinic visits took 37.5% longer with EHR than without (35.2 versus 25.6 minutes). Otherwise no significant differences in consultation times were found in mean time across visits. EHR physicians adopted a more active role in clarifying information, encouraging questions, and ensuring completeness at the end of a visit. Suggestion that EHR physicians might be less active than control physicians in three somewhat more patient-centred areas (outlining the patient's agenda, exploring psychosocial/ emotional issues, discussing how health problems affect a patient's life).
Gadd CS, Penrod LE. Proc. AMIA Symp 2000	EpicCare	Longitudinal assessment of physician and patient attitudes using surveys and interviews	Out-patient service in a clinic in Pittsburgh, USA	Physicians' concerns about use of EHR; patients' satisfaction with clinical encounter	For physicians, concerns about physician-patient rapport increased with EHR use over time. Patients did not discern any loss of rapport with physicians.
Gadd CS, Penrod LE. Proc AMIA Symp 2001	EpicCare	Pre- and post-implementation surveys	6 out-patient clinics in Pittsburgh, USA	Physicians' concerns about EHR	Physician disenchantment with EHR 6 months post-implementation.

4 Costs and cost savings					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Barlow S, Johnson J, Steck J. J Healthcare Inf Man, 18(1), 46-51, 2004	IDX	Claimed observational evidence of savings in storage, transcription, etc upon introduction of EHR – but details not given	Multi-site, multi-specialty out-patient clinics, USA	Estimates of cost savings over one year, prediction of future cost savings	Substantial cost savings predicted. We cannot validate the claims in this paper (it is included to illustrate a class of papers found in the literature)
Zdon L, Middleton B. Proc Health Inf Man Sys Soc. 4:97-117, 1999	Logician EMR (from MedicaLogic)	Claimed observational evidence, plus use of Return on Investment approach – but details not given	Out-patient settings, hospital in Minneapolis	Estimates of cost savings post implementation, prediction of future cost savings	Substantial cost savings predicted. We cannot validate the claims in this paper (it is included to illustrate a class of papers found in the literature)

5 Time costs					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Keshavjee K, Troyan S, Holbrook AM, VanderMolen D. Proc AMIA Symp, 309-13, 2001.	Hardware not identified. Software: Purkinje's DOI v1.4 under Windows NT	Observational: timings of physician and administrative staff work practices	Family physicians in Ontario	Time taken for a range of tasks, eg chart writing, billing tasks	See the two tables in the text above, in the Time Costs section
Saarinen K, Aho M. Acta Anaesthesiol Scand, 49:62-5, 2005	CareSuite 6.1 (from Picis, USA)	Observational: timing study of nursing activity before and after CIS implementation	Intensive care in a hospital in Finland	Time spent on specified activities.	Post CIS implementation the total time the nurses spent on documentation of nursing care increased by3.6% (not significant), 15min per shift of 8 hours per nurse. The total time they spent on patient care increased by 5.5% (P<0.05), 21min. Intensive care nursing activities increased by 3.7% (P<0.05), 14min.
Rodriguez NJ, Murillo V, Borges JA, Ortitz J, Sands DZ. Proc. AMIA Ann Symp 2002, p667	In-house "research prototype"	Quasi-experimental comparison of paper versus EHR use, plus survey of users	1 hospital in Puerto Rico (17 physicians), 1 in Boston (19 physicians)	Time to complete defined tasks, user satisfaction	The results of the study did not reveal a significant difference in the overall time to complete typical physician tasks. However, on average physicians can perform *viewing* tasks faster, *documenting* tasks slower and *ordering* tasks at about the same speed on the graphical-based system than on the paper based system. Physicians were significantly more satisfied with the graphical-based system than with the paper-based system.

Pizziferri L, Kittler AF, Volk LA, Honour MM, Gupta S, Wang S, Wang T, Lippincott M, Li Q, Bates DW. J Biomed Inf, 38;176-8, 2005	Longitudinal Medical Record system – appears to be an in-house system	Observational: timing study of physicians before and after EHR implementation, plus physician survey	5 primary care clinics, USA	Time spent on specified clinical and administrative activities, subjective perceptions of EHR use	Post EHR implementation, the adjusted mean overall time spent per patient during clinic sessions decreased by 0.5 min (p = 0.86; 95% confidence interval [-5.05, 6.04]) from a pre-intervention adjusted average of 27.55 min (SE = 2.1) to a post-intervention adjusted average of 27.05 min (SE = 1.6). A majority of survey respondents believed EHR use results in quality improvement, yet only 29% reported that EHR documentation takes the same amount of time or less compared to the paper-based system.
Newmark L, Kittler A, Lippincott M, Volk LA, Honour MM, Gupta S, Wang SJ, Bates DW. Medinfo 2004; 17	Ambulatory EHR developed in-house	Observational: timing study of physicians before and after EHR implementation	5 primary care clinics, USA	Time spent on specified clinical and administrative activities	No significant difference in consultation time between EHR and paper records
Apkon M, Singhaviranon P. Intensive Care Med 27:122-30, 2001	In-house system	Observational: timing study of documentation tasks, plus retrospective analysis of documentation	1 paediatric intensive care unit, USA	Comparison of electronic and handwritten documents: time taken to complete tasks, completeness of records	Documentation time varied by user (but not charting method). 13% less time to document using EHR (NS). Electronic documents contained 50% more descriptors than handwritten documents (17.8 +/- 1.4 versus 11.6 +/- 1.4)

6 Patient/User Perceptions of EHR					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Ralston JD, Revere D, Robins LS, Goldberg HI. Brit Med J 328: 1159, 2004	In-house web-based system, providing remote access to hospital EHR	Semi-structured interviews with patients, analysis of patient diaries, for people with Type II diabetes	None – patients' homes in Washington state, USA	Patient views on access to their records	There are several observations in the paper about the use of EHR. For example, participants valued seeing the results of their medical testing online. Seeing the results in the live record at home filled a need not previously met by the usual methods of reporting results. And, as patients uploaded and interacted with the information on their blood glucose levels and the lifestyle information in the module, they felt their provider was benevolently watching them.
Hier DB, Rothschild A, LeMaistre A, Keeler J. Medinfo 2004; 1300-3	Powerchart (Cerner Corporation)	Survey of physicians	1 hospital, Chicago, USA	User acceptance of EHR	Good user acceptance of the EHR. 88.0% (168 out of191) of the house staff and 64.7% (90 out of 139) of respondents preferred the EHR over a paper record. Note only 36.3% response rate.
O'Connell RT, Cho C, Shah N, Brown K, Shiffman RN. J Am Med Inf Assoc 11(1); Jan/Feb 2004	Logician ambulatory care system	Survey of physicians in 2 specialties (medicine and paediatrics)	Yale-New Haven Hospital, Primary Care Centre	Satisfaction with EHR, perceptions of practicality, impact on clinical practice	100% response rate (N=45). Satisfaction with the EHR implementation was high for both groups of physicians. Internal medicine residents were significantly less likely to be satisfied with the EHR implementation (relative risk [RR] = 0.84, 95% confidence interval [CI] = 0.73–0.98) and less likely to believe that their colleagues were satisfied with it (RR = 0.56, 95% CI = 0.41–0.77).

7 Other Papers					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Hippisley-Cox J, Pringle M, Cater R, Wynn A, Hammersley V, Coupland C, Hapgood R, Horsfield P, Teasdale S, Johnson C. Brit Med J 326;1439-43, 2003	UK general practice systems	Quasi-experimental study comparing paper-based and computerized practices	25 general practices in Trent in England (53 GPs)	A range of tests of records – legibility, completeness, etc.	More paperless records were fully understandable (89.2% *v*69.9%, P=0.0001) and fully legible (100% *v* 64.3%, P < 0.0001). Paperless records were significantly more likely to have at least one diagnosis recorded (48.2% *v* 33.2%, P=0.05), to record that advice had been given (23.7% vs 10.7%, P=0.017), and, when a referral had been made, were more likely to contain details of the specialty (77.4% *v* 59.5%, P=0.03). When a prescription had been issued, paperless records were more likely to specify the drug dose (86.6% *v* 66.2%,P=0.005).
Ernst ME, Brown GL, Klepser TB, Kelly MW. Am J Health-Syst Pharm; 58;2072-5, Nov 2001	Not stated	Pharmacists documented differences between actual prescription and recording of the prescription in an EHR, during prescription renewal clinics	Family medicine out-patient clinic, University of Iowa	Number of recording errors	Pharmacists processed 950 prescription-renewal requests for 134 medications during the study period. Medication discrepancies were noted for 250 (26.3%) of these requests. Over half (58.8%) of the discrepancies were for prescriptions that the patient was taking but that were not recorded in the medication list.

Manley HJ, Drayer DK, McClaran M, Bender W, Muther RS. Pharmacotherapy 23(2):231-9, 2003	Not stated	Pharmacists documented differences between actual prescription and recording of the prescription in an EHR, based on record review and patient interviews	Out-patient haemodialysis clinic, Kansas City	Number of recording errors	215 drug interviews were conducted in 63 patients. One hundred and thirteen drug record discrepancies were identified in 38 patients (60%). Discrepancies (mean ± SD 1.7 ± 1.3, range 1-7) were identified during 65 drug interviews (30.2%). Electronic drug records were discrepant by one drug record, two drug records, and more than two drug records 60.0%, 26.2%, and 13.8% of the time, respectively. Drug record discrepancies placed patients at risk for adverse drug events and dosing errors in 49.6% and 34.5%, respectively, of 113 discrepancies.

EHR

Patient outcomes	Work patterns	Costs and cost savings
•One good paper shows lipid measure reductions	• Some good papers demonstrating changes in patterns of service delivery	• Papers making strong claims, but evidence relatively weak
Time costs	**Other papers**	
•Systematic review shows redistribution of time costs between physicians, nurses and admin staff	•Range of relatively weak supporting evidence	

Key: strong reasonable weak none

COMPUTERISED PHYSICIAN ORDER ENTRY (CPOE)

Introduction

A report from the Institute of Medicine in the USA in 2000[1], "To Err is Human", estimated that 44000 Americans die each year as a result of medical errors, of these 7000 due to medication errors (MEs** - see definitions listed at the end of this section). It suggested that more than 50% of 1.8 billion prescriptions used incorrectly and drug related problems along with adverse drug reactions (ADEs***) account for 10% of hospital admissions. A report by the Department of Health in England in 2000[2], "An Organisation with a Memory", stated that 10000 hospital patients per year had a serious ADE and that 20% of clinical negligence litigation stems from hospital MEs. A 2001 Audit Commission report, "A Spoonful of Sugar[3]: Medicines Management in NHS Hospitals", showed an upward trend in deaths from MEs and adverse events from medicines between 1990 and 2000.

Following these and other publications in the literature (Gurwitz et al 2003[4], 2005[5]), the Institute of Medicine report "Crossing the Quality Chasm" (2001)[6] and The Leapfrog Group - a patient safety organisation of 170 healthcare companies and organizations - have recommended widespread use of CPOE to improve safety and quality of healthcare delivery. In 2002 less than 5% of US hospitals used CPOE and only between 5 and 18% of physicians did so. However surveys carried out in 2004 by HIMSS Analytics found this had risen to 22% (based on data from 3989 hospitals) and in April 2005 by the American Hospital Association (based on a representative sample of over 900 community hospitals) found that 48% had implemented some form of basic CPOE for pharmacy and 62% for radiology [(7)].

CPOE is an expensive and complex application, which requires a large investment in redesigning inpatient care processes, changing clinical practices involving nurses, physicians, pharmacists and ancillary staff. There have been numerous studies on the implementation and effect of CPOE in the medical literature from 1980s onwards. The majority of studies involve custom-developed systems in large academic medical centres over a period of years.

Most studies are concerned with medications, and there a very few studies concerned with CPOE for laboratory and imaging tests. The majority of studies showed a reduction of medication errors to varying degrees. There was little reduction in the preventable ADE rate. There is sufficient evidence to show that the use of clinical decision support (CDSS****) in CPOE is a necessary function to realise benefits and increases clinical engagement. However in the AHA 2005 survey only around 10% of the CPOE systems in use have any CDSS functionality [(7)]. There are limited data on the financial implications of CPOE.

Potential Benefits of CPOE:
We identified a number of variables that CPOE might be expected to influence:

- Reduction in ME rate
- Reduction in preventable ADE rate
- Standardization of care – through use of defined protocols and clinical decision support
- Improved efficiency of care delivery – through automation of manual tasks, reduction in illegibility, reduced turn around time, scheduling
- Improved quality of care – through faster access to information, release of time from administrative task to clinical care
- Cost savings – through reduction in; ADEs, length of hospital stay, utilisation of tests, expensive medications and litigation

Reduction in ME rate
There is evidence that use of CPOE significantly reduces all medication errors by 40- 80%.

Major studies from Brigham and Women's Hospital, Boston show a significant decrease in serious medication errors by 55% (Bates et al 1998)[8] and 86% (Bates et al 1999)[9], this includes all type of errors – dose, frequency, route, substitution and allergies. Most medication errors are recognised before incorrect treatments are administered to patients and pose little threat to them. Less than 5% of all MEs result in an actual ADE.

Reduction in preventable ADE rate

There is no significant evidence that use of CPOE reduces preventable ADE rate. Studies show a trend towards reduction but numbers are too small to reach significance. Bates (1998)[8] showed a decrease in preventable ADEs of 17%, Potts (2004)[10] showed that use of CPOE on Paediatric unit would prevent one ADE every 64 days. However, numbers in both studies were too small to achieve significance.

Standardization of care

There is sufficient evidence to show that the use of clinical decision support (CDSS) in CPOE is a necessary function to realise benefits and increases clinical engagement. Benefits observed depend on the functions and complexity of CDSS used in studies (Nebeker et al 2005[11], Scott Evans et al 1998[12]). CPOE linked to just a few laboratory results can have a positive impact on prescription errors (Oliven et al 2004)[13].

Studies have tended to be on specific interventions – use of antibiotics (Scott Evans et al 1998)[12], Vancomycin (Shojania et al 1998)[14], Histamin2 blockers, Ondasteron and subcutaneous heparin (Teich et al 2000)[15], patients with renal insufficiency (Chertow 2001)[16]. Benefits included increase in the use of recommended drugs from 15% to 81%, 10% increase in accuracy of prescribing dosage, and frequency from 6% to 75% (Teich et al 2000)[15]. A study of CPOE with CDSS in laboratory tests showed a 50% reduction in ordering of redundant laboratory tests, by using guidelines (Bates et al 1999)[17].

Improved efficiency of care delivery

Illegible prescriptions are reduced to 0% with CPOE, and record availability is 100% (Almond 2002)[18]. Turn-round times from ordering to dispensing have been shown to decrease by up to 2.5 hours (Lehman et al 2001)[19]. The time taken by physicians to write orders increases by around 5%: this decreases with time, and with familiarity with the system (Overhage et al 2001[20], Shu et al 2001[21]). This is often offset by a decrease in time spent by nurses, although in one observation study in UK the time to complete the ward medication administration rounds doubled (Almond 2002)[18]. There is no evidence of reduction in pharmacist time spent dealing with prescriptions.

Reduction in the ME rate improves efficiency of care, as even MEs that do not harm the patient take up personnel time, largely for nurses and pharmacists.

Improved quality of care

Although there is no reduction in pharmacist time associated with CPOE, there are changes in their work patterns. Pharmacists have an important quality control role in checking prescriptions. An analysis of 6 hospitals in the UK (Audit Commission 2001)[3] showed that up to 50% of observed errors were routine, e.g. patient's name incorrectly spelt. Pharmacists only spent 5%-20% of their time on clinical care. Prescription monitoring and adaptation was reduced to less than 10% in a UK hospital using CPOE, allowing pharmacists to spend around 70% of their time on direct patient care (Abu-Zayed et al 2000)[22]. In a US study the pharmacists spent 46% more time on problem solving activities and 34% less time filling in prescriptions (Murray et al 1998)[23].

Cost savings

Most papers do not attempt to discuss costs and savings, those that do have extrapolated from results in one or two units to a general hospital or to national level.

Over the last ten years the major studies have come from Brigham and Women's Hospital, Boston. The results from these studies have been used by the US Institute of Medicine and the Leapfrog Group in their call for widespread use of CPOE. These studies have estimated hospital wide savings of $480,000 for reduction in ADE rate and costs of developing (this is a system developed in-house over several years) and implementing CPOE at $1.9 million with maintenance costs of $0.5 million (Bates et al 1998)[8].

Where specific CDSS interventions have been used, savings on the use of drugs have been observed (Ondansetron $250,000 in first year (Teich et al 2000)[15], Vancomycin $22,500 to $90,000 (Shojania et al 1998)[14]).

In a study sponsored by the Leapfrog Group Birkmeyer, Bates et al (2002)[24] have estimated costs and potential savings. The results depend on factors such as the size of an organisation and the status of its clinical information systems. Implementation and

running costs can vary ten fold. A small hospital (200 beds) with a CIS with electronic order entry capabilities already in place might have typical implementation costs of $0.5M. with running costs of $174,000 per year. For a large hospital (1000 beds) needing a new CIS, the implementation cost could be $15m with running costs of $1.5m. per year.

Other studies (Classen et al[25], Bates et al 1997[26]) have costed savings associated with ADEs at $2000-$2600. However, no study has demonstrated an actual reduction in ADEs. MEs, 5% of which result in an ADE, have been shown to be reduced by up to 80% (Bates et al 1998[8], 1999[9]) and even MEs that do not harm patients have cost implications, related to impacts on personnel time and other efficiency measures.

A report by First Consulting Group on Computerized Physician Order Entry: Costs, Benefits and Challenges (2003)[27], for the American Hospital Association and the Federation of American Hospitals presents case studies of six health organizations implementing CPOE, all with different commercial systems. It sets out a cost model for implementation in a 500 bed hospital with high capacity network and some level of CIS in place of $7.9m for one-time capital plus operating costs and $1.35m annual ingoing costs.

The most important variables that need to be taken into account are the size of the organization, the number of sites and existing technology, both network and CIS. While we have included this type of study, we have reservations about these predictive models, and comment on them later on in this Section.

Johnston et al (2004)[28] studied the value of different levels of functionality of CPOE and estimated costs and benefits. One conclusion was that the benefits of a basic CPOE system for prescription and diagnostic orders will never outweigh its costs, regardless of practice size, and advanced systems are only cost effective in practices with 10 or more physicians.

Definitions (taken from Kaushal et al 2003)[29]

* CPOE refers to a variety of computer-based systems that share the common features of automating the medication (and sometimes the laboratory and imaging) ordering process and that ensure standardized, legible and complete orders.

** MEs are errors in the process of ordering, transcribing, dispensing, administering or monitoring medications

*** ADEs are injuries resulting from drug use. Potential ADEs are MEs with significant potential to harm a patient that may or may not actually reach a patient. ADEs associated with a ME are considered preventable.

**** CDSSs are built into all CPOE systems to varying degrees. Basic clinical decision support provides computerized advice regarding drug doses, routes and frequencies, and more sophisticated CDSSs can perform drug allergy checks, drug-laboratory value checks, and drug-drug interaction checks and can provide reminders about corollary orders or drug guidelines.

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Section 2 Computerised Physician Order Entry – Benefits Table

1 Introduction					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Gurwitz JH, Field TS, Harrold LR, Rothschild J, Debellis K, Seger AC, Cadoret C, Fish LS, Garber L, Kelleher M, Bates DW. J Am Med Assoc. 289(9):1107-16, 2003		12 month cohort study	Older people in ambulatory setting in 1 multi specialty group practice.	Incidence and preventability of ADEs	*30,400* person years of observation reviewed. *1523* ADEs identified (50 ADEs / 1000 person years), of which *27% (421)* considered preventable (14 ADEs / 1000 person years). *38% (578)* of ADEs serious, life-threatening or fatal, of which *42% (244*) were preventable. Errors associated with preventable ADEs occurred most often at prescribing *(246, 58.4%)* and monitoring *(256, 60.8%).*
Gurwitz JH, Field TS, Judge J, Rochon P, Harrold LR, Cadoret C, Lee M, White K, LaPrino J, Erramuspe-Mainard J, DeFlorio M, Gavendo L, Auger J, Bates DW. 2005. Am J Medicine. 118(3):251-258, 2005		9 month cohort study	long stay patients in 2 academic long-term care facilities	Incidence of and risk factors for ADEs	*8336* person months of observation reviewed. *815* ADEs identified (9.8 ADEs / 100 person months), of which *42% (338)* considered preventable (4.1 ADEs / 100 person months). *28% (225)* of ADEs serious, life-threatening or fatal, of which *61% (137*) were preventable. Errors associated with preventable ADEs occurred most often at ordering *(198, 59%)* and monitoring *(271, 80%).*

2 Reduction in Medication Error Rate					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Bates DW, Leape LL, Cullen DJ, Laird N, Petersen LA, Teich JM, Burdick E, Hickley M, Kleefield S, Shea B, Vander Vliet M, Seger DL. J Am Med Assoc. 280(15):1311-1316, 1998	CPOE function of internally developed Brigham Integrated Computing System (BICS). Menu of medications, default doses, range of potential doses. Consequent orders, limited drug-allergy checking, drug-drug-interaction and drug-laboratory checking	Before and after comparison. Phase 1 Baseline 6 months, 1993. Phase 2 Randomized comparison between CPOE and CPOE plus team intervention, changing role of pharmacists, 9 months, 1994/5.	Brigham and Women's Hospital, Boston. Academic, tertiary hospital of 726 beds. All adults admitted to 6 medical and surgical units.	Non intercepted serious MEs	Phase 1 *2491* admissions Phase 2 *4220* admissions Non intercepted serious MEs fell by *55%*, from *10.7 events/1000 patient days to 4.9 events/1000 patient days.* Reduction in errors at all stages of medication-use process (ordering, transcription, dispensing, administration). Dose errors decreased by *23%*, known allergy errors by *56%*, drug-drug interaction errors by *40%* (not statistically significant). (the 134 MEs not prevented could have been by functional changes in CPOE system) No difference with pharmacist team intervention
Bates DW, Teich JM, Lee J, Seger D, Kuperman GJ, Ma'Luf N, Boyle D, Leape L. J Am Med Inf Assoc. 6(4):313-321, 1999	CPOE function of internally developed BICS. See Bates 1998 - CPOE functionality increased over time.	Prospective time series analysis – 7 to 10 week periods in 4 different years. 1992 baseline prior to CPOE. 1993/4/7 after CPOE introduced	Brigham and Women's Hospital, Boston Academic, tertiary, 700 beds. 2 general medical units and 1 ICU	MEs, (excluding missed dose errors)	MEs fell by *81%* overall from *142/1000 person days to 27/1000 person days.* Serious MEs fell *86%* overall Results were similar on both ICU and medical wards All types errors fell – dose, frequency, route, substitution and allergies.

3 Reduction in preventable Adverse Drug Events					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Bates DW, Leape LL, Cullen DJ, Laird N, Petersen LA, Teich JM, Burdick E, Hickley M, Kleefield S, Shea B, Vander Vliet M, Seger DL. J Am Med Assoc. 280(15):1311-1316, 1998	CPOE function of internally developed Brigham Integrated Computing System (BICS). Menu of medications, default doses, range of potential doses. Consequent orders, limited drug-allergy checking, drug-drug-interaction and drug-laboratory checking	Before and after comparison. Phase 1 Baseline 6 months, 1993. Phase 2 Randomized comparison between CPOE and CPOE plus team intervention, changing role of pharmacists, 9 months, 1994/5).	Brigham and Women's Hospital, Boston. Academic, tertiary hospital of 726 beds. All adults admitted to 6 medical and surgical units.	Preventable ADEs Non intercepted potential ADEs Intercepted potential ADEs	Phase 1 *2491* admissions Phase 2 *4220* admissions Preventable ADEs rate fell by *17%* in phase 2 (not statistically significant) Rate of non intercepted potential ADEs fell by *84%* in phase 2 Rate of intercepted potential ADEs fell by *58%* in phase 2 , (not statistically significant) No difference with team intervention
Potts AL, Barr FE, Gregory DF, Wright L, Patel NR. Pediatrics. 113(1):59-63, 2004	CPOE (WizOrder) with CDSS – allergy alerts, dose checking, drug interaction, clinical pathways. Interfaces with clinical data repository – order related and laboratory alerts. Patient and place specific dosage	Prospective cohort, before (2mths) and after (2mth) study	20 bed pediatric critical care unit, Vanderbilt Children's Hospital, all patients.	Frequency of medication ordering errors: Potential ADEs	Pre CPOE 268 patients, 6803 tests ordered Post CPOE 246 patients, 7025 tests ordered ADEs: Pre CPOE *147, 2.2/100* orders potential ADEs Post CPOE *88, 1.3/100* orders potential ADEs Most errors in both stages were wrong dosage Significantly reduced errors in wrong units. Needs paediatric specific CDSS

4 Standardization of Care					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Nebeker JR, Hoffman JM, Weir CR, Bennett CL, Hurdle JF. Arch Intern Med. 165:1111-1116,2005	CPOE – allergy, some drug-drug and drug-disease interaction checking. No advanced decision support or drug selection, dosing or monitoring advice	Prospective case review over 20 week period Aug-Dec 2000, of newly admitted patients to all wards. Cases randomly assigned to 1 of 2 pharmacists	VA Medical Centre, Salt Lake City 110 bed tertiary care teaching facility	ADE	Review of 937 of 2306 admissions. *483* clinically significant ADEs – *70/ 1000* patient days. *67%* of ADEs caused changes in Treatment plan Adverse drug reactions accounted for *93%* of ADEs, *7%* over or under dosing. *91%* were moderate, *9%* serious. High rate of ADEs identified after implementation of CPOE probably due to very good computerized data. Indicate there is a problem with CPOE systems that lack decision support for drug selection, dosing and monitoring.
Scott Evans R, Pestontnik SL, Classen DC, Clemmer TP, Weaver LK, Orme JF, Lloyd JF, Burke JP. NEJM. 338(4):232-238, 1998	CDSS for antibiotics. Linked to patient records, recommends regimes and course of therapy with immediate feedback	Prospective 1 year intervention study 1994-5. Baseline collected for 2 yrs prior to this.	LDS Hospital Salt Lake City, 12 bed ICU.	ADEs Use and cost of antibiotics Cost of hospitalization Length of hospital stay Mortality	545 patients, CDSS used 942 times Physicians prescribed recommended drug, dose, route and interval in 46% but followed recommendations for does and interval in 93% ADEs *28 pre, 4 post CDSS – reduction of 70%* Significant reductions in: orders for drugs to which patients were allergic *(146 pre vs 35 post)* excess drug dosage *(405 vs 87)* Antibiotic-susceptibility mismatches *(206 vs 12)* Costs of drugs *($427 vs $102)* Total hospital costs *($44,865 vs $26,315)* Length of stay *(16.7 vs 10 days).*
Oliven A, Michalake I, Zalman D, Dorman E, Yeshurun D, Odeh M. International J Med Informatics. 74:377-386, 2005	CPOE connected to patients database and drug database, linked to Hospital administration and laboratory databases	Prospective daily review of all orders for 6 months. 1 ward with hand written prescribing (HWdept), 1 with CPOE in use for 3 years (CDOEdept)	Bnai-Zion Medical Centre, Haifa, Israel. Acute care university hospital with two 44 bed medical wards.	Incidence and type of Prescription errors (PE) Usefulness of different components of CPOE Usefulness of specific patient data	10,002 hospital days evaluated Incidence of PEs related to drug database, (incorrect names, dosage, intervals, transcription, drug-drug interactions): HWdept *5.21 per 100 pt days* CDOEdept *1.36 per 100 pt days* Incidence of PEs related to patient database, (: HWdept *7.2 per 100 pt days* CDOEdept *3.02 per 100 pt days* Linking CDOE with few, specific, laboratory results has impact on prevention of PEs

Shojania KG, Yokoe D, Platt R, Fiskio J, Ma'Luf N, Bates DW. J Am Med Inf Assoc. 5:554-562, 1998	CPOE function of internally developed BICS. With CDSS for Vancomycin. Guidelines displayed when order put into CPOE	Randomised Controlled Trial. Physicians randomly assigned to intervention or control group over 10 months.	Brigham and Women's Hospital, Boston. Academic, tertiary hospital of 726 beds.	Frequency and duration of vancomycin use.	396 physicians, 1798 patients *32%* fewer Initial orders *(control 16.7 vs intervention 11.3 orders per physician)* *36%* fewer renewal patients given or renewed vancomycin *(control 10.3 vs intervention 7.4 orders per physician)* *36%* lower duration of therapy *(control 41.2 vs intervention 26.5 days)*
Teich JM, Merchia PR, Schmiz JL, Kuperman GJ, Spurr CD, Bates DW. Arch Intern Med. 160:2741-2747, 2000	CPOE function of internally developed BICS. with computerized guideline initiated when physician enters order (drug use guidelines, alternative therapies, dosage and frequencies)	Time series analysis, 2 successive 4-week periods Oct 1993 preceding intervention, followed by 2 similar periods after guideline in place.	Brigham and Women's Hospital, Boston. Academic, tertiary hospital of 726 beds.	Effect on orders, dosage etc of histamine$_2$ -blockers, ondasteron, subcutaneous heparin	Use of recommended of histamine$_2$ -blockers went from *15.6% to 81.3%* Decreased SD of drug doses by *11%* Reduced exceeded doses from *2.1% to 0.6%* Increased use of approved frequency from *6% to 75%* Use of heparin to prevent thrombosis increased from *24% to 47%.* All changes persisted at 1 and 2 year follow up CPOE with computerized guideline changed physician behaviour.

Chertow GM, **Lee J, Kuperman GJ, Burdick E, Horsky J, Seger DL, Lee R, Mekala A, Song J, Komaroff AL, Bates DW.** J Am Med Assoc.286(22):2839-2844, 2001	CPOE function of internally developed BICS. with CDSS for adjusting drug dose in patients with renal insufficiency	4 consecutive 2 month intervals of control (usual CPOE) with intervention (CPOE with CDSS)	Brigham and Women's Hospital, Boston. Academic, tertiary hospital of 726 beds.	appropriate prescription dose and frequency Length of stay Hospital costs Pharmacy costs Changes in renal function	7490 patients with 97,151 orders, 15% had at least one dosing parameter altered by computer Appropriate dosage *54% control vs 67%* intervention Appropriate frequency *35% control vs 59%* intervention Mean length of stay *4.5 vs 4.3 days* No significant differences in hospital or pharmacy costs or changes in renal function
Bates DW, Kuperman GJ, Rittenberg E, Teich JM, Fiskio J, Ma'Luf N, Onderdonk A, Wybenga D, Winkelman J, Brennan TA, Komoroff AL, Tanasijevic M. Am J Med. 106:144-150, 1999	CPOE function of internally developed BICS. With reminders about clinically redundant laboratory tests	Prospective RCT. 4months baseline, 4 months intervention. Unit of randomization patient admission. Physicians either given or not given reminder that test had been performed when they requested repeat test within test-specific interval	Brigham and Women's Hospital, Boston. Academic, tertiary hospital of 726 beds. All inpatients to medical and surgical wards.	Number of redundant test ordered Number of redundant tests performed Charge savings (14 common and/or costly tests used)	11586 patient admissions randomized. Control group 13,847 tests Intervention group 13,425 tests *502* redundant tests ordered in control group *437* redundant tests ordered in intervention group *257 (51%)* carried out in Control group *117 (27%)* carried out in Intervention group (found that many repeat tests ordered on paper, only 44% ordered through CPOE) Annual saving of $35,000 at 1994 charges

5 Improved efficiency of care delivery					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Almond M. BJHC. 19(2):41-46, 2002	Commercial Electronic prescribing (EP) and electronic medicines administration (EPMA) with CDSS - MediChain	Prospective controlled before (3mths) and after (6mths) study with external validation from London School pharmacy. Plus control ward.	Southend DGH, UK Acute medical ward (33 beds), subspecialty renal, complex admissions – 50 clinicians, 24 nurse (7 prescribing), 29 pharmacists, dietician, ward clerks.	Prescribing quality. Errors in Prescription Administration Record availability Ward Procedures User Views	Prescribing quality improved. *100%* prescription legible – *94%* needed no modification - eliminating need for pharmacists to spend time clarifying prescriptions. Errors reduced from *10% (of 1169) to 4.6% (of 18357)* Administration improved to *96% from 91%* due to availability of chart, legible prescriptions, identified route. *1:4* rounds affected or complicated by missing charts pre-intervention. Increase in time of medicine administration rounds (almost doubled, affecting HC assistants most) but nursing staff able to leave trolley (more secure) if urgently needed elsewhere. User views: Longer to create a prescription for medical staff. System safer Needed support and help desk
Lehman ML, Brill JH, Skarulis PC, Keller D, Lee C. Proc AMIA Symp: 359-363, 2001	Software customized SMS-Invisin system	Before and after study. 2 month baseline, 2 month after implementation	Rush-Presbyterian-St Lukes Medical Centre, Chicago. Academic Hospital 2 surgical services – Neurosurgery and Transplant	Turn-around times	Baseline 100 orders – 34% incomplete data. Average pharmacy-order-around times *3hrs 49mins.* Post-implementation 147 orders Average pharmacy-order-around times *1hr 23mins.*
Overhage JM, Perkins S, Tierney WM, McDonald CJ. J Am Med Inf Assoc. 8(4):361-371, 2001	Medical Gopher system – developed overtime in association with Wishard Memorial Hospital	RCT – practices randomized Observation studies over a 2 year period Survey of physician attitudes	Wishard, Indianapolis. 11 Primary Care internal medicine practices with 34 physicians	Time spent per patient Time taken to write orders Duplicative tasks	Using CPOE *2.2 mins more /patient* but continued to do some task that system would do – if these taken out only spent 0*.43mins longer*. With experience time taken fell by *3.73 min/patient*. Physicians believed that use of POE improved patient care and wanted it to continue in their practices

Shu K, Boyle D, Spurr C, Horsky J, Heiman H, O'Connor P, Lepore J, Bates DW. Medinfo. 10(pt 2):1207-1211, 2001	CPOE function of internally developed BICS.	Prospective study with random reminder methodology	Brigham and Women's Hospital, Boston. Academic, tertiary hospital of 726 beds.	Time spent by interns on ordering through CPOE	Interns spent *9%* of their time ordering with CPOE, compared with *2.1%* before. Decreased time spent by nurses and pharmacists and increased quality and efficiency. CPOE represent major process change

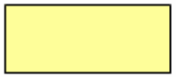
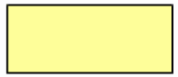
6 Improved quality of care					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Abu Zayed L, Farrar K, Mottram DR. Am J Health Syst Pharm. 57:2006-2007, 2000 PhD, Liverpool John Moore University 1998	CPOE	Activity analysis	6 UK Hospitals. 1 with CPOE (Wirral)	Ward Pharmacist activity	Pharmacists at CPOE hospital spent *7%* of their time on prescription monitoring and *70%* on clinical activities, compared to average of *20%* on prescription monitoring and *19%* clinical activity in non CPOE hospitals.
Murray M, Loos B, Wanzhu T, Eckert GJ, Xioa-Hua Z, Tierney WM. J Am Med Inf Assoc. 5:546-553, 1999	VAX-based pharmacy CPOE module in Regenstrief Medical Record System	Before (3mths) and after (2mths) study. Multidimensional work sampling (activity, function, contact) of pharmacist	Regenstrief Health Centre, Wishard Health Services, Idianapolis. General medical practice and outpatient facility with outpatient pharmacy,	Effect on pharmacist working practices	Average 1000 prescriptions/day *13%* more time checking prescriptions – improved safety *4%* less time waiting for work *2.2%* less time in discussion *34%* less time filling prescriptions *46%* more time in problem solving activities *3.4%* less time giving advice

7 Cost Savings					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Bates DW, Spell N, Cullen DJ, Burdick E, Laird N, Petersen LA, Small SD, Sweitzer BJ, Leape LL. J Am Med Assoc. 280(15):1311-1316, 1998	CPOE function of internally developed Brigham Integrated Computing System (BICS). Menu of medications, default doses, range of potential doses. Consequent orders, limited drug-allergy checking, drug-drug-interaction and drug-laboratory checking	Before and after comparison. Phase 1 Baseline 6 months, 1993. Phase 2 Randomized comparison between CPOE and CPOE plus team intervention, changing role of pharmacists, 9 months, 1994/5).	Brigham and Women's Hospital, Boston. Academic, tertiary hospital of 726 beds. All adults admitted to 6 medical and surgical units.	Estimated costs	Estimated annual cost of ADEs in Brigham and Women's hospital at *$2.8m*. Decrease in ADE rate by *17%*, if hospital wide, would mean savings of *$480,000/ year* (not including costs of injuries, admissions due to drug errors, malpractice suits or extra work generated by non serious errors). Costs of developing and implementing CPOE estimated at *$1.9m* with maintenance costs of *$0.5m/year*.
Teich JM, Merchia PR, Schmiz JL, Kuperman GJ, Spurr CD, Baates DW. Arch Intern Med. 160:2741-2747, 2000	CPOE function of internally developed BICS. with computerized guideline initiated when physician enters order (drug use guidelines, alternative therapies, dosage and frequencies)	Time series analysis, 2 successive 4-week periods Oct 1993 preceding intervention, followed by 2 similar periods after guideline in place.	Brigham and Women's Hospital, Boston. Academic, tertiary hospital of 726 beds.	Effect on orders, dosage etc of histamine$_2$ -blockers, ondasteron, subcutaneous heparin	Costs: Overall costs to implement and maintain CPOE *$7m annually.* Cost savings from ondansetron intervention approx $250,000 in first year. Overall savings from reduction of drug costs, from appropriate use of laboratory tests and diagnostic studies and from prevention of ADEs estimated to be between $5-10m annually. Incremental costs for each new improvement is minimal

Shojania KG, Yokoe D, Platt R, Fiskio J, Ma'Luf N, Bates DW. J Am Med Inf Assoc. 5:554-562, 1998	CPOE function of internally developed BICS. With CDSS for Vancomycin. Guidelines displayed when order put into CPOE	Randomized Controlled Trial. Physicians randomly assigned to intervention or control group over 10 months.	Brigham and Women's Hospital, Boston. Academic, tertiary hospital of 726 beds.	Frequency and duration of vancomycin use.	Annual hospital costs for vancomycin *£300,000*. Therefore reduction in use due to CDSS gives projected savings of *$90,000* per year. However vancomycin *($12/day*) may be replaced by alternative antibiotic – 1st generation cephalosporins *($9/day)* , then estimated savings would be *£22,500/year*
Birkmeyer CM, Lee J, Bates DW, Birkmeyer JD. Eff Clin Pract. 5:67-74, 2002	Review of costs and savings from Implementing CPOE systems, uses data from published papers. Costs are dependant on size of hospital and status of clinical information system (pre-requisite) Can vary ten fold from small hospital with good CIS with electronic order entry capabilities *$0.5m with running costs of $174,000* to large hospital needing new CIS *$15m with running costs of $1.5m/yr* Also need to include costs of computer staff and Clinician time. Savings from reduction in MEs and ADEs *Cost of ADEs* $2013 (Classen 1997), $1939 (Evans 1997), $2595 (Bates 1997) But no studies show significant reduction in ADEs following implementation of CPOE *Cost of MEs* mainly related to personnel time and inefficiency Overall saving proportional to hospital size – e.g. *$184,000/yr 200 bed, $919,000/yr 1000 bed* *Other sources of savings* Medication substitution, Reduced laboratory and imaging tests, Increase in patients on cost effective, disease specific pathways, Potential gains in clinical efficiency Have not assessed indirect economic benefits associated with better quality of care. Leapfrog group estimated CPOE could save *$549m annually* Brigham and Women's hospital estimate savings between *$5-10m* Sarasota Memorial Hospital *$8m*				
Classen DC, Pestotnik SL, Evans RS, Lloyd JF, Burke JP. J Am Med Assoc. 277(4): 301-306, 1997	ADEs	Matched case-control 3 year study	LDS Hospital, Salt Lake City. Tertiary care.	length of stay costs of hospitalization mortality	2.45 ADEs per 100 admissions mortality 3.5% for ADEs vs 1.05% matched controls Length of stay *7.69 vs 4.46 days* Costs of hospitalization $*10,010 vs $5335*. Overall excess cost attributable to ADE *$2282*

Bates DW, Spell N, Cullen DJ, Burdick E, Laird N, Petersen LA, Small SD, Sweitzer BJ, Leape LL. J Am Med Assoc 277(4):307-11,1997	ADEs	Nested case-control study within a prospective cohort study. Stratified random sample	11 medical and surgical units in 2 tertiary care hospitals	Post event length of stay Total costs	190 ADEs – 60 preventable Additional length of stay for ADE was 2.2 days Increased cost associated with all ADEs was *$2595* and for preventable ADEs *$4685* Estimate annual costs attributable to all ADEs for a 700-bed teaching hospital are *$5.6m*
First Consulting Group. Report for AHA and FAH, 2003	Presents case studies of 6 health organizations implementing CPOE – all different organizations and CPOE systems. Developed representative cost- model: E.g. for implementation of CPOE in 500 bed hospital: One-time capital plus operating costs of *$7.9m*, Annual ongoing costs of *$1.35m.* Important variables: Size of organization, Number of sites, Existing technology – network and CIS				
Johnston D, Pan E, Walker J. J Healthcare Inf Management. 18(1):5-8, 2004	CPOE in Ambulatory care – model of costs and savings of different levels of CPOE (Basic Rx, Basic Rx-Dx, Intermediate Rx, Intermediate Rx-Dx , Advanced Rx-Dx) using estimates of Clinical benefits, Financial benefits, System costs, Provider cost benefit. Estimated national figures to give annual savings of $3.5b with basic system to $44.2b with most advanced. Also state benefits of basic system never out weigh their costs and advanced systems only costs benefit if practice has more that 10 clinicians				

Computerized Physician Order Entry

Reduction in ME rate  •strong evidence from clinical trials in large academic tertiary hospitals	**Reduction in preventable ADE rate**  •Trend towards reduction but no significant evidence	**Standardisation of care**  •Use of CDSS helps realise benefits and increases clinical engagement
Improved Efficiency  •Reasonable evidence to show reduces turn round time and inaccurate orders	**Improved Quality**  •Allows pharmacist more time for more clinical and problem solving activities	**Cost Savings**  •Evidence on cost savings is weak and varies with size of organisation, systems in place and functionality of CPOE

Key: strong  reasonable  weak  none 

IMAGING TECHNOLOGIES

Imaging technologies are now in routine use in many different clinical environments. Largely for historical reasons, these technologies have gone under different names in the literature, including telemedicine, picture archiving and communication systems (PACS). In this review it is most helpful to present evidence about clinical images in the round, rather than separate out the literature using the common terms.

Studies of these technologies have, in most cases, focused on single links between a radiology service and a clinical setting, e.g. telemedicine studies of links to GP practices, or of single clinics in hospital in-patient or out-patient settings for PACS. In this section we review studies of any imaging technologies which generate clinical images that could be included in an EHR.

Overall conclusions

The quality of evidence about the use of clinical imaging, with or without EHR, is poor. A stark, though authoritative, statement in a review by Whitten et al (2002)[1] is that:

> "There is no good evidence that telemedicine is a cost effective means of delivering health care."

There is better evidence about the value of clinical imaging in hospital settings, although the number and quality of papers reporting positive results is small, and we found just one good cost study, which reported that PACS increases hospital running costs.

Clinical imaging in hospital settings: evidence from PACS

In this section we present evidence about the costs and effects of clinical imaging in hospital settings:

- In relation to diagnostic accuracy
- In influencing work patterns in radiology services
- In in-patient and out-patient settings
- In settings outside hospitals

Clinical imaging in hospitals

Most of the evidence about the costs and effects of clinical imaging in hospitals comes from studies of PACS. A carefully conducted systematic review in 1997 (Anderson et al 1997b)[2] identified four main variables of interest, and concluded as follows:

1. *Diagnostic accuracy*. There was no consistent pattern of evidence on the question of the accuracy of diagnosis using digital images relative to plain x-ray film
2. *Work process efficiency*. There were few good studies of the impact of PACS on work practices, but the better published studies indicated that:
    a. PACS appeared to save time in generating, retrieving and delivering images;
    b. PACS can reduce problems with missing images;
    c. Images were interpreted on workstations as quickly, or more quickly, compared to plain film;
    d. There was only one good study of turnaround time – the time taken from ordering of an x-ray to its delivery to the ordering clinician – and this suggested that PACS led to images being available sooner than with conventional film, but it was not clear whether this translated into faster or more appropriate treatment.
3. *Clinical care and patient outcomes*. No high quality published studies were found.
4. *Costs*. No high quality published studies were found.

Our literature review can usefully be viewed as an update of the Anderson et al (1997)[2] study, though omitting the diagnostic accuracy and clinical care/patient outcomes categories here, as no papers were found which reported on the effects of an EHR under these headings.

General observations

- Continuing accounts of problems with implementation, and those problems negatively influencing observed benefits (Bennett et al 2002[3]; Maass et al 2004[4])
- Argument that cost savings, productivity gains and improved patient care can only be realised if work redesign accompanies PACS implementation (Siegel and Reiner 2003[5])
- Both radiologists and other clinicians report strong preferences for PACS over conventional radiology services in surveys (Chan et al 2002[6])

Work process efficiency

In radiology services -

- PACS improves productivity by shortening mean reading delays or by maintaining mean reading delays despite increases in the volume of exams interpreted (Lepanto et al 2004[11])
- Evidence of no change and of positive change in different papers. Speculation that the differences stem principally from different implementation strategies (Reiner et al 2002[12])
- Reduction in lost images and unreported images (Hayt et al 2001[13])
- Reduced preparation time for clinician-radiologist meetings (Weatherburn et al 2000[14])
- Reduction in time required to perform a CT (Reiner et al 2001[15])

In other clinical settings -

- Suggestive evidence of reduced in-patient length of stay (Watkins et al 2000[16])
- PACS increases the volume of images ordered from both in-patient and out-patient settings (Reiner et al 2000[5])
- PACS significantly improves the speed of delivery of routine images to the ICU, but does not have a significant effect on the instigation of clinical actions, which are assumed to be affected by organisational factors within the ICU (Watkins et al 1999[18])
- Survey evidence that PACS is valued by clinical users, who perceive that it has improved the availability of images and the time spent searching for images. However, the clinicians also reported that PACS did not improve the availability of radiology reports (Bryan et al 1999[19])

Costs

- PACS increases hospital running costs (Bryan et al 2000[20])
- Prediction of cost saving, though not evidence based (Siegel et al 2003[5])

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Section 2 Imaging Technologies – Benefits Table

1 Overall Conclusions					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Whitten PS, Mair FS, Haycox A, May CR, Williams TL, Hellmich S. BRIT MED J,324:1434-7, 2002	Any telemedicine application	Systematic Review	Any	Any found in the literature	"There is no good evidence that telemedicine is a cost-effective means of delivering health care."

2 Clinical Imaging in Hospitals					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Anderson D, Flynn K. Shared Decision Making Programs, Report No. 6, Tech. Assess Prog; Veterans Affairs Medical Center, Health Services Research & Developments Service, Management Decision & Research Center, 1997	PACS	Systematic review	Hospitals	Diagnostic accuracy, patient outcomes, work process measures, costs	"The published evidence does not answer critical questions about the productivity, efficiency or cost-effectiveness of PACS."

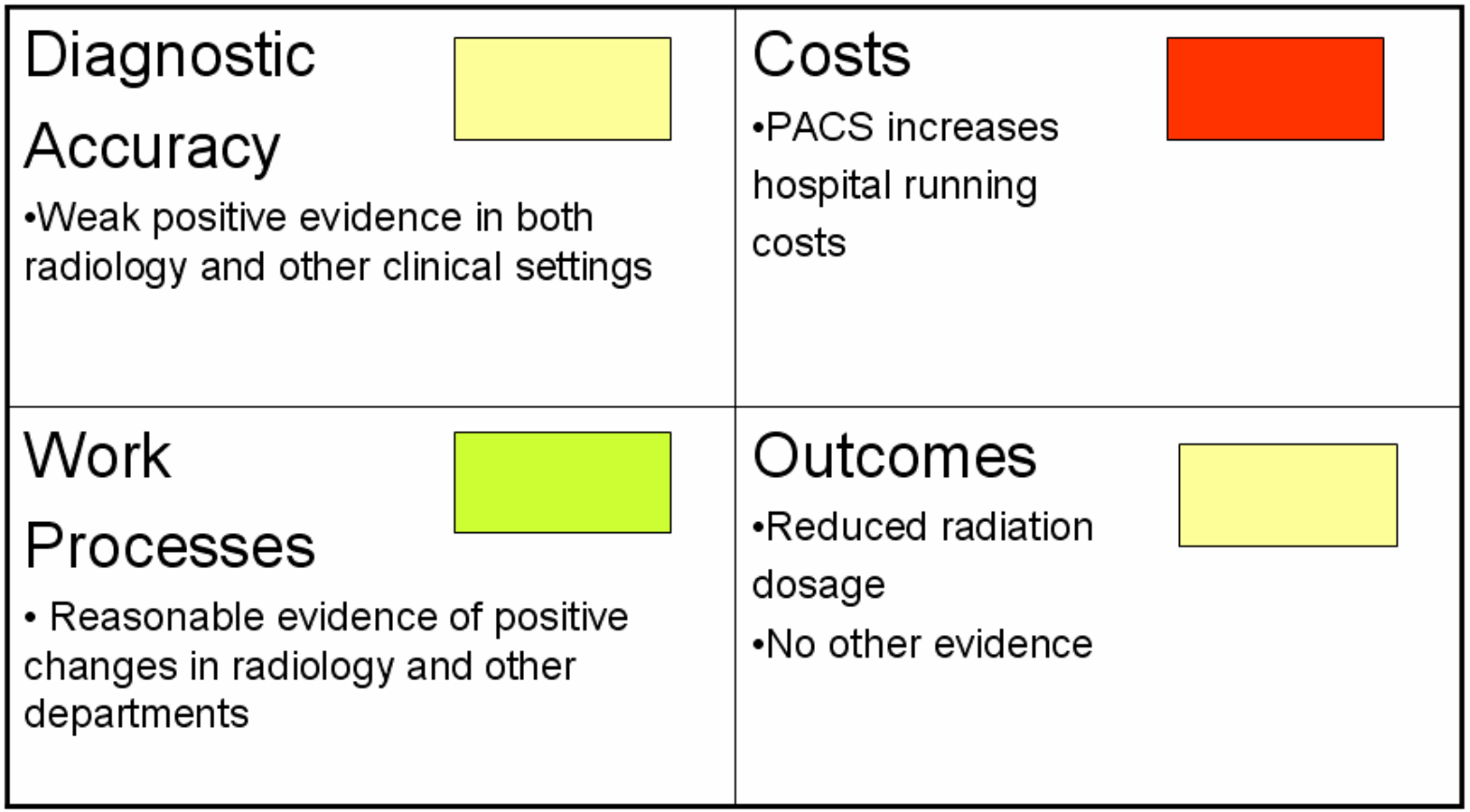
3 General Observations					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Bennett WF, Vaswani KK, Mendiola JA, Spigos DG. J Digit Imaging;15 Suppl 1:171-4, 2002.	PACS	Interviews with PACS users	Single hospital in Ohio	Interviews: perceptions of changes in practice	Reports of changes in the ways in which images are viewed, most evident where the number of images per patient is larger, e.g. with CT scans
Maass MC. Proceedings of 37th Hawaii International Conference on System Sciences - 2004	PACS	Range of methods, including time and motion study, user surveys, analysis of routine data, cost estimation	Single hospital in Turku, Finland	Range of process measures	Hospital staff were unprepared for the introduction of PACS. Inexperience and lack of key expertise slowed down the implementation process. Technology providers had insufficient knowledge of clinical requirements. Budgets were not adequate for the build-up of a comprehensive cost-effective system. Expected cost savings and process improvements were not found.
Siegel EL, Reiner B. J Digit Imaging, vol 16, no. 1, 164-8, 2003	PACS	Comparison of work processes before and after PACS	Single hospital in Baltimore	None – observational comments about process changes	The principal benefit of PACS is in supporting the re-design of work flow patterns.
Chan L, Tramabert M, Kywi A, Hartzman S. J Digit Imaging, vol 15, suppl 1, 131-6, 2002	PACS	Survey and analysis of costs	Single hospital in Santa Barbara, California	User perceptions, cost changes	High user acceptance and satisfaction reported. Unconvincing claims made for cost savings.

4 Work Process Efficiency					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Lepanto L, Pare G, Aubry D, Robillard P, Lesage J. Cahier de la Chaire de recherche du Canada en technologie de l'information dans le secteur de la santé;No 04-02, 2004.	PACS	Observational study of time between image acquisition and interpretation, with and without PACS	3 hospitals in a university teaching hospital system, Canada	Time between image acquisition and interpretation	PACS improves productivity by shortening mean reading delays or by maintaining mean reading delays despite increases in the volume of exams interpreted.
Reiner B, Siegel E, Carrino JA. J Digit Imaging, 15(3), 141-52, 2002	PACS	National survey of radiology technologists (USA)	-	Time costs associated with image acquisition.	Facilities with medical IT and facilities approaching filmless operation have improved workflow, as defined by the proportion of technologists' time allocated to the task of image acquisition.
Hayt DB, Alexander S, Drakakis J, Berdebes N. J Digit Imaging, June; 14(2):62-71, 2001	PACS	Observational study of lost films and turnround time between ordering and reporting of images.	Single hospital in New York City	Lost films and turnround times.	Reported reduction in lost films and in report turnround times with the introduction of PACS.
Weatherburn G, Bryan S, Cousins C. Eur Radiol; 10(6):1006-9, 2000.	PACS	Clinicians completed time sheets recording preparation times for clinico-radiology meetings.	Single hospital in Hammersmith, England	Time costs	The introduction of PACS at Hammersmith Hospital significantly reduced the time spent by radiologists in preparing for two clinico-radiological sessions observed.
Reiner BI, Seigel EL, Hooper FT, Pomerantz S, Dahlke A, Rallis D. Am J Reontgenol; 176(4);861-4; 2001.	PACS	100 CT examinations selected at random. Reviewed by four radiologists using conventional hard copy interpretation and PACS images. Time	Department of Radiology, Veterans Affairs Maryland Healthcare System	Radiologists' times in interpreting CT scans. Total time required to display, interpret and dictate findings	Reduction of 16.2% in overall time required. (Average from 9 down to 7.5 minutes for all radiologists).

		and motion analysis.			
Watkins JR, Bryan S, Muris NM, Buxton MJ. Int J Technol Assess Health Care; 15(3):497-505, 1999.	PACS	Observational study using routine hospital data and primary data collection: before and after study design	Single hospital in Hammersmith, England	Length of stay and other process measures for total knee replacement (TKR) and total hip replacement (THR)	There was an apparent reduction of 25% in the average LOS for TKR patients at the time PACS was introduced, but this is unlikely to be a true PACS effect. No similar reduction in LOS was shown for THR patients.
Reiner BI, Siegel EL, Flagle C, Hooper FJ, Cox RE, Scanlon M. Radiology;215(1):163-7, 2000.	PACS	Before and after study of rate of film use per patient per day. Comparison with national data.	Single hospital in Baltimore, MD.	Numbers of films viewed per patient per day.	Increase in rate of film viewing per patient per day for both inpatients and outpatients.
Watkins J, Weatherburn G, Bryan S. Eur J Radiol; 34(1):3-8; 2000	PACS	Before and after study. All ICU patients	Intensive Care Unit, Hammersmith Hospital, England.	Effect on image availability and impact on behaviour of ICU physicians. Times of X-Ray request, acquisition, availability and any image based clinical action taken by ICU physicians.	Significantly reduced time between request and image availability by 50% (30 mins. to 15 mins.) Did not have measurable impact on time clinical actions were initiated.
Bryan S, Weatherburn GC, Watkins JR, Buxton MJ. Br. J Radiology, 72, 469-78, 1999	PACS	Survey of clinical users	Single hospital in Hammersmith, England	Subjective perceptions of processes, ie image availability, availability of radiologist reports, junior staff time searching for images.	Image availability improved with PACS, junior staff time fell substantially. Availability of radiologist reports remained a problem with PACS in place.

5 Costs					
Paper	**Technology**	**Study type/level of evidence**	**Organisations**	**Outcomes measured**	**Results**
Bryan S, Buxton M, Brenna E. Int J Tech. Assess in Health Care; 16:3; 787-98, 2000.	PACS	Range of methods including time series analysis and direct observation of resource use.	Single hospital in Hammersmith, England	Changes in resource use associated with PACS	PACS almost certainly increases hospital running costs.
Siegel EL, Reiner B. J Digital Imaging, 16, No. 1 (Mar.), 164-8, 2003.	PACS. General Electric plus home-grown.	Overview of costs and benefits based on a range of methods and sources.	Single hospital in Baltimore, MD.	Estimates of a range of costs and benefits.	Paper argues that benefits of PACS are greater than costs – although the basis of some calculations was not clear, and estimated effects of PACS on clinician time costs are only based on (ambitious-looking) subjective estimates.

Hospital Clinical Imaging



SECTION 3

CASE STUDIES

Another potential source of information on the benefits of EHR systems is through case studies of implementations. These are not formal academic studies but they can provide interesting and relevant information, although it needs to be recognised that there may be an element of positive bias in such reports.

A review of the literature found a paper by Doolan et al in 2003[1] which is a case series of advanced US sites that use computers for clinical care. They review a series of 5 US hospitals all of whom won the Computer-Based Patient Record Institute Davies' Award between 1995 and 2000. The hospitals in this series are also the ones that have carried out many of trials and studies we have reviewed in the section 2 of this report.

The Davies' Awards have continued (now known as the Health Information and Management System Society Davies' Awards) and we have reviewed 4 case studies from winning hospitals between 2002 and 2005.

A further search for case studies on the WWW has not revealed any which give enough information to be useful. Typically, hospitals will write reports but these will be internal documents.

Information from Doolan et al's paper and the more recent case studies follows:

References

1 Doolan DF, Bates DW, James BC. The use of computers for clinical care: A case series of advanced US sites. J Am Med Inf Assoc, 2003;10:94-107

2 Maimonides Medical Center makes a quantum leap with advanced computerized patient record technology, 2002 www.himss.org/content/files/davies_2002_maimonides.pdf

3 Cincinnati Children's Hospital Medical Center. Improving the quality and safety of care through implementation of an integrating clinical informatics system, 2003 www.himss.org/content/files/davies2004_evanston.pdf

4 Evanston Northwestern Healthcare, Transforming healthcare with a patient centric electronic health record system, 2004 – www.himss.org/content/files/davies2004_evanston.pdf

5 Citizens Memorial Healthcare Project Infocare, 2005, www.himss.org/content/files/davies/2005/CMH_FULL_APPLICATION.pdf

SECTION 3

EHR Benefits – Case Studies

Doolan DF, Bates DW, James BC. The use of computers for clinical care: A case series of advanced US sites. J Am Med Inf Assoc . 2003;10:94-107[1]

Objective:
To describes advanced clinical information systems in the context in which they are Implemented and being used.

Case series of 5 US hospitals*:(all had won Computer-Based Patient Record Institute Davies' award)
LDS Hospital, Salt Lake City (LDSH) in 1995
Wishard Memorial Hospital, Indianapolis (WMH) in 1997
Brigham and Women's Hospital, Boston (BWH) in 1996
Queen's Medical Centre, Honolulu (QMC) in 1999
Veteran's Affairs Puget Sound Healthcare System, Seattle and Tacoma (VAPS) in 2000

Survey data collected 2000
Visits (semi-structured interviews) Jan – May 2001

Measured:
Use of computerized results, notes, orders and event monitors
Type of decision support
Data capture mechanisms and data form
Impact of clinician satisfaction, clinical processes and outcomes
Organizational factors associated with successful implementation

Results:
All sites implemented wide range of clinical information systems with extensive decision support.
Well accepted by clinicians
Improved clinical processes
Successful implementation required leadership and long-term commitment, focus on improving clinical processes and gaining clinician involvement and maintaining productivity.

Despite differences in approach similarity in systems used and factors important to successful implementation

*The hospitals in this review have all published papers that we have included in the EHR and CPOE sections

Case Studies from Health Information and Management Systems Society Davies' award:

Maimonides Medical Center 2002[2]

Located in southwest Brooklyn, New York, Maimonides Medical Center is a not-for-profit, voluntary hospital and the third-largest independent teaching hospital in the country, with 705 bed hospital and provides care for 36,861 discharges, 77,118 emergency room visits, and 253,316 ambulatory visits. With a staff of 4,612 employees, the hospital's 277 staff physicians coordinate care with a network of 978 community physicians throughout the borough.

System:

Maimonides Access Clinical System (MACS) 4 EMR systems:
Eclipsys 700 inpatient CPR (replaced by Eclipsys Sunrise Clinical Manager in 2004), NextGen Ambulatory Care CPR. E&C IPRob Perinatal CPR, A4 Health Systems Emergency Department CPR
In addition to the four CPR systems, feeder systems include (among many others): Misys laboratory system (formerly Sunquest), HemoCare blood bank system, IDXrad system, SynerSource transcription system, StorCOMM PACS system, SMS/American Healthware patient management and accounting system, Eclipsys TSA decision support system, PeopleSoft HR and financial systems, TalkTechnology voice recognition system, SurgiSever O.R. system.

Benefits

Patient Safety	*Length of stay*	*Efficiency*	*Patient Access*	*Regulatory/ Quality Assurance*	*Patient satisfaction*	*Medical Education*	*Fiscal Viability*
55% decrease in medication discrepancies 58% reduction in problem medication orders CDSS identified 164,000 drug-drug, allergy, food, duplication alerts leading to 82,000 beneficial changes in treatment /yr	30% reduction in average length of patient stay (7.26 to 5.05 days 1995-2001)	68% decrease in medication processing time (276 to 88 mins) 92% reduction in radiology time from order to final report (180 to 14 hours) 48% reduction in duplicate laboratory tests	32,168 additional in patients over 7 years Radiology workload increased by 27% ED patient turn round time decreased and pt visits increased by 20,000	Ambulatory CPR improved regulatory compliance from: 67-97% for current problem list 88-100% for allergy documentation to 95% for pain assessment	Improvement in all areas of survey questions improved – advanced technology significant influencing factor	Recruitment and retention of Residents – advanced technology significant influencing factor	$50m increase in revenue – 25% attributable to CPR 1995-2001 patient revenues $3695m-509m cash $27m-203m Profits $751K-6m

Key Success factors: Establishing programmes and methodologies aimed at physician participation, buy-in and ownership, building a clinically focused MIS staff, selecting appropriate vendor partners, winning support of key leaders and advocates

Cincinnati Children's Hospital Medical Center 2003[3]

324 bed tertiary care freestanding children's hospital serving a primary area with over 550,000 children in the southern Ohio, northern Kentucky, eastern Indiana, western West Virginia region and secondary referral areas from 42 states and 31 countries. In addition to the main campus, there are 15 off site clinics, with 1045 physicians and 1750 nurses and allied health professionals.

System:

Integrating Clinical Informatics System (ICIS),
includes Browser Technology based systems, computerized clinical order entry (COE), clinical documentation, electronic medication and intravenous charting (Med/IV Charting), rules engine, and lifetime electronic clinical record (LCR). Linked to existing financial, management and decision support systems.

Benefits

Patient Safety	*Consistency of care*	*Efficiency*	*Regulatory/Quality Assurance*	*Patient/staff satisfaction*	*Medical Education*	*Fiscal Viability*
Complete, unambiguous, legible orders Reduced turn around time for critical medications and radiographic studies Reduced all medication errors by 50% Reduction in percentage of mislabeled laboratory specimens Improved Internet and Intranet-based informational resources	Better use of guidelines and CDSS – 20% improvement	Improved patient registration process and reduced documentation Reduced medication turn around time by 52% Reduced time to take and receive results for radiographs Earlier enactment of patient care orders through use of the computer on rounds Complete and accurate patient information on orders and reduced clarification Quality management and assurance via data reporting provide the needed data feedback to continually improve process and systems	Reduced verbal orders. Reduced verbal orders for controlled substances. Improved security in patient information. Improved compliance with pain assessment to almost 100%	Improved electronic communication of employee issues, concerns and suggestions Community physician access to ICIS and improved satisfaction	Rapid and complete access to electronic results, reference resources and teaching material and enhancement of the care delivery process	By automating nurse charge capturing it was estimated that this has improved by 8.5 %

Prior to ICIS implementation, much work was performed to accurately analyze the clinician workflow in order to design and build system applications that would support clinician practice.

Evanston Northwestern Healthcare 2004[4]

Evanston Northwestern Healthcare owns and operates three hospitals with nearly 800 beds with 1600 physicians and 1300 nurses and allied health professionals. ENH also employs some 500 physicians in 68 faculty group offices (284 of whom are community-based).

System:

Epic software to support seven operational areas: Registration — *Prelude*, Scheduling — *Cadence*, Physician billing — *Resolute*, Inpatient and outpatient clinical documentation and orders — *EpicCare Inpatient*, Ambulatory (offsite) clinical documentation and orders — *EpicCare Ambulatory*, Pharmacy — *EpicRx*, Emergency Department — *EpicCare ED*.

Benefits

Patient Safety	*Length of stay*	*Efficiency*	*Consistency of care*	*Patient satisfaction*	*Medical Education*	*Fiscal Viability*
Transcription errors Reduced to zero Delayed administration of medications Decreased 70%: from 20 per month to 6 per month Omitted administration of medications Decreased 22%: from 18 per month to 14 per month System assures compliance with National Patient Safety Goals (NIM) Near-instant implementation of new safety procedures and performance improvments	Shortened inpatient diagnostic and treatment cycles	Instant accessibility to records Reduction in turnround time for ambulatory test results (e.g. general blood from 1-2 to same day, X-ray 1-5 to 1 day, Mammogram 10+ to 1 day, MRI 5+ to 1 day)	Allows ENH to embed best-practice pathways throughout continuum of care across all facilities Clinicians can review patient progress and influence outcomes in real time	System supports patients' increasing involvement in care Introducing"MyChart" function	Improved recruitment and retention of nursing staff – system reduces administration load.	$1M direct cost savings related to shortened length of stay over 6 months Cost reduction: Staff related $7.5m Revenue related: increased hospital charge capture £2.5m Service related$2m Overall $12,404,000

Key Factors to success: End-to-end process redesign before implementation - viewed project as a clinical project supported by IT tools with a full-scale analysis and redesign of all clinical processes.
Software functionality - worked with a software vendor that was willing to modify and enhance the applications to meet ENH's needs.
End-to-end system integration - fully integrated electronic health record with One hundred percent adoption across the organization

Citizens Memorial Healthcare 2005[5]

Citizens Memorial Healthcare (CMH) is an integrated rural health care delivery system with 1,538 employees and 98 physicians. The system includes one hospital, five long term care facilities, 16 physician clinics and home care services. The hospital is now chartless- no paper charts are maintained.

System:

Project Infocare - MEDITECH Clinical Applications (ED management, Imaging and therapeutic services, physician order management, Operating theatre managment, Patient care system, Pharmacy, Lab), MEDITECH Administrative Applications (Admissions/Registration, Abstracting & Coding, Health Information Management, Community wide Scheduling), MEDITECH/LSS Practice Management, Quick Study Radiology, Patient Care Technologies – Home Care Services and Manager, Imagenow Perceptive software, Krames on Demand, £M Coding system, Firstdatabank Pharmact Formulary.

Benefits

Patient Safety	*Length of stay*	*Efficiency*	*Fiscal Viability*
Elimination of handwriting and transcription errors and Completeness of orders through the use of required fields in CPOE Clinical decision support during the ordering process Immediate access to clinical information, including orders, nursing documentation, response to treatments, radiology exams and lab results, which supports physician care decisions. (**64,860 unique patient records)** Access to complete patient medical history Access to knowledge bases with information for use in patient education (medication monographs and diagnosis /procedure instructions) and for physician reference (drug references and side effect checking)	Adjusted Occupied Beds (a measure of in and outpatient volume), have increased from 101 to 138	Over $1,000,000 per month in supply and procedure charges are captured as a byproduct of care documentation	Revenues have increased by 23% since in implementation Reduction of FTE's per Adjusted Occupied Bed from over 6.0 to 5.5. At 138 AOB's, that difference totals 69 FTE's. No decrease in transcription costs. Elimination of all medical records filming costs which were $48,000 to $60,000 per year before Project Improvement in the revenue cycle - decreased accounts receivable for the CMH physician clinics from over 80 days to less than 50 days due to centralize billing and charging functions and databases across 16 physician clinics Supply charges per patient day have increased by $34 (net of price increases) since the implementation of automatic charge capture. Reduced claims denials through the use of real-time medical necessity checking. More accurately quantify the effects of marketing efforts through analysis of patient-centered, longitudinal data.

"Top IT Issues" identified prior to project Infocare**:** Disparate systems and databases; No common patient identification; Lack of continuity of patient care information across the delivery system; Lack of clinical documentation systems; Operational inefficiency; No availability of medical record in electronic format; No decision support capability, Minimal information technology standards; Insufficient information systems resources.

SECTION 4

COMMENTARY ON THE AVAILABLE EVIDENCE

The majority of relevant papers were found in our searches under the EHR and CPOE headings. Papers were also found through searches on evidence about PACS, although they shed less direct light on the costs and benefits of EHR. We searched under other terms, including patient identification and social services/social care, but did not identify any additional relevant papers.

The papers set out in Section 2 show that there is positive evidence of process change associated with EHR. The systematic review by Poissant et al (2005)[1], the paper by Garrido et al (2005)[2] on the introduction of EHR in Kaiser Permanente in the EHR section, the evidence of the benefits of CDSS in the CPOE section, and several other papers can all be used with confidence.

Equally, there is also evidence that EHR can increase time costs, particularly for physicians, in the Poissant et al (2005) review and in several other papers in the EHR and CPOE sections. More generally, the evidence presented is quite mixed, in the sense that gains have to be balanced against losses. For example, a reduction in nursing staff time spent on handling document based tasks has to be balanced against an increase in doctor or pharmacist time. As a result, some of the observations are not straightforward – not negative, but not unequivocally positive either.

In many papers the evidence was not decisive. There is, for example, evidence of clinician dissatisfaction with EHR, and also evidence that little of the available functionality is used. There is no compelling evidence that EHR reduce the incidence of adverse drug events (ADEs), or that the introduction of EHR increases – or decreases – consultation time.

Limitations of Study Designs

The study designs used, even in the good papers limit what we can say about EHR. In particular, only Laerum et al (2001)[3] compared different EHR systems with one another. Almost all other papers reported comparisons of EHR with pre-existing paper-based

systems, or with a relatively weak comparator, e.g. survey data on regional or national usage of systems. Several of the best papers were written by teams who worked at the study sites, and who had often been involved in the development of EHR locally. This must introduce the risk of bias in the reporting of results. And, some of the best studies were undertaken in sites with idiosyncratic characteristics. For example, the excellent Bates et al (1998)[4] paper in the CPOE section is from Brigham and Women's Hospital in Boston, USA. This is a highly specialised hospital which offers a number of tertiary referral services. It is not possible, with any confidence, to generalise the results from this sort of hospital to other settings.

Towards A Realist Synthesis

One practical problem with the literature, which we highlighted in Section 1, is that the evidence is scattered across many different clinical contexts, and involves reports on many different types of EHR. In order to provide a balanced assessment, it is helpful to interpret the results within the broad context that we set out in Section 1. That is, we can set out our expectations about the kind of evidence that we expected to find, and where we expected to find it, based on our own 'theories of change'. We felt that it was reasonable to expect to find evidence about 'micro' effects of EHR, such as effects on communication patterns between clinicians, or between clinicians and patients. It also seemed reasonable to hope that we would find evidence about the 'macro' effects of EHR, given that they can be used by thousands of people in the course of any one day. To this we can add another reasonable expectation, namely that we would expect to find evidence about cost changes and about patient experiences and outcomes, over and above evidence about process changes.

Taking this view of the evidence, the limited coverage of the field is striking. We found very little solid economic evidence, and even the better studies that presented cost data did not employ health economists. It is for all practical purposes true to say that we found no technically sound evidence about cost changes associated with EHR, bar the paper by Bryan et al (2000) on PACS. Similarly, we found limited evidence about the impact of EHR on patient experiences and outcomes. A systematic review (Delpierre et al 2004)[5] judged that the available evidence was limited and inconclusive. We have found no evidence at all about 'network effects'. There is now good evidence that

modern electronic networks have measurable positive economic effects in other contexts (Varian et al 2004)[6], but there do not appear to have been any studies in health care settings.

The papers we identified tend to support two theories of change. They support the view that EHR can have a direct impact on behaviour, and that it can influence communication patterns and the quality of communications (generally positively). We did not find studies which shed any light on any other possible mechanisms whereby EHR influence behaviour at the 'micro' level – and, as we have already noted, we found no evidence at all about 'macro' network effects.

This is, in part, due to the study designs used by health services research teams. Most of the good studies were able to demonstrate a causal link between EHR and work processes by using experimental study designs, where comparisons were made between processes with and without the EHR. As a result, these studies typically have limited scope – e.g. paediatric primary care, a lipid clinic – because the research teams focused on services where they could observe direct relationships between EHR and their effects on work patterns or communications.

Which Unit of Analysis?

Our 'flexible framework' led us to assume that EHR can influence behaviour in several ways at once. Thus it might lead to changes in communications between clinicians, changes in the ways in which consultations are conducted and to structural changes, e.g. the sequencing of activities, all at the same time. It is perfectly possible to imagine a study design which monitors all of these changes simultaneously. It is only necessary to decide to observe a linked set of processes, such as the steps in ordering and performing a radiology examination, or the end-to-end process of admitting someone to hospital, treating them and discharging them. But, we found no such studies. This has two important implications, namely, (1) there were no studies which actually sought to capture all of the costs and benefits associated with an EHR at the level of a process, or within a single hospital setting, and, (2) none of the published studies provided us with adequate contextual information to evaluate the evidence presented properly.

Both of these statements look strong, but we think both are justified. The first statement implies that no studies have attempted to capture all of the costs and benefits associated with an EHR, even in a relatively limited clinical context such as a primary care surgery or hospital department. The studies have focused only on detailed aspects of work in those settings, e.g. chart/EHR management. The result is that it is difficult to interpret the results, even when there is good evidence available, because we have no information on the 'knock on' effects – what economists call externalities - of those changes on other activities. To take a simple example, it might be that doctors spend more time on documenting their actions and decisions with EHR, but they might save time elsewhere as a result – we just don't know.

This state of affairs leads to the second statement. Because we don't know how the specific changes reported might be influencing other activities undertaken by study participants, it is not possible to interpret most of the results with any confidence. There are some exceptions to this somewhat bleak conclusion, for example in the Garrido et al study[2] (of Kaiser Permanente in the USA), which reports clear evidence of reductions in ambulatory visits following EHR implementation. That study focused on a major unit of activity - ambulatory visits – and therefore included a natural end point. That is, the reduction in ambulatory visits could have been the result of several different types of effect of EHR on activity in ambulatory care settings within Kaiser Permanente – but we know the overall impact of the EHR, because the reduction in ambulatory visits provided a sort of 'global indicator' of change in a clinical setting. This study aside, however, we are not in a strong position to interpret the results – all we can say is that localised change occurred in a particular context.

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SECTION 5

ELECTRONIC HEALTH RECORDS: INTERPRETING THE COST EVIDENCE

We were not surprised by the absence of rigorous evidence on the costs of EHR use. It is the usual finding in reviews in all aspects of medicine. The lack of evidence is always frustrating, but particularly frustrating in the case of EHR, where the justification for implementation depends in significant part on evidence about costs.

This note addresses three questions:

1. What is the status of the literature on the costs of, and cost savings associated with, EHR?
2. What is wrong with this literature?
3. What can be done to improve the quality of work in this area?

The literature on costs and cost savings

In the course of the review we came across a number of papers which claimed substantial cost savings associated with EHR implementation. Most were rejected on quality grounds, and even those that were included in the review had important flaws. There were two main types of flaw. First, most authors opted to estimate time saved on specific tasks, e.g. reduction in administrative task time when an EHR is introduced. This is useful in helping to identify the micro effects of EHR on working practices, but the data cannot easily be used for costing purposes. That is, the study results do not indicate the overall effect on the costs of services, so that we don't know whether the shifts in time costs led to a net increase or decrease in service costs. Studies should, ideally, have calculated the impact of EHR on the unit costs of providing a service, and/or the cost per patient of providing a service.

Second, papers fail to consider all of the possible sources of costs. Amazingly, several papers failed to include the cost of purchasing and maintaining the EHR itself. Most papers did not include any estimates of the costs that might be associated with shifting care from hospital to (cheaper) non-hospital settings. We could go on – the point is that

most papers failed to include all reasonable costs, irrespective of whether they would tend to increase or decrease overall costs.

Third, most papers made linear projections of cost savings in future years, typically up to 5 years ahead. Even if we leave aside the measurement problems we have already noted, authors did not provide a convincing basis for their projections. They assumed that the savings would cumulate each year, and be extended from a limited number of services across a whole hospital or health system, typically resulting in telephone number cash savings. Unfortunately, there is no basis for these projections. Few technologies have diffused in a linear pattern in the past. In the most successful cases, including the Internet, usage has grown exponentially (i.e. more rapidly than a linear projection), while at the other extreme other technologies have diffused slowly (e.g. PACS and HISS in health care) or failed (any number of systems over the years). We just don't know how EHR usage will diffuse over the next few years.

Towards An Alternative Approach

These arguments suggest that the approaches cited in the literature are doomed. So, what to do? We think that it is best to abandon the majority of the literature and look for a different approach. The paper by Walker et al (2005)[1] suggests what a viable alternative might look like. They developed a model for estimating savings across all of US health care, based on the following assumptions:

1. The principal benefits of modern systems will come through inter-operability of existing – but often isolated – systems;
2. It is possible to estimate the costs of providing interfaces between these systems. The study team estimated the average cost of providing an interface between any two existing systems (at $50,000 per interface).
3. It is also possible to estimate the cost savings associated with the interfaces, by using data from the published literature, and generated by expert panels convened by the study team. For example, they obtained data about the current level of transactions between systems – a reasonable measure of interoperability – and combined this with judgements from an expert group. They used the data to predict the levels of savings that could be obtained from reductions in the costs of laboratory test

ordering ($200,000 per year in a medium sized hospital), electronic pharmacy management ($70,000), and so on.

Walker et al (2005)[1] went on to estimate total potential savings from improved inter-operability over ten years, making further assumptions about the rate of implementation. They produced a total of $77.8bn. net cost savings per annum once the infrastructure was fully implemented.

We think that this approach is interesting. It makes sensible-looking assumptions about the costs of implementing and maintaining large scale networks. It makes a plausible assumption about the way in which new electronic services will yield savings, i.e. through increased inter-operability, which will lead to reduced costs of transactions such as lab test ordering or payment for services (highly relevant in both private and social insurance systems).

Respected economists believe that this sort of 'network effect' is generated by electronic networks in other sectors (Shapiro and Varian 1999[2], Varian et al 2004[3]). We do not know whether such effects exist in health care – there is no evidence either way - but it is reasonable to assume that they do, until evidence is available to the contrary. Crucially, the approach moves us away from the naïve focus on the minutiae of time costs and localised process changes. Walker and colleagues are, in contrast, arguing that large scale inter-connectivity in health care will lead to structural changes in the way that data are transmitted from place to place, and that this will be the major source of cost savings.

Objections can be made to this approach, and indeed these are set out in a companion paper in the same issue of Health Affairs by Baker (2005)[4]. Baker points out that some of the estimates are too optimistic. The overall figure of $77.8billion looks very high. (Health care spending in the USA in 2003 was $1.7trillion, so that the projected savings are 0.5% of total spending, saved through better inter-operability alone.) Baker also points out that the projected savings in the costs of laboratory tests are too high – most lab staff in the USA would be laid off according to the model - as are assumptions about reductions in the costs of pharmacist time in checking prescriptions with doctors.

Conversely, he points out that Walker and colleagues pin all of their hopes on the benefits of inter-operability, and there are likely to be other sources of benefits, including improvements in the quality of care and patient outcomes.

Next Steps

Where does this leave us? There seem to be three options. First, it would not be a huge task to re-work the Walker model, using more realistic data, as Baker suggests. Baker implies that a revised model would probably still show that benefits outweigh costs, just not at the rate of $77.8bn per year. Given the fixation – apparent in many countries - with saving 10 minutes here and there, publication of sensible figures on the total cost savings across a health care system would help to shift discussions onto more fruitful territory.

Second, it is not difficult to see how to improve upon the model. Baker makes some simple, helpful observations, e.g. that it must be possible to come up with better estimates of the reduction in unit costs of activities such as lab test ordering, and that there must be other sources of both financial and non-financial savings, which would tend to increase total projected savings. It would also be perfectly possible to re-examine the assumptions made about the rate at which costs and savings accrue over time. And, it will be more meaningful to many people to focus on an area smaller than the whole of the USA – a community of 500,000 or 1 million people might be more appropriate. Relevant data could be obtained for the NHS in England to populate a model in the first instance – though the work could in principle be done in any of several countries. This model would be distinct from Walker's model – the Accenture Cost-Benefit Model, perhaps.

Third, and linked to the second point, it would also be possible to develop a model of potential costs and savings - and non-financial benefits – for individual services. We were disappointed that the literature did not provide us with the data to estimate the changes in unit costs of any health service associated with introduction of an EHR. This would be more speculative than we would like, but as the literature is not up to the job, responsible speculation is justified. For example, the Garrido et al (2005)[5] paper cited earlier reports significant reductions in ambulatory care visits across two Kaiser

Permanente regions. Unit cost data could be applied to estimate the cost changes involved. If the changes had taken place in England, a simple calculation based on the Colorado data would be as follows:

(total reduction in visits)*(unit cost) gives (50000)*(£188 per visit) or £9.4Million per annum for Colorado.

£168 is the unit cost for an out-patient clinic attendance in England in 2004.

The frustration of this particular paper is that it does not give absolute increases or decreases in numbers of people treated, only percentages. However, there is enough information in the paper to allow us make a reasonable guesstimate: and Kaiser Permanente might release their raw data if approached. And, once again, the introduction of unit cost data would help to shift the focus away from the naïve approaches that currently dominate much of the literature.

References

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