Chapter XXXI
Achieving Effective Health Information Systems

Jim Warren
University of Auckland, New Zealand

Karen Day
University of Auckland, New Zealand

Martin Orr
University of Auckland, New Zealand

ABSTRACT

In this chapter we aim to promote an understanding of the complexity of healthcare as a setting for information systems and how this complexity influences the achievement of successful implementations. We define health informatics and examine its role as an enabler in the delivery of healthcare. Then we look at the knowledge commodity culture of healthcare, with the gold standard of systematic reviews and its hierarchy of evidence. We examine the different forms of quantitative and qualitative research that are most commonly found in healthcare and how they influence the requirements for health information systems. We also examine some domain-specific issues that must be considered by health information systems developers, including those around clinical decision support systems and clinical classification and coding systems. We conclude with a discussion of the challenges that must be balanced by the health systems implementer in delivering robust systems that support evidence-based healthcare processes.

INTRODUCTION

Effective health information systems are ones that improve health outcomes and/or reduce healthcare delivery costs. To implement these health information systems successfully we must have some understanding of the healthcare domain and adopt techniques that are attuned to managing the innate complexity of health information and healthcare in general.

Health can be viewed as a complex adaptive system (Dooley, 1997), in which many parts of the system interact interdependently in varying and unpredictable degrees with one another and their environment (Plesk & Greenhalgh, 2001a; Plesk & Wilson, 2001b; Tan, Wen, & Awad, 2005). We usually function well when most of our world is reasonably certain and predictable, fairly unambiguous, familiar, mostly known and knowable, and

where interdependencies and relationships are fairly simple (Plesk et al., 2001a). Once we move out of this apparently less complex environment, we find ourselves in the zone of complexity as described by Langdon (as cited by Plesk et al., 2001a). Decisions are no longer straight forward and we are in a situation that is somewhere between simple and chaotic. Our natural tendency is to reduce ambiguity and uncertainty by attempting to create firm plans from which to work, or to strip some of the paradoxes around us by simply ignoring them. Others have found that it may be more productive to work with ambiguity and uncertainty by being reflective, learning from the consequences of our actions as we go, or creating a cycle of plan, act, review and modify as used in action research and in quality improvement practice (Waterman, Tillen, Dickson, & de Koning, 2001).

We tend to move in and out of the zone of complexity as we work through the day, acting out agreements between ourselves and others, working according to habits and pre-existing accepted patterns of activity. In healthcare we spend a high proportion of our time in the zone of complexity. For example, when a doctor calls the IS support service about a problem he is calling from a complex situation in which patient care is demanding his attention, his IT skills are limited and his capacity to describe his computer problem is not as efficient as his medical skills. Although for the most part the IT person who takes the call is able to wade through the ambiguous descriptions given by the doctor, there is still a high degree of complexity where the two worlds of medicine and IT meet, where jargon and terminology are dissimilar, and the demands of their respective worlds differ greatly. It is in this context that health informatics plays a role in supporting the delivery of safe, effective healthcare.

WHAT IS HEALTH INFORMATICS?

Health information systems stand apart from the mainstream of endeavour in computer-based information systems. To some extent, it is just an issue of a large sector with its own specific demands—in this sense defence information systems equally stand apart from business information systems. However, with health, things have gone a step farther. A field known as *Health Informatics*, has emerged. It is also called *Medical Informatics*, and one will find frequent reference to significant sub-domains such as *Nursing Informatics, Primary Care Informatics* and *Public Health Informatics*. For the purpose of this chapter we will refer to *Health Informatics.*

The field can be defined, as "the science of using system-analytic tools… to develop procedures (algorithms) for management, process control, decision making and scientific analysis of medical knowledge" (Shortliffe, 1984, p. 185). Alternatively, van Bemmel (1984, p. 175) defines the field as comprising "the theoretical and practical aspects of information processing and communication, based on knowledge and experience derived from processes in medicine and health care." This second definition appears to be less specifically clinical; each definition reflects a key aspect of the field in practice. The unusual term 'informatics' itself derives from the French 'informatique médicale', and provides a useful reminder that the field is not just IT for health. The name *Medical Informatics* is historically entrenched, but *Health Informatics* is the preferred term to indicate:

a. That professions alongside of medicine (e.g., nurses, pharmacists, dieticians) are equally relevant, and
b. The somewhat broader goal of health, inclusive of the well members of populations.

Degrees in *Health Informatics* are available from many universities around the world, with the programmes at Stanford, Columbia and Oregon Health & Science University being some of the most historically prominent in the US. There are numerous journals and conferences in the field, with *Journal of the American Medical Informatics Association* having the highest impact factor, while

the International Medical Informatics Association (IMIA) lists 48 member nations (as at April 2007). Interestingly, while there is broad agreement that there are too few formally-trained health informaticians, there is far less agreement on just who should be trained, and in what (Hersh, 2006). The field has a long tradition of involvement in technical computer science topics, e.g., the development of the MUMPs operating system, which had leading edge features for its time (1960s); medical expert systems being at the forefront of artificial intelligence in the 1970s; and the ongoing importance of advances in medical imaging technologies. However, the field is increasingly driven by the recognition of the importance of human and organizational topics, and by a broadened view of the user base, incorporating topics such as *Consumer Health Informatics*.

There are two significant motivations for IT professionals and academics to pay particular attention to the health domain.

1. **Health is big (and growing and *changing*).** At the population level, we have a seemingly endless appetite for healthcare. In the US, healthcare costs were 15.3% of GDP in 2003, significantly outpacing income growth (Gutierrez & Ranji, 2005). Moreover, the healthcare system is challenged by the need to adapt to the changing profile of patients and illness. Populations are ageing (which in part represents the **success** of medicine, after all), aided by the baby boomer generation. This demographic shift is accompanied by a preponderance of chronic illnesses, either as presenting complaints or as underlying and/or complicating factors. Moreover, choices to consume energy-dense diets (like a hamburger and cola) with reduced physical activity have set in motion the emergence of new, and combinations of, chronic conditions such as obesity and diabetes.
2. **To take lessons learned in health into other complex domains.** In healthcare, the richest and most complex possible data and knowledge (of the human body) is integrated by a diversity of professionals. Levels of preparation vary by role, but are on average extremely high, and extend to the most intensive and lengthy levels, e.g., the apocryphal 'brain surgeon'. The disciplines are often quite difficult with, and even dismissive of, one another! The interplay of these professionals and their complex equipment is undertaken 24x7 on a vast scale, under constant time pressure, with the stakes no less than 'life and limb.'

It should be noted that our focus is on the health sector, as chiefly characterized by those who directly provide health care and their support infrastructure. We distinguish this from the biomedical research community (although, in practice, the boundary can be very blurry). There are separate lessons to be learned from biomedical research, especially in areas related to genomics and modelling of proteins and other key molecules. However, that is not the subject of the present chapter.

FACTORS INFLUENCING HEALTH INFORMATION SYSTEMS

Effective health Information system design must embrace the unique developmental nature and complexity of the health system it is aiming to enhance. There are and will continue to be different and changing views on what effective healthcare might look like, or how the components should interact (Glouberman & Mintzberg, 1996). However we can identify a number of core principles or features of an effective electronic health information system that may be independent of technology, time or place. The mnemonic C.A.R.E. G.A.P.S. F.I.R.S.T. attempts to encapsulate some of these core features. An effective health information system should seek to enhance every stakeholder's 'capacity to C.A.R.E.' or 'motivation to C.A.R.E.'. In other words, to carry out in an integrated fashion the core clinical, administrative, research and educational functions of healthcare (Orr & Day, 2004).

An electronic information system that is developed to support these functions, should embrace the power of leveraging the whole healthcare network, engaging and empowering all the key stakeholders. These stakeholders include general practitioners, allied health services, patients and their community of supports. The system design should appreciate, embrace and enhance the complex environment in which it exists and be Fast, Intuitive, Robust, Stable and Trustworthy within this complex environment (Orr, 2004; Plesk et al., 2001a; Sveiby, 1996).

Historically, the design and implementation of electronic health information systems have too often been associated with failure or limited effectiveness. Clinical, administrative, research and educational systems have not been integrated or shared common drivers. Major stakeholders have been neglected particularly patients and their supports and the large contribution they play in attaining effective health outcomes. Systems have not been fast, intuitive, robust, stable or trustworthy enough, to integrate seamlessly and enhance the complex environment in which they exist. (Ash, Berg, & Coiera, 2004; Heeks, Mundy, & Salazar, 1999; Littlejohns, Wyatt, & Garvican, 2003).

Patient Safety First

An additional complexity factor is the low tolerance for failure and error in the healthcare system (Institute of Medicine (U.S.), 2000). Errors in the delivery of healthcare as well as problems with IT in this context can end up with adverse events for patients, sometimes resulting in death or serious illness that could have been avoided. There is an imperative for health IT projects to succeed (Orr et al., 2004). A central tenet of the ethical practice of medicine is *primum non nocere* or 'first do no harm'. It is recognised that almost all interventions in healthcare have both risks and benefits. It is the role of an individual clinician, or service, to work with a consumer and their supporting community to come to an understanding and agreed balance or accommodation of these risks and benefits, associated costs and opportunity costs. Although an intervention may appear attractive on its perceived benefits, in decision making it is usually at least as important to consider the capacity to manage the perceived risks. Central to healthcare is the weighing of risks and benefits, costs and opportunity costs and making judgements in situations of ambiguity, limited time, information and resource (Protti, 2003; R. Smith, 1996). The planning decisions for health information systems are in no way immune from these factors.

Electronic systems may play a role in decreasing medical error, and increasing the efficiency and quality of workflow (Leape & Berwick, 2005). However, poorly designed or integrated systems could lead to inefficient and unsafe care (Sidorov, 2006). In healthcare every second and every click counts. Every non-essential or inefficient task has a cumulative opportunity cost on a typically highly limited clinical resource. As we strive to attain the potential benefits that can be derived from health information systems, we cannot ignore or neglect our responsibilities to consider our capacity to afford and manage the risks of such systems.

The Imperative for Security and Privacy

Bearing in mind the exhortation to do no harm, we are confronted by the problems of confidentiality (privacy) and security. In order to make good decisions and to manage risks, benefits, costs and opportunity costs, we need information (Wyatt, 2001). Multiple clinical processes, within and between healthcare services, are becoming increasingly critically dependent on system interoperability and security. However, as the number of systems and diversity of users, uses and interactions continues to rapidly increase, there has been an exponential increase in complexity and the potential for insecurity as illustrated by the examples in Box 1. Although different people are using the same patient's information, they use this information for different reasons (like clinical care, planning,

evaluating, or for billing purposes), but experience different problems with the same information (Wiener, Gress, Theimannn, Jenckes, Reel, Mandell, & Bass, 1999). Multiple pieces of data may be drawn from multiple systems to produce the screen display or decision presented to the clinician. This capacity to facilitate the aggregation and analysis of clinical data is of great potential benefit to safe, timely cost effective quality care (Ash et al., 2004; Institute of Medicine (U.S.). Committee on Quality of Health Care in America, 2001). However just one error in the system interoperability, standards, data entry, sourcing, aggregation or display could lead to a fatal error.

Safe, effective healthcare is dependent upon secure, trustworthy information (Health Information Steering Committee (NZ), 2005; Institute of Medicine (U.S.). Committee on Quality of Health Care in America, 2001). The confidentiality, evidential integrity and availability of our information systems are core to clinician and public trust as well as business continuity. If the information stops, safe effective healthcare stops. If the quality of the information is corrupted, the quality of the associated healthcare will be corrupted (Ash et al., 2004). Some of the problems that could occur are technical as much as they are related to the people who use the information systems. A possible illustrative scenario would be a large metropolitan healthcare service that supports a complex array of electronic clinical information systems. The system servers all operate out of the one room. The clinical

Box 1. Same record, different views and different problems

A clinical applications portal utilises a web browser. Clinicians start to notice that when they call up a patient's lab results a different patient's lab results appear. The fault appears intermittently. The fault is later traced to a configuration error in the browser where a previous patient's cached results are brought through into the new patient view.

A mental health service uses a computerised patient record both in the community and hospital settings. A clinician is carrying out an assessment in a patient's home using a laptop with a VPN connection. The VPN connection is suddenly lost and will not reconnect. The clinician cannot access nor record any further information on the patient.

A messaging standard sets a text field length at a maximum of 50 characters for transmission. The electronic discharge summary application a clinician is using allows them to type as many characters as they want into a text field. The copy on the clinician's screen and stored in the local system displays all the information typed in by the doctor. The copy printed for the patient is also complete and intact. However once the message is transmitted electronically, it is truncated in transition to 50 characters. Only the first 50 characters of the text field appearing on the receiving doctor's screen

In another healthcare region transmission issues with the same standard (as described above) results in multiple electronic discharge summaries being rejected and not being delivered to primary care clinicians. However, as with the truncation error, the sending clinician is not aware that any problem has occurred

In another region, the patient's current primary care clinician details have not been updated in a hospital's electronic record. The electronic discharge summary is sent to a former primary care clinician of the patient, delaying the initiation of urgently required follow up treatment.

processes in this health service are now critically dependent on the clinical information systems. A small fire starts in the server room. The server room has sprinklers which are activated. There is data backup but no operational server backup or fallover system in place to facilitate business continuity. There is severe clinical impact for five days until the clinical systems are rebuilt from the backup data tapes.

Through proactive risk management we can seek to minimise the frequency, imminence, likelihood and magnitude of security risk (Buchanan & Connor, 2001). However, when using risk management processes we have to recognise that seeking to identify and control all potential variables that may lead to an adverse outcome, is of limited efficacy in a complex environment. Adverse health outcomes may arise from variables interacting in a specific way in a specific context which may be difficult to predict at the time of deployment (Garg, Adhikari, McDonald, Rosas-Arellano, Devereaux, Beyene, Sam, & Haynes, 2005; Leape et al., 2005). In a complex environment, while not neglecting the need to identify and limit bad factors that may lead to bad outcomes, we should also focus on increasing the frequency of good factors that we know, or at least suspect, are associated with good outcomes. Creating a network that makes it easier for users to do the right thing and rapidly feed back any problems or opportunities for improvement, for analysis, resolution and deployment, should improve the frequency of good outcomes (Protti, 2003; Southon, Perkins, & Galler, 2005).

The risks to patients vary along a number of related spectrums from intermittent to continuous, localised to systematic. Traditionally the impact of a security deficit was restricted by the limited reach of the individual components of the related system. The impact of a security deficit with one record was limited to one patient, or deficits in the processes of individuals or services were limited in impact to the span of the related individuals or services (Littlejohns et al., 2003; Lorenzi et al., 1997). The impact of one patient's paper notes being mixed up with another's is limited to two patients. A deficit in one clinician's or support staff's practice (from confidentiality breaches to failures of integrity), even if repetitive, will be limited to all the patients with whom they come into contact. However, a single security deficit in a widely diffused electronic system could impact on thousands of individuals, depending on the nature of the deficit and the delay before it is detected and resolved. The inefficiency and duplication of our current mixed paper and electronic systems may actually afford some protection in terms of limiting the impact of a security deficit. For a negative impact to actually occur, often multiple system deficits need to line up. If a record in one system states one thing and a record in another states something different there is at least the potential that this discrepancy will alert the user that there is a potential error. If one part of a mixed system goes down, other parts of the system may afford at least some backup.

In developed countries, the IS implementer will find that aspects of security and integrity requirements will be formulated within legislation and/or standards that must be adhered to as a matter of duty of care. The most prominent piece of legislation in the area of health information systems is the Health Insurance Portability and Accountability Act (HIPAA), which provides standards for electronic healthcare transactions and the handling of health data (see http://www.hhs.gov/ocr/hipaa/).

The Need for Business and Healthcare Continuity

While most healthcare services are in the process of developing electronic information systems, many activities are still dependent upon a combination of paper and IT. Good information is only as good as the workflows in which it can be used, and the complexity of these workflows adds to the difficulty in delivering relevant information appropriately to the users (Ash, 1997). This is illustrated in the example of laboratory results in a hospital setting. Laboratory tests are ordered using a paper system.

The results are provided electronically and signed off electronically. The paper ordering system does not have the granularity to always identify the specific individual who ordered a test and return the result of that test to that specific individual for sign off and action (where appropriate). The levels of specificity as to where and who ordered a test may only be at a service or clinical consultant team level. Patients may also be transferred between teams or services (within the hospital) while a result is being processed. Unless there are very clear and agreed work flow processes between the paper ordering and electronic sign off system, there can be potentially significant clinical delays in results being viewed, signed off and actioned. On a different level, these processes also have to cope with staff moves, sickness and leave. The introduction of a health practitioner index and moves towards electronic ordering should help minimise the concerns of unviewed, unsigned, and unactioned abnormal results, due to a result not being directed to the right person and that person not being prompted to act on it. Even so, there will still be significant safety issues around electronic and human process interoperability.

There is an argument for local, regional, national and indeed international backup systems to facilitate business continuity (Wyatt & Keen, 2005). This will stimulate debate around whether we build national data centres to facilitate disaster recovery and business continuity or whether these functions should be outsourced to multinationals who have a specific focus and expertise and can bring significant economies of scale to bear. Ownership and ethical control of the data, particularly if it is moved overseas, will become a significant component of this debate.

Healthcare is complex and the analysis, design, implementation and evaluation of health information systems must reflect and work with this complexity in order to support the closing of the CARE GAPS FIRST in the delivery of safe, private and secure healthcare. The complexity is exacerbated by the vast amounts of knowledge available for the delivery of healthcare and the need to harness it for quality care. Knowledge becomes a commodity.

THE KNOWLEDGE COMMODITY

Various features and fashions of health care have collided to create an environment where knowledge is treated as a commodity. There is a tendency for the results and character of individual research studies to become buried in the vastness of available medical evidence, such that the whole is managed more as a fluid rather than as a set of discrete contributions. The vast number of clinical concepts and terms has become the subject of extensive systems to support standardization and interchange. The combination of the problem of too much information, the imperative for evidence based care and the different ways in which we generate and use research evidence, results in the tension between the need for knowledge management and a tendency to treat knowledge as a commodity.

The Problem of Too Much Information

The first force for commoditization of health knowledge is the problem of 'information overload' as it pertains to any healthcare professional, to the physician in particular and most acutely to the primary care physician who deals with initial presentations of complaints. It is often quoted (although rarely with citation) that medical knowledge doubles every 19 years (Wyatt, 1991). One can build various cases to illustrate the hopelessness of the physician's attempts to keep up with all relevant information. For instance, Hanka et al (1999) assert that, not even counting basic or specialist clinical knowledge, a primary care physician in the UK is expected to know the contents of numerous health authority policies, referral protocols, governmental circulars, warnings of adverse effects of drugs, and other material sufficient to form a column 18 inches (46cm) tall. The problem of keeping up in medicine is such

that providing evidence of formalized continuing medical education is a requirement for continuing to practice in many countries. Moreover, the challenge creates an emphasis on learning in the work place – looking up answers quickly, to answer immediate needs (Wyatt & Sullivan, 2005). Tools such as Quick Clinical, which federates search results over a number of online resources with a mean search time of 4.9s, have emerged to support exactly this sort of practice (Coiera, Walther, Nguyen, & Lovell, 2005). Even in the face of too much information there is a need for evidence based medicine in order to provide safe and effective healthcare.

The Imperative for Evidence Based Care

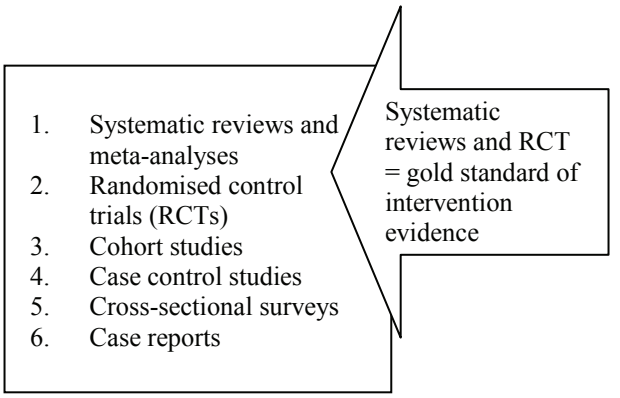
The second force for commoditization of health knowledge is evidence based medicine (EBM). EBM connects scientific evidence with patient needs in an appropriate setting by means of making judicious decisions based on conscientious and explicit use of the available evidence (Mayer, 2006). The EBM movement introduced critical thinking into clinical care, shifting clinicians away from 'expert doctrine' that was at risk of setting us up for clinical error and risking the safety of our patients (Guyatt, Cook, & Haynes, 2004; Mayer, 2006). Evidence is available in great volumes but requires critical appraisal because of varying levels of quality, validity, impact and applicability. Each publication requires critical appraisal prior to being used at the point of care in order to avoid inappropriate use of evidence or use of poor quality or inappropriate evidence. Because of the plethora of evidence and the difficulty in assessing all relevant information at the point of care, a hierarchy of evidence has been developed to assist us in identifying believable, safe and useful knowledge. This hierarchy is outlined in Figure 1. What we take from the evidence and how we interpret it in everyday clinical practice remains the clinician's responsibility.

The Mixed Blessing of Systematic Reviews

Since health information is so plentiful and clinicians are encouraged to practice on the basis of the evidence that is available, systematic reviews have become the panacea for those who need and desire the evidence but are unable to process it all themselves. A systematic review is a summary of the available evidence, which in turn is the outcome of a distinctive process (Khan, Kunz, Kleijnen, & Antes, 2003; Petticrew & Roberts, 2006). The process involves five steps and applies equally to qualitative and quantitative research. The steps include formulating a question; searching, assessing and summarising the evidence; and interpreting the the review and disseminating the outcomes. These steps are inter-related and follow preceding steps logically, making use of judgements of quality, validity and applicability in terms of the content of the literature under review. Initially, in healthcare, these reviews were limited to RCTs, but systematic reviews are growing in popularity in all forms of quantitative and qualitative research, and in different arenas such as healthcare, social sciences and business. The systematic review is becoming the evidence *du jour*, a new form of knowledge as a commodity. It makes health knowledge more accessible in what is considered to be a trustworthy format for rapid, simple, structured access to healthcare evidence at the point of care and under the demands of general practice.

As with any commodity, there are different versions of systematic review, such as the Cochrane Reviews (see http://www.cochrane.org/reviews/) and the use of systematic reviews in the development of clinical guidelines (Rousseau, McColl, Newton, Grimshaw, & Eccles, 2003). Once the review results are presented in publications, they reinforce the evidence in ways that limit interpretation at the point of care, aiming at reducing the risk of misinterpretation and information overload, thus supporting safer delivery of care. It is therefore essential to ensure the use of quality, reliable and valid research to inform these reviews.

Figure 1. Commonly-used hierarchy of evidence for healthcare interventions (after Petticrew & Roberts, 2003)



While the systematic review offers accessibility to vast amounts of information about interventions, it simultaneously removes the user from direct access to the richness of the 'raw evidence' of individual research projects reported in the literature. Such raw evidence is available in RCTs to those practitioners who require more granularity in knowledge and/or have the capacity to do their own critical appraisal of the evidence.

Tracking Down Clinical Knowledge with RCTs

RCTs are considered the gold standard to accessing good clinical treatment or intervention evidence (Stanley, 2007). A randomised control trial (RCT) is a quantitative form of medical research that follows a specific design in order to reveal the effectiveness of a treatment (Mayer, 2006). The research design allows for comparison between the effect of a treatment, (positive effect for treatment or intervention purposes, side effects, and adverse effects), and the absence of such a treatment, e.g., the therapeutic effect of antihypertensive drugs and their side effects compared against those who take a placebo or a different drug. The structure of the design narrows the focus of the research as closely as possible onto the treatment being researched, with every effort being made to exclude confounding or contributing factors and any possible bias. In this way new knowledge about treatments is stripped of extraneous information. The published report reflects this economy in its clarity of the study objective, and component of the research design such as randomization, selection of population to be studied and its control population, statistical power (sample size), blinding, the specific nature of the clinical trial and how the participants were monitored for safety (Stanley, 2007).

Structured, Compact and Indexed Literature: The Impact of Positivism on Health Research

Perhaps as a response to the high volume of medical literature and the influence of EBM-thinking, publications themselves are becoming increasingly structured, compact and systematically indexed.

In the health and medical domain, the properties of a good abstract have been formalized. Many journals require structured abstracts. In the IT domain, we are accustomed to encountering abstracts to preface articles, especially those in peer-reviewed academic literature. A good abstract should provide, in perhaps 150 to 300 words, a brief picture of the whole message of the paper. In this way it is distinct from, say, an editor's introduction to a work of fiction, wherein you might not want to give away the ending. Especially where empirical findings are concerned, the abstract should give an indication of the population that was studied, sample size, measures taken, and the results found. Guidelines used by the *Medical Journal of Australia* are typical (Medical Journal of Australia, 2002) of those encountered in the medical literature. The abstract is divided into sections including: objective, design, setting, patients/participants, intervention, main outcome measure, results and conclusions. Even the most respected business information systems journals, such as *Information Systems Research* or *Management Science*, while certainly exhibiting

high quality research with good abstracts, have not yet taken this structuring step.

The compactness of modern medical literature is striking. There is little tolerance for unsupported statements. The page and word counts of medical journals and conference proceedings are short by IT standards. A minor, but telling, facet of the compactness (and uniformity) of the medical literature is in its preference for the International Committee of Medical Journal Editors style, notably its reference style, also known as Vancouver (National Library of Medicine, 2006). Consider the following reference in the Vancouver style:

Gadzhanova S, Iankov I, Warren J, Stanek J, Misan G, Baig Z, Ponte, L. Developing high-specificity anti-hypertensive alerts by therapeutic state analysis of electronic prescribing records. *J Amer Med Inform Assoc* 2007; 14(1):100-9.

The style strives to save each and every possible character through compact presentation of the author name list, use of standardized journal name abbreviations, and by indicating the page range as '100-9' since a span from pages 100 to 109 can logically be inferred.

Another notable characteristic of the medical literature is the dominance of the systematic literature review as a means of generating evidence about what is already known. While the use of systematic reviews is not unknown in the IS literature, it is the norm in medical and health sciences. In a systematic literature review, the exact criteria, tools and results of the literature search are reported. Most typically this entails reporting the set of index terms used, the search engines interrogated, the number of results returned initially, any exclusion criteria used to narrow those results and a complete identification (sometimes in an appendix) of all remaining papers. The resemblance of systematic literature reviews to methods for knowledge discovery and data mining is striking.

An interesting thing about the systematic literature review is that the Health Informatics community has applied this technique to IT. That is, systematic literature reviews have been undertaken on articles reporting evaluations of health information systems. Box 2 summarises results of some major systematic literature reviews that are illustrative of the power (and limitations) of this technique when applied to IT. The findings from such reviews are highly influential in the field. With respect to those reported in Box 2, each concludes with a call for even more systematic reporting of evaluation findings in the health informatics literature.

One of the most commonly used tools in health-related systematic literature reviews is PubMed, a service for online retrieval of biomedical literature citations provided by the National Center for Biotechnology Information within the US National Library of Medicine (NLM). In fact, PubMed is just one of the major database services provided by NLM; other major databases include Nucleotide and Protein Sequences, Protein Structures, and Complete Genomes. PubMed accesses over 15 million references, and is regularly updated from some 5000 journals in 37 languages. MeSH is a hierarchical structure of terms used to index PubMed. Although the MeSH terms have been designed to simplify searches and deliver comprehensive results, the relative newness and the hybrid nature of health informatics means that the best way to search this database is by means of a combination of MeSH terms and free text. The EBM culture encourages healthcare providers to issue queries to online resources regularly (i.e. to get a practical answer to the clinical problem at hand, not merely as an academic exercise). The NLM promotes access to PubMed through a variety of interfaces to facilitate use at the point-of-care – there's even an SMS txt interface to PubMed.

The structured nature of the medical literature is conducive to extensive IT processing for integration of EBM queries into point-of-care health information systems. In fact, the NLM encourages this and provides E-Utilities that facilitate programmatic access and can provide responses to PubMed queries as XML. There is a high awareness of online

resources in the healthcare (especially medical) community. Health information system implementers are increasingly expected to integrate access to online resources with point-of-care systems, such as those used for Computerized Physician Order Entry (CPOE, ordering tests and procedures via the computer). Box 3 describes the case of a substantial evaluation of a widely-deployed tool for computerized decision support in primary care. The case is illustrative for identifying ways in which an IT based tool can fail to have a positive impact in healthcare. However, it also demonstrates the subtle, and to some extent fundamental, challenges in applying the RCT approach to information systems.

The insistence of evidence from RCTs as the basis for medical decision making regarding treatments has seen its detractors in the medical community. In their article 'Parachute use to prevent death and major trauma related to gravitational challenge: systematic review of randomised controlled trials' Smith and Pell (2003, p. 1459) parody the structure of many modern medical journal articles and lament the lack of willingness to rely on other forms of reasoning to justify decisions. They conclude that "everyone might benefit if the most radical protagonists of evidence based medicine organised and participated in a double blind, randomised, placebo controlled, crossover trial of the parachute."

There is too much information in healthcare as evidenced by the drive to be clear and straightforward in the literature that reflects and supports evidence based care. Knowledge becomes a commodity for use in providing evidence based care, the hierarchy of evidence indicating that systematic reviews and RCTs are the most rigorous and acceptable forms of medical research. The clinical treatment slant towards the use of specific quantitative research methods such as clinical trials presents problems when different questions are asked in search of knowledge that is not directly related to clinical treatments of healthcare interventions.

Prevailing Research Approaches and Methods in IS

Since management of information systems (MIS) is a relatively new discipline, having emerged in the last 40 years, no particular research discipline can be said to represent it (Palvia, Mao, Salam, & Soliman, 2003), in the same way as positivism represents medical research (Malterud, 2001). There does appear to be certain patterns in how MIS research is conducted and the common themes under examination (Palvia et al., 2003). According to Culnan's categorisation of MIS research topics (as outlined by Orlikowski & Baroudi, 1991),the types of MIS research include

- Individual, management and organisational approaches to IS,
- Research foundations, and
- IS curriculum.

Roughly 30 topics fit these categories, such as MIS theory, artificial intelligence and global information technology as the top three topics, with BPR and organisational impact of MIS, innovation, IS planning, implementation and usage somewhere in the middle of the list (Palvia et al., 2003). Surveys, conceptual frameworks and case studies are the most popular study design with literature analysis, mathematical modelling and interviews in the middle of the list (Orlikowski et al., 1991; Palvia et al., 2003) and action research as a form of qualitative[1] research at the end of the list of choices for research design. Action research features in 0.6 - 0.8% of MIS research and does not appear (in the literature) to be growing in popularity in terms of IS research (Orlikowski et al., 1991; Palvia et al., 2003).

To help understand the choices made in MIS research, research is broken down into empirical or positivist, and non-empirical or interpretive and critical research (Orlikowski et al., 1991; Palvia et al., 2003). Positivism is an objective form of research in which the researcher remains distanced from

Box 2. Some results from systematic literature reviews on health information systems

EPR quality. Thiru et al. (2003) reviewed scope and quality of electronic patient record (EPR) data in primary care. To be included in the review the papers had to have a 'reference standard' for judging the EPR quality (e.g. comparison to patient interview findings), and the papers had to have the objective of measuring EPR quality or to have used EPRs and commented on their quality. They found 37 studies measuring EPR data quality and 15 studies that made scoping comments. They found that prescribing data were generally of better quality than diagnostic or lifestyle data. The finding is not entirely surprising since electronic prescribing is widely used in the UK (the source of many of the accepted studies) and hence has a functional relationship to clinical workflow (the doctor enters the prescription into the EPR, not purely as an act of recordkeeping, but in order to actually prescribe).

There is a strong methodological component to the conclusions of this paper. The focus of the conclusions is on limitations in the current reporting of EPR quality. Moreover, Thiru et al. list providing a framework for categorizing and selecting papers reporting data quality in primary care as a contribution of the paper. Thiru et al. noted that most of the select research had been published since 1995 (although they searched back to 1980), indicating the growth and movement toward evidence generation in the field.

Improving clinical practice using decision support systems. Kawamoto et al. (2005) used a systematic review to assess the success factors for clinical decision support based on review of only those papers that assessed outcome with a randomized controlled trial. They found 70 appropriate studies and identified four independently significant factors: (1) automatic provision of decision support as part of clinician workflow; (2) provision of recommendations rather than just assessments; (3) provision of decision support at the time and location of decision making; and (4) computer based decision support. While only 68% of the selected systems improved clinical practice, of the 32 systems possessing all four features, 94% significantly improved clinical practice.

It is notable that Kawamoto et al. did not limit their search to computer-based decision support interventions, but instead allowed this to emerge as a success factor.

Impact of health IT on outcomes. Chaudhry et al. (2006) undertook a systematic literature review of studies that evaluate the impact of health information technology on the quality, efficiency and cost of healthcare. They found 257 studies that met their inclusion criteria. They found evidence of three major quality benefits: increased adherence to practice guidelines, improved surveillance, and decreased medication errors. They found the major efficiency benefit to be decreased utilization of care, with mixed results on time utilization.

The interesting thing about the results is that four benchmark institutions accounted for 25% of the studies found, and were the only institutions each accounting for 5% or more of the studies. Each of these four institutions demonstrated their results with internally-developed systems related to decades-long sustained initiatives. Only nine studies evaluated commercially developed, multi-functional systems of the type that most healthcare organizations would be considering; and the limited evidence from these studies does not support the guideline adherence benefit. Thus the authors are forced to conclude that it is in fact unclear whether other institutions can achieve the benefits from health IT that have been demonstrated by the benchmark institutions. They call for more evaluation of commercially developed systems in the community setting and more uniform standards for reporting research of health IT implementations.

phenomena under examination. Interpretivism and critical research are seen as being subjective, where the researcher's participation in the research itself is acknowledged, and their experience is part and parcel of understanding the phenomenon being examined. It appears that non-empirical research is favoured when researching management and organisational topics while empirical research methods are preferred in the more technical topics (Alavi & Carlson, 1992). The salient difference between the two non-empirical forms of research is the outcome – for critical research it is social change while interpretive research aims at understanding the meaning people attach to social action.

When MIS and healthcare intersect there is no way of determining which approach will be used.

Box 3. Case Study – The system that had no effect

Eccles et al. (2002) evaluated the effect of computerised evidence based guidelines on management of asthma and angina in adults in primary care. This study was significant for being a methodologically-sound, substantial, RCT-type investigation of the benefits of IT to support chronic disease management in the primary care setting, involving 60 general practices in north east England. This is important because of the trend for chronic, rather than acute, illness to dominate healthcare budgets (and the burden of disease). The study was also significant for coinciding with a large-scale primary healthcare decision support development project sponsored by the UK's National Health Service (NHS), known as PRODIGY (Prescribing RatiOnally with Decision-support In General-practice studY). The director of the Centre responsible for PRODIGY was listed as an author on the paper, and the system being studied, appeared to be an implementation of PRODIGY decision support.

The study provided a resoundingly negative assessment of computerized decision support for chronic conditions in primary care. No effect was found either on the process of care (i.e., guideline adherence) nor on disease-specific patient outcomes. Levels of system use were low. And the study called into question the feasibility of integrating computerized decision support into the complex setting of chronic disease management. Moreover, Rousseau et al. (2003) reported a qualitative interview-based study conducted in parallel to the RCT that provided additional insight on the trial findings. Rousseau et al. found that the clinical users had three major areas of concern: (a) timing of the decision support; (b) ease of use; and (c) helpfulness of the content (which is a fairly comprehensive set of concerns!). These concerns stemmed in part from limitations in the integration of the decision support to the electronic medical record, requiring the user to switch between systems. Ease of use was further exacerbated by an inadequate training and support plan. Notably, there was perceived to be an excessive gap between the training and the opportunity to use the system, and an over-extension of the 'train the trainers' concept wherein only a couple of professionals per site were sent for training. The difficulty of using the system was compounded by opinion that use of 'on demand' resources (including PubMed) provided better decision support than that embedded in the system.

The messages from this study are more complex than they may at first seem. Ten 'rapid response' letters (including an author's reply) were posted within three weeks of the initial study's publications. The letters are interesting for illustrating the tensions between different stakeholders and professional perspectives, but also demonstrate the subtle, but fundamental, difficulties in what the study attempted.

The *identity* of the system is a key challenge in evaluation of an advanced system, such as the decision support tool examined by Eccles et al. and Rousseau et al. The response letters indicate that the system was not exactly the latest-generation PRODIGY decision support tool, but rather was software that stemmed from an earlier version of PRODIGY. The letters provide conflicting (or at least complex to interpret) descriptions of when the software was evaluated, ranging from 1997-98 (several years before the publication date) to a more timely 1999-2000. At any rate, the intervention and its data collection spanned a significant period of time. During an experimental intervention, one would like conditions to remain constant, but it is natural for new and innovative software to be updated regularly. The letter from Eccles indicates that the software was in fact updated to fix problems. Over the span of an evaluation, features of the broader environment will also change, such as the availability and quality of other decision support tools.

The response letters also point out the relevance of the broader context of use of a decision support tool, including such issues as financial incentives. One cannot make an isolated change in the workflow of healthcare professionals. Time spent working with a decision support tool, and enacting its recommendations where appropriate, is time not spent on other forms of care provision.

In light of the challenges, it is perhaps not surprising that only limited evidence for benefits of health IT is available. And we are reminded to always remain critical to the context (in time, technology, policy and procedures) of any given evaluation.

Clinical medical research defaults to positivism in the form of randomised clinical trials because the circumstances of searching for evidence to support clinical decisions require rapid evidence retrieval for the purpose of appropriate clinical care (Hamilton, 2005). However, there is a growing need to match the research design to the question to be answered. Because of this, health research no longer adheres strictly to the traditional hierarchy of evidence: it is more appropriate to use qualitative research methods for asking questions about how and why (Petticrew et al., 2003), such as questions about organisational change linked to health IT projects. Action research is most prevalent in healthcare when nurses conduct research - it appears to resonate well with the way in which they normally work (Waterman et al., 2001). Action research is becoming more widely used in healthcare because of the growing variety of opportunities to use it, especially with more patient empowerment and consumer participation in the delivery of healthcare.

Action Research for Pragmatic Knowledge Development

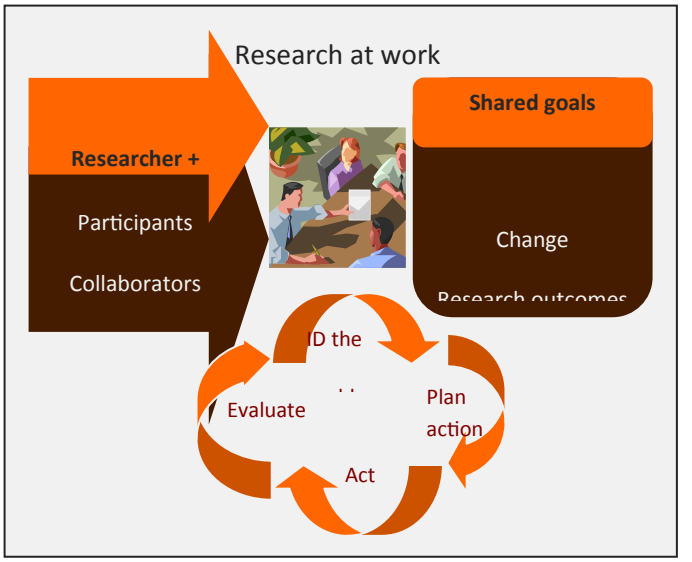
Action research (AR) has waxed and waned in popularity over the last century, depending on what researchers wanted from it, and the situation in which it was used. The concept 'action-research' was first used by Lewin who combined research, practice and change, when he referred to change resulting from research based on social action (Waterman et al., 2001). In this way AR emerged as a tool for social change: research and practice are conducted simultaneously and the research subject is a participant in the research and in the application of new knowledge (Brydon-Miller et al., 2003). There is usually an emphasis on the development of knowledge in the practical situation where a researcher and the researched (both acting as participants, partners and collaborators of change, research and new practice) participate holistically in the achievement of shared goals (Day, Orr, Sankaran, & Norris, 2006; Waterman et al., 2001) as can be seen in Figure 2.

AR as a research methodology has two key elements: a cyclic process, and partnership with the research subjects, respondents or participants (Waterman et al., 2001). With such a strong people focus, the most appropriate definition of action research has been presented by Rapoport (1970, p. 499), as aiming to "...contribute **both** to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework". This definition presents the idea that action research is not only a methodology, or simply a research process – it is a way of life, of working, that plays out in a mutually desired manner for all participants (researcher and researched) in a social research project.

Action research emerged in information systems in the latter half of the 20th century and echoed the early action researchers' challenge that positivism and quantitative research were not the only form of appropriate research in information systems. According to Avison et al. (2001, pp. 94 - 95) several information systems contributions have been made in the form of the Multiview contingent systems development framework, soft systems methodology, the Tavistock School sociotechnical design, Scandinavian trade union research regarding user bargaining power in systems development, and the Effective Technical and Human Implementation of Computer-based Systems (ETHICS) approach to participative systems development. Action research can be used to link the people in their complex healthcare services to the information systems they use in much more pragmatic ways than by other means (Avison et al., 2001).

Because of the broad scope of health IT research and the wide range of areas of healthcare that information systems affect, we need to carefully match the research question with an appropriate way of accessing the associated knowledge. On the flipside, the nature of health research determines to some extent the ways in which we represent, and support the use of, knowledge in health information systems.

Figure 2. The relationships of people, goals and AR cycle in action research (Day et al., 2006)



USING HEALTH KNOWLEDGE EFFECTIVELY

Different forms of health knowledge are used in a variety of settings, and for reasons that differ according to the user. Clinical information is made available at the point of care and also later classified and categorised for purposes of planning, policy making, and evaluating of healthcare service delivery. Clinical decision support systems present clinical guidelines in a format that aims at making evidence-based care more achievable, another form of knowledge commodity.

Clinical Information Systems: Recording, Accessing and Using Clinical Information

There is a range of 'workhorse' information systems components that are likely to already be in place in most developed countries, at least in the more centralized healthcare delivery facilities e.g., a classic metropolitan hospital or large clinic. In many countries – notably Denmark, the UK, the Netherlands, Australia and New Zealand, and to a lesser extent Canada and most of the rest of the EU – these systems will also extend in large part to all but the smallest or most remote local care providers. Table 1 provides a summary based in large part of van Bemmel and Musen (1997).

The challenge for the modern health information system implementer often revolves around working with the existing *legacy* systems, those systems already in place. These challenges can include enhancement of the existing functions to meet higher requirements for reporting, security and integrity, automated decision support or timely data exchange, as well as to provide gateways for integration with larger regional or national networks, and mobile and remote access.

Guidelines and Clinical Decision Support Systems (CDSS)

The American Institute of Medicine defines clinical practice guidelines as "systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances" (Field & Lohr, 1992, p. 27). Such guidelines are developed and distributed on paper, but of course also increasingly find distribution channels in electronic formats. In a loose sense,

any material on computer or paper that provides information to aid a decision can be considered 'decision support.' However, when the guidelines are automated to the point of automatically computing patient-specific advice, then the resultant technology is rightly termed a *clinical decision support system* (CDSS).

As per Box 2, there are a number of factors now to influence the success of decision support for clinicians; notably, making it electronic, providing recommendations specific to the patient at hand, and providing a good fit to current workflow. There is a vast range of decision technologies that can provide the underlying mathematical models for such support, including production rule expert systems, artificial neural networks, fuzzy logic, case-based reasoning systems and Bayesian reasoning systems (see Warren & Stanek, 2006 for a more complete discussion). Such systems can provide an array of 'artificial intelligence' type functions, such as suggesting diagnoses in relation to symptoms, advising on treatment strategies, including computation of recommended dosage, or calculating risks. CDSS technology can be deployed in a consultative role (where it is invoked by the clinician) or can serve as a 'critic' and provide pop-up advice or an alert for a dangerous or sub-optimal situation, such as an attempt to order a drug that may cause an adverse interaction with one already prescribed or to which the patient has a recorded an allergy. The systems may provide an explanation of reasoning, and, ideally, will provide pointers to the medical literature that supports the system recommendation. This latter aspect is extremely useful since it directs the user back to the humans that undertook the supporting clinical research, rather than advising the human user (generally a doctor) to accept the recommendation of a machine per se.

There is a growing demand for the use of CDSS to promote (if not enforce) guideline adherence, both to promote EBM for optimal patient outcome and to control costs associated with testing and procedures beyond those indicated in guidelines. The demand for CDSS is further enhanced by the desire to provide patient safety through the ability of machines to integrate tirelessly all available information, thus avoiding certain classes of adverse events.

An essential enabler for CDSS that integrates with clinician workflow is the systematic use of terminology and coding in the clinical practice, which allows the system to accurately associate the data in the health information system with key decision concepts.

Coding, Classification and Terminology Systems for Usable Knowledge

The rise of coding, classification and terminology systems is a response to the volume and complexity of information associated with the delivery of healthcare, and the different groups of people who need to use such information (like clinicians, managers and researchers). A particular feature of health information processing is the use of formalized coding and classification schemes to represent clinical concept. Table 2 provides a summary of some of the most commonly used and important schemes.

Many of the schemes are tightly tied to billing and reimbursement processes, and as such take on a life of their own. A key example is the DRG (Diagnosis-Related Group) process, as used by the US government's Medicare and, with variation, many other health funders around the world. The International Classification of Disease (ICD) codes (in variations of version 9 in the US, or version 10 in most other places) are used as the basis for assigning a patient to one of some 500 DRGs, where each DRG is meant to represent a category of approximately uniform resource consumption for the patient's care. DRG coding is functionally the mediator through which a significant proportion of hospital funding is obtained, and hence, naturally, involves specialized software and staff to optimize the claims process.

Coding and classification schemes also serve as key roles in statistical reporting, including com-

Table 1. Types of 'workhorse' (foundational) health information systems at the point of care

Type of System	Description
ADT – Admission, Discharge and Transfer	System for registering and tracking the presence of a patient in a facility, and creating clinical and administrative reports upon service completion – often tied to billing
Ordering	Systems to order tests and procedures to be performed on a patient
Results reporting	Systems to view the results of tests for ongoing patient diagnosis and treatment
Radiology	Systems to manage orders and reports of medical imaging; often integrated with a PACS function
PACS – Picture archiving communications systems	Systems to manage storage, retrieval and distribution of high-resolution medical images
Pharmacy	Systems for drug inventory and administration management, including support for preparations made onsite (as with many intravenous solutions)
Nursing	Systems supporting records of nursing care procedures delivered and patient status
Departmental systems	Systems specialized to the needs of a given department due to the nature of its business, e.g., Emergency Department, surgical facility or Intensive Care Unit, and/or providing discipline-specific features in data collection or decision support.

pliance to government regulation and support for research and management reporting. To illustrate the latter usage, if management wanted to know the average length of stay of all patients who had suffered a stroke, then a look-up of all patients with ICD9 codes in the range 430-438 is a good start. Of course, for this to be effective, procedures must be in place to achieve collection of all relevant codes. And one should not underestimate the complexity of some of these coding schemes and the opportunities available for coding a particular event in any of multiple ways.

Achieving an agreed formalized *terminology,* i.e., a set of natural-language strings that map to underlying concept codes, is considered an essential step in preparing a clinical sub-domain for extensive use of IT. An obvious advantage of an agreed term set for any concept is the ability to put it on a menu or, when the domain is very large, implement some form of structure look-up control. For large and complex domains (such as diagnosis coding in an Emergency Department), the clinical users providing care will not have an active understanding of the entire coding/classification system, and thus will record terms at the point of care. The ideal user interface allows clinicians to record terms that match the standardized terminology and hence readily match to concept codes. This point-of-care input may be later mediated by a clinical coding specialist (as in the process of DRG coding for reimbursement). The SNOMED CT scheme is particularly complete in its representation of clinical terminology (with a one-to-many mapping of natural language terms to underlying concepts). While SNOMED has a sophisticated ability to represent clinical concepts, the scheme is large and complex. SNOMED is gaining increasing acceptance, with the US and UK, and more recently Australia, taking out national licences.

Coding and classification underpins ***systems interoperability,*** that is, the ability for distinct computer systems, particularly those provided by different vendors, to exchange information. Health Level 7 (HL7) is the most important set of elec-

tronic messaging standards in healthcare. Within a given message between two healthcare information systems the agreed clinical codes allow specific fields to be interpreted correctly by the receiving system. For example, Logical Observation Identifiers Names and Codes (LOINC) has since 1999 been the preferred terminology for laboratory test orders and results in HL7 messages.

Coding and classification systems are constantly being updated, and often diverge into local variations. Any health information system implementation must include a mechanism for achieving regular updates to its terminology and underlying coding and classification schemes. Moreover, there are numerous other relevant standards outside of the schemes we have discussed, such as Digital Imaging and Communications in Medicine (DICOM), a popular standard for storage and transmission of medical imaging.

LESSON/CONCLUSION

Healthcare is a complex domain that demands fast, intuitive, robust, stable and trustworthy systems that can address the needs of a range of distinct classes of users and the diverse functions they perform. Systems must be designed to support patient safety first, and to protect confidentiality of patient data. Implementers must aggressively and proactively undertake risk management to minimize the frequency and impact of system failures.

The commodity approach to health knowledge has powerful implications for health information systems analysis and design. These implications come in two general varieties:

1. The pressure for systems to manage health knowledge as a commodity, and
2. The pressure to justify design decisions and system success in the terms of the knowledge commodity culture.

The first of these implications can be, in a sense, relatively easy to manage. This is just a question of good user interface design - to speak the user's language (in accordance with Nielsen's (1994) second usability heuristic, 'match between system and the real world'). Any application that provides clinical decision support must reflect a savvy approach to EBM. Clinical input will be required not just in the functional aspects of the system specification,

Table 2. Commonly-used clinical classification and coding schemes

Scheme	Main Use	Approximate Size	Owner
ICD9 / ICD10 – International Classification of Disease	Discharge diagnosis; statistical classification	200,000 classes	World Health Organization (WHO)
SNOMED CT - Systematized Nomenclature of Medicine – Clinical Terms	Comprehensive and precise clinical terminology	350,000 concepts (>1M terms)	International Health Terminology Standards Development Organisation
LOINC - Logical Observation Identifiers Names and Codes	Laboratory test orders and results	>30,000 distinct observations	Regenstreif Institute
CPT - Current Procedural Terminology	Billing codes for services rendered	8600 codes and descriptors	American Medical Association
ICPC-2 – International Classification of Primary Care	Reason for encounter (RFE) and other General Practice Medicine concepts	750 codes	World Organization of Family Doctors (WONCA)
UMLS – Unified Medical Language System	Facilitate development of automated reasoning systems in biomedicine and health	>1M concepts (>5M concept names)	US National Library of Medicine

but in every stage of formulating the user interface presentation. Clinical coding and classification schemes, standardized terminology and other standards (such as those for medical imaging and interoperability of health messages) must be carefully considered at every stage.

The second implication is more demanding on the structure of health information systems projects. There will be a pressure to justify design decisions in a manner that is symmetric to evidence-based clinical decisions – by weight of high-quality evidence, collected via systematic literature review and critical appraisal. And there is a pressure to measure a project's success to the standard of success for clinical interventions—via an RCT. As we have seen with the Eccles et al. case study (Box 2), this path is fraught with impracticalities in terms of time-scale and constraints on the natural evolution of systems. Awareness of the broader spectrum of research approaches, notably the action research paradigm, which integrates action and reflection, will help the IS implementer to proceed on a credible basis without being hamstrung by expectations that are not feasible.

These pressures for evidence-based practice will be minimal where the system is at some distance from the clinical (notably physician) culture, such as in support for the logistics of medical supplies. In operational terms, significant pressure will be for system integrity—reliability, robustness and security. As the system moves closer to the clinical interface, however—and especially where the system is directly involved in clinical decision support—there will come the expectation to keep to the norms of the clinical domain.

The rising expectations for clinical systems can be seen with respect to CPOE systems. Ash, Berg & Coiera (2004) provide a taxonomy of the types of errors *caused* by health information systems, including such categories as: (a) cognitive overload by overemphasizing structured information; (b) human-computer interfaces not suitable to interruptions; and (c) misrepresenting clinical work as a predictable workflow. In many settings, health IT systems are no longer optional – they are often the only way to work within a given healthcare setting. Health information systems designers will be under increasing pressure to deliver systems that truly fit with clinical work and can be demonstrated to have a net positive contribution to health outcomes.

One of the most amazing things about health information systems is that, despite the enormous barriers to their implementation, people get on with doing it anyway. It is worth noting that the US, while home to some islands of excellence in healthcare IT, is not on the aggregate a world leader in its deployment. This probably owes in part to the decentralized nature of its healthcare system, wherein the sector is not as prone to responding to a central government directive as, say, the UK with its National Health Service (NHS). However, the past couple of years have seen a major top-down push for health IT in the US with resulting major initiatives in the Department of Health and Human Services (see http://www.hhs.gov/healthit/initiatives/).

Even in environments that are heavily or fully electronic, the effort continues to achieve higher levels of integration and greater benefits from health IT. For example, in New Zealand, where virtually all primary care physicians use computers, and paperless practices are not rare, the implementation of both national and local health strategies shows nothing but acceleration in the level of health information systems implementation activity. The methods and challenges of this area are both instructive and, equally, in need of further study. Moreover, the diversity of approaches taken in healthcare can inform our choice of techniques to achieve an effective implementation in other multidisciplinary and complex domains.

The drive to achieve effective interoperability of health information systems is increasing in momentum through the 'connectathon' process as promoted by IHE (http://www.ihe.net/Connectathon/index.cfm). A connectathon is a venue for vendors to prove their implementation by exchanging information with complementary systems from other vendors, and performing all of the required

transactions their system's roles in a selected profile of use cases. This process is driving ahead health information systems practice by putting vendor claims of standards adherence to the test.

On the research side, what is needed is more evaluation of the effectiveness of healthcare implementations. As per Box 2, Chaudhry et al. (2006) find rather limited evidence to support the notion that organisations can expect to achieve benefits related to health outcome from health IT deployment. This is not to say that outcomes are failing to be achieved – just that the process has not been adequately articulated. In this regard there is a particular need to understand the implementation pathways and outcomes associated with deployment of off-the-shelf systems (as compared to 'home grown' software solutions).

While we have provided some insights into the complexities of information management and systems success in health care, it is impossible to address the entire domain of Health Informatics in a single chapter. The interested reader is recommended to investigate the textbooks by Shortliffe (2006) and Coiera (2003) listed below.

REFERENCES

Alavi, M., & Carlson, P. (1992). A review of MIS research and disciplinary development. *Journal of Management Information Systems, 8*(4), 45-62.

Ash, J. (1997). Organisational factors that influence information technology diffusion [EP in Academic Health Sciences Centres]. *Journal of the American Medical Informatics Association, 4*(2), 102-111.

Ash, J., Berg, M., & Coiera, E. (2004). Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. . *Journal of the American Informatics Association, 11*, 104-112.

Avison, D., Baskerville, R., & Myers, M. D. (2001). Controlling action research projects. *Information Technology & People, 14*(1), 28.

Brydon-Miller, M., Greenwood, D., & Maguire, P. (2003). Why action research? *Action Research, 1*(1), 9-28.

Buchanan, D., & Connor, M. (2001). Managing process risk: Planning for the booby traps ahead. *Strategy & Leadership, 29*(3), 23-28.

Chaudhry, B., Wang, J., Wu, S., Maglione, M., Mojica, W., Roth, E., et al. (2006). Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. *Annals of Internal Medicine, 144*(10), 724-752.

Coiera, E. (2003). *Guide to Health Informatics* (2nd ed.). Hodder: Arnold.

Coiera, E., Walther, M., Nguyen, K., & Lovell, N. (2005). Architecture for knowledge-based and federated search of online clinical evidence. *Journal of Medical Internet Research, 7*(5), e52.

Day, K., Orr, M., Sankaran, S., & Norris, T. (2006). The reflexive employee: action research immortalised? *Action Learning and Action Research Journal, 11*(2).

Dooley, K. (1997). A complex adaptive systems model of organization change. *Nonlinear Dynamics, Psychology, and Life Sciences, 1*(1).

Eccles, M., McColl, E., Steen, N., Rousseau, N., Grimshaw, J., Parkin, D., et al. (2002). Effect of computerised evidence based guidelines of asthma and angina in adults in primary care: cluster randomised controlled trial. *British Medical Journal, 325*(7370), 941-948.

Field, M. J., & Lohr, K. N. (1992). *Guidelines for clinical practice: from development to use*. Washington, DC: Institute of Medicine, National Academy Press.

Garg, A. X., Adhikari, N. K. J., McDonald, H., Rosas-Arellano, M. P., Devereaux, P. J., Beyene, J., et al. (2005). Effects of computerized clinical decision support systems on practitioner performance and patient outcomes. *Journal of the American Medical Association, 293*(10), 1223-1238.

Glouberman, S., & Mintzberg, H. (1996). Managing the care of health and the cure of disease. Part 1: differentiation. *Healthcare Management Review, 26*(1), 56-59.

Gutierrez, C., & Ranji, U. (2005). US Health Care Costs: Background Brief. Henry J. Kaiser Family Foundation. Retrieved 16 April 2007, from http://www.kaiseredu.org/topics_im.asdp?imID=1&parentID=61&id=358

Guyatt, G., Cook, D., & Haynes, B. (2004). Evidence based medicine has come a long way. *British Medical Journal, 329*, 990-991.

Hamilton, J. (2005). The answerable question and a hierarchy of evidence. *Journal of the American Academy of Child and Adolescent Psychiatry, 44*(6), 596-601.

Hanka, R., O'Brien, C., Heathfield, H., & Buchan, I. (1999). *WAX ActiveLibrary; a tool to manage information overload.* Paper presented at the 32nd Hawaii International Conference on System Sciences, IEEE Computer Society Press.

Health Information Steering Committee (NZ). (2005). *Health Information Strategy for New Zealand*. Wellington: New Zealand Ministry of Health.

Heeks, R., Mundy, D., & Salazar, A. (1999). *Why health care information systems succeed or fail. Information systems for public sector management. Working paper series 9.* Manchester: Institute for Development Policy Management.

Hersh, W. (2006). Who are the informaticians? What we know and should know. *Journal of the American Medical Informatics Association, 13*, 166 - 170.

Institute of Medicine (U.S.). (2000). *To err is human: Building a safer health system*. Washington, DC: National Academy Press.

Institute of Medicine (U.S.). Committee on Quality of Health Care in America. (2001). *Crossing the quality chasm: a new health system for the 21st century*. Washington, D.C.: National Academy Press.

Kawamoto, K., Houlihan, C., Balas, E., & Lobach, D. (2005). Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. *British Medical Journal, 330*(7494), 765.

Khan, K. S., Kunz, R., Kleijnen, J., & Antes, G. (2003). Five steps to conducting a systematic review. *Journal of the Royal Society of Medicine, 96*, 118-121.

Klein, H. K., & Myers, M. D. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly, 23*(1), 67-94.

Leape, L. L., & Berwick, D. M. (2005). Five years after *To Err is Human*. What have we learned? *Journal of the American Medical Association, 293*(19), 2384-2390.

Littlejohns, P., Wyatt, J. C., & Garvican, L. (2003). Evaluating computerised health information systems: hard lessons still to be learned. *British Medical Journal, 326*, 860-853.

Lorenzi, N. M., Riley, R. T., Blyth A. J. C., Southon, G., & Dixon, B. J. (1997). Antecedents of the people and organisational aspects of medical informatics: Review of the literature. *Journal of the American Medical Informatics Association, 4*(2), 79-93.

Malterud, K. (2001). Qualitative research: standards, challenges, and guidelines. *The Lancet, 358*(August 11), 483-488.

Mayer, D. (2006). Evidence-based medicine. *Epilepsia, 47*(Suppl. 1), 3-5.

Medical Journal of Australia. (2002). *MJA structured abstracts*. Retrieved 14 April 2007, from http://www.mja.com.au/public/information/abstract.html

National Library of Medicine. (2006). *International Committee of Medical Journal Editors Uniform*

Requirements for Manuscripts Submitted to Biomedical Journals: Sample References. Retrieved 14 April 2007, from http://www.nlm.nih.gov/bsd/uniform_requirements.html

Nielsen, J. (1994). Heuristic evaluation. In J. Nielsen & R. L. Mack (Eds.), *Usability Inspection Methods*. New York: John Wiley & Sons.

Orlikowski, W. J., & Baroudi, J. J. (1991). Studying information technology in organizations: research approaches and assumptions. *Information Systems Research, 2*(1), 1-28.

Orr, M. (2004). Evolution of New Zealand's health knowledge management system. *British Journal of Healthcare Computing and Information Management, 21*(10), 28-30.

Orr, M., & Day, K. (2004). Knowledge and learning in 'successful' IT projects: a case study [Electronic Version]. *Health Care and Informatics Review Online* from http://www.enigma.co.nz/hcro/website/index.cfm?fuseaction=articledisplay&Feature.

Palvia, P., Mao, E., Salam, A. F., & Soliman, K. S. (2003). Management information systems research: what's there in a methodology? *Communications of the Association for Information Systems, 11*, 289-309.

Petticrew, M., & Roberts, H. (2003). Evidence, hierarchies, and typologies: horses for courses. *Journal of Epidemiology & Community Health, 57*(7), 527-529.

Petticrew, M., & Roberts, H. (2006). *Systematic reviews in the social sciences. A practical guide*. Malden, MA: Blackwell Publishing.

Plesk, P. E., & Greenhalgh, T. (2001a). The challenge of complexity in health care. *British Medical Journal, 323*, 625-628.

Plesk, P. E., & Wilson, T. (2001b). Complexity science: complexity, leadership, and management in healthcare organisations. *British Medical Journal, 323*, 746-749.

Protti, D. (2003). Local clinician involvement in clinical information systems: luxury or necessity? A review of two international experiences. *British Journal of Healthcare Computing and Information Management, 20*(10), 28-30.

Rapoport, R. N. (1970). Three dilemmas in action research. *Human Relations, 23*(6), 499-513.

Rousseau, N., McColl, E., Newton, J., Grimshaw, J., & Eccles, M. (2003). Practice based, longitudinal, qualitative interview study of computerised evidence based guidelines in primary care. *British Medical Journal, 326*(7384), 314.

Shortliffe, E. (1984). The science of biomedical computing. *Medical Informatics, 9*, 185-193.

Shortliffe, E. (2006). *Biomedical Informatics: Computer Application in Health Care and Biomedicine* (3rd ed.): Springer.

Sidorov, J. (2006). It ain't necessarily so: the electronic health record and the unlikely prospect of reducing health care costs. *Health Affairs, 25*(4), 1079-1085.

Smith, G., & Pell, J. (2003). Parachute use to prevent death and major trauma related to gravitational challenge: systematic review of randomised controlled trials. *British Medical Journal, 327*, 1459-1461.

Smith, R. (1996). What clinical information do doctors need? *British Medical Journal, 313*, 1062-1068.

Southon, G., Perkins, R., & Galler, K. (2005). Networks: a key to the future of health services. *Journal of the Australian Healthcare Association, 29*(3), 317-326.

Stanley, K. (2007). Design of randomized controlled trials. *Circulation, 115*, 1164 - 1169.

Sveiby, K. (1996). Tacit knowledge. Transfer of knowledge and the information processing professions. *European Management Journal, 14*(4), 379.

Tan, J., Wen, H. J., & Awad, N. (2005). Health care and services delivery systems as complex adaptive systems. Examining chaos theory in action. *Communications of the ACM, 48*(5), 37-44.

Thiru, K., Hassey, A., & Sullivan, F. (2003). Systematic review of scope and quality of electronic patient record data in primary care. *British Medical Journal, 326*, 1070.

Van Bemmel, J. (1984). The structure of medical informatics. *Med Inform, 9*, 175 - 180.

Van Bemmel, J. H., & Musen, M. A. (Eds.). (1997). *Handbook of Medical Informatics*. Netherlands: AW Houten.

Warren, J., & Stanek, J. (2006). Decision support systems. In M. Cornick (Ed.), *Health Informatics: Transforming Healthcare with Technology* (pp. 248 - 261): Thomson Learning.

Waterman, H., Tillen, D., Dickson, R., & de Koning, K. (2001). *Action research: a systematic review and guidance for assessment.* Norwich: Queen's Printer and Controller of HMSO 2001.

Wiener, M., Gress, T., Theimannn, D. R., Jenckes, M., Reel, S. L., Mandell, S. F., et al. (1999). Contrasting views of physicians and nurses about an inpatient computer-based provider order-entry system. *Journal of the American Medical Informatics Association, 6*(3), 234 - 244.

Wyatt, J. (1991). Uses and sources of medical knowledge. *Lancet, 338*, 1368 - 1372.

Wyatt, J. (2001). Top tips in knowledge management. *Clinical Governance Bulletin, 2*(3), 8.

Wyatt, J., & Keen, J. (2005). The NHS's new information strategy. *British Medical Journal, 317*(7163), 900.

Wyatt, J., & Sullivan, F. (2005). Keeping up: learning in the workplace. *British Medical Journal, 331*, 1129-1132.

KEY TERMS

Action Research: The use of the cycle of act and reflect to solve problems in the workplace while simultaneously conducting research, within mutually agreed upon ethical parameters (Rapoport, 1970). Although AR is usually used for qualitative research it is increasingly becoming a mixed methods research tool, using both qualitative and quantitative research methods in a single study.

Clinical Decision Support Systems (CDSS): Electronic tools (usually) that have been developed from clinical guidelines in order to present clinical information appropriately, quickly and effectively at the point of care. They aim to support the delivery of evidence-based medicine.

Complex Adaptive System: Health is a complex adaptive system in that many parts of the system interact interdependently and mostly unpredictably with one another and their environment. These systems are sensitive to initial conditions, support the emergence of the unexpected, and result in unanticipated consequences.

Evidence-Based Medicine: The use of clinical evidence derived from research, best practice and experience to provide healthcare aimed at quality, cost-effective outcomes.

Health Informatics: The theoretical and practical science of using information systems, tools and processes to support and enable healthcare delivery from a range of perspectives and to achieve a broad scope of healthcare goals and objectives.

Health Information Systems: These consist of IT infrastructures and applications that support the delivery of healthcare by means of acquiring, storing and reusing electronic information.

Health Knowledge Management: The acquisition, storage, use and reuse of information as it merges with the experience of healthcare practitioners and service providers, e.g. clinicians and

managers (knowledge workers). Tacit and explicit knowledge are exploited for improved health outcomes in applications such as clinical decision support systems, randomised control trials, and other components of the hierarchy of evidence.

ENDNOTE

[1] Although the literature outlining IS research categories and themes classes action research as a form of qualitative research, recent practice patterns present action research as a framework that enables both qualitative and quantitative forms of research (Brydon-Miller, Greenwood, & Maguire, 2003; Klein & Myers, 1999).