Mapping Healthcare Information Technology

by

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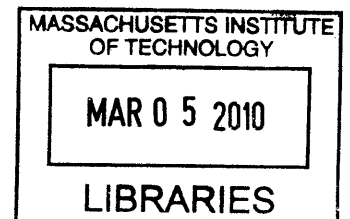
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Biography

William Crawford is a Master's candidate in the Biomedical Enterprise Program at the Harvard-MIT

Division of Health Sciences and Technology. He is also currently the Director of the Informatics Solutions

Group at Children's Hospital, Boston, where he is responsible for an internal consulting organization that

studies, designs and implements IT based solutions to business and operational challenges within the

hospital and the larger Harvard Medical School community. ISG projects included implementing key

software for the Dossia Consortium, a group of Fortune 50 retail and industrial firms that sought to

deploy Personally Controlled Health Records for their employees. Before joining Children's he served as

a policy staff member at the Centers for Medicare and Medicaid Services in Washington, DC, where he

was involved in coordinating the activities of CMS and other Federal agencies around HIT issues. He was

previously Director of Product Technology at Perceptive Informatics, Inc., a subsidiary of PAREXEL

Corporation, and Chief Technology Officer of Invantage, Inc., which was acquired by PAREXEL in 2002.

Mr. Crawford is the co-author of three books in enterprise software development, *Java Servlet

Programming* (1998, 2001), *Java Enterprise in a Nutshell* (1998, 2002, 2005) and *J2EE Design Patterns*

(2003) as well as numerous articles. In 2006 he co-founded and co-chaired the Harvard Medical School

Meeting on Personally Controlled Health Record Infrastructure, a successful event that was held again in

2007. He is a frequent speaker at conferences and has guest lectured at Harvard Medical School, MIT,

the MIT Sloan School, Boston University and Claremont Graduate University.

Mr. Crawford graduated from Yale University, where he was President of the Yale Political Union, in

2001 with a BA in Economics and History and from MIT Sloan in 2008 with an MBA. He resides in Boston,

MA.

Conflicts of Interest

The author has no conflicts of interest to declare.

Abstract

In this thesis I have developed a map of Healthcare Information Technology applications used in the United States for care delivery, healthcare enterprise management, clinical support, research and patient engagement. No attempt has previously been made to develop such a taxonomy for use by healthcare policy makers and on-the-spot decision makers. Using my own fifteen years of experience in HIT, along with an extensive set of literature reviews, interviews and on-site research I assembled lists of applications and organized them into categories based on primary workflows. Seven categories of HIT systems emerged, which are Practice Tools, Advisory Tools, Financial Tools, Remote Healthcare Tools, Clinical Research Tools, Health 2.0 Tools and Enterprise Clinical Analytics, each of which have different operational characteristics and user communities. The results of this pilot study demonstrate that a map is possible. The draft map presented here will allow researchers and investors to focus on developing the next generation of HIT tools, including software platforms that orchestrate a variety of healthcare transactions, and will support policy makers as they consider the impact of Federal funding for HIT deployment and adoption. Further studies will refine the map, adding an additional level of detail below the seven categories established here, thus supporting tactical decision making at the hospital and medical practice level.

1. Introduction

Healthcare Information Technology (HIT) promises to provide a set of underlying tools to accelerate the restructuring of the healthcare industry in the United States. Information technology has been cited in major health reform proposals as a key to reducing the cost of healthcare and improving quality. [1] Standardized interchange of healthcare data between providers, alone, has been estimated as potentially saving the United States up to $77 billion annually. [2] Adoption of HIT has nonetheless been slow, as physicians express concerns about their ability to use and support new systems[3] and experience higher overall costs, even when counterbalanced by improved quality of care.[4] In comparison, use of Electronic Health Records, a core component of an HIT infrastructure, is claimed to approach 80-90% in the UK, Netherlands, Australia and New Zealand, and 40% in Germany.[5]

In 2004, the Bush administration signaled its interest in promoting HIT through Executive Order 13335, which established a new position, the National Coordinator for Healthcare Information Technology, an office to support the coordinator, and an allocation of several million dollars for various initiatives. [6] The Coordinator's office was formalized in statute in the American Recovery and Reinvestment Act of 2009, which also included $2 billion for policy, workforce training and implementation grants, and an additional $38 billion in incentives for providers to adopt healthcare information technology systems. [7] Whether these funds are being well used is a matter for ongoing debate, as there are few if any analytical tools available to evaluate the most effective use of stimulus dollars for HIT, as related to achieving improvements in clinical performance and reduction in overall healthcare systems costs.

When different stakeholders discuss HIT, they may be referring to any number of components contributing to a complex tapestry of applications, settings, and intended users. HIT is as varied as the practice of medicine itself. Just as the practice of medicine may be analyzed by activity (history, examination, diagnosis, at times consultation, treatment and prescribing, and follow-up); location

(inpatient and outpatient settings, at the patients' home, in skilled nursing and rehabilitation facilities, in the physicians' office, on the battlefield, at workplace and even remotely, at a distance from the practitioner); by specialty; by scale (individuals or populations, individual practitioner or institution; single specialty or multispecialty); and by thrust (preventative or therapeutic; back office billing, revenue cycle management or clinical decision support); so must an HIT implementation be evaluated in the context of its purpose or application, the site of care, and the level of novelty associated with the endeavor . Anesthesiology and operating room management systems, for example, are required to integrate large amounts of information in real time, and to provide logistical as well as clinical support and documentation. Primary care providers managing a population panel require much less granular information, but the information must be rendered for the physician in a way that renders trends across time extremely clear. Systems directed at both primary care physicians and specialists will be called upon increasingly to justify themselves by providing data and support for the "pay for performance" provisions instituted or contemplated by many payers. [8] Electronic data capture (EDC) promises to reduce the time and cost of the submission of data to regulatory bodies such as the Food and Drug Administration (FDA) in clinical trials and to improve the reliability of data obtained.[9] For individual physicians and academic departments, EDC also offers the opportunity to participate in such trials or, indeed, to run them without incurring unmanageable overhead.

Certain settings may benefit more from an IT investment than others: in the outpatient setting, for example, clinicians must coordinate information gathered over time from a variety of sources of varying reliability – and they may generate very little of those data themselves.

Assessment tools for HIT are in their infancy,[10] and standard inpatient directed hospital quality measures may not account for some of the potential contributions of an electronic hospital chart upon discharge. It is reasonable to imagine that an accurate, electronically generated discharge note that fully informs

the referring physician of the care delivered in-hospital setting will improve follow-up care. An accurate, comprehensive and accessible discharge summary is a *sine qua non* of medical tourism, which has been proffered as yet another instrument by which to reduce healthcare costs. Hospitals such as Bangkok's Bumrungrad International have accordingly made substantial investments in HIT, particularly around exchanging patient data with other care providers. [11] Such notes and summaries are no less important in the practice of telemedicine, in which physician-physician and physician-patient consultations enabled by broadband technologies take place remotely.

1.1. Interoperability of Healthcare IT

Since so many of the potential economic benefits of HIT derive from sharing information, HIT discussions tend to hinge on the idea of "interoperability". For stimulus funding purposes, the government is currently defining a set of interoperability criteria for HIT. As interoperability continues to be a key subject of discussion in HIT circles it is worth taking a moment to provide a brief introduction to its definition in this context. In its initial set of standards, the government has focused on three key areas: vocabularies, encodings and transactions. Vocabularies allow different systems and institutions to identify information consistently. Examples include the ubiquitous ICD-9 code, used to tag diagnoses, as well as more specialized vocabularies such as RxNorm (for medications), SNOMED-CT (for a lexicon of clinical terms) and LOINC (Logical Observation Identifiers Names and Codes) for laboratory results reporting. Adoption of standardized vocabularies has been slow. The author's experience is that laboratories are only slowly embracing LOINC, and standard medication terminologies are only coming into widespread use as a result of the rise of electronic prescribing. The interoperability rules imposed by the government as part of the stimulus package are likely to increase the use of standard vocabularies, although many institutions are equally likely to perform translations from local vocabularies to common ones at the boundary layer that separates them from their partners.[12]

Encodings organize sets of data in consistent ways that can be understood by multiple systems. One

example is the Continuity of Care Record (CCR), which is used to record a variety of summary data about

a patient, either at the visit level or longitudinally. Finally, transactions govern how encoded information

is exchanged between different healthcare entities. Transaction management is equal parts policy and

technology, as the institutions at each end of the transaction must come to an agreement on what data

they will accept and under what circumstances. At a regional level, resource limitations have tended to

mean that providing a set of policies that enable transmission of, for instance, CCR documents across

institutions without explicit patient involvement has presented a serious challenge, particularly if an

independently sustainable business model is required. [13]

1.2. Health IT as a Unique Case in Information Technology

Delays in the adoption of HIT are not new. In 1966, Dr. Octo Barnett, the head of the Laboratory of

Computer Science at Massachusetts General Hospital and the developer of what is widely acknowledged

as the first functioning electronic health record system, wrote in response to an article proposing the

establishment of a nationwide health information network, that:

> The unwary reader may make the erroneous inference that we have a program at the MGH that
>
> is capable of operational participation in such a network. The problems of using a computer to
>
> collect and process the information in the medical record are complex, and the techniques we
>
> have evolved in our Laboratory of Computer Science are, in many ways, primitive and
>
> inadequate for a total system. There is still considerable developmental effort required in the
>
> areas of computer technology and terminal utilization and especially in our understanding and
>
> formularization of the problems and methods of solution. Any network capable of functioning in
>
> the next few years would contain only very limited patient information, and certainly not the
>
> total hospital record. Miller is certainly correct in his thesis that a computer network for

transmitting patient care information from one hospital to another is a desirable feature, not

only to facilitate improved patient care in a mobile urban society, but also to make possible

medical research on a large population. However, a network is only feasible when there are

viable units, and this latter objective has not yet been realized. The significant problems concern

the nature of medical practice and the characteristics of individual hospitals; once these are

solved, the net-work problems should not present severe barriers.[14]

Dr. Barnett's letter could just as easily have been written forty years later. And yet during this time,

information technology revolutionized virtually every other major American industry. Thus, the

proverbial visitor from another planet visiting an American hospital forty years ago and returning today

would notice an increase in technology usage at the point of care, particularly in the radiology,

laboratory and pathology departments. Were he to study the back-office, he might also notice an uptick

in automated billing systems. But by and large a visitor would see few differences in the application of

information technology at and around the point of care.

Contrast this with situation with advances and improvements in information systems and automation in

the retail, financial services or airline industries of the 1960s, or even manufacturing. The difference is

striking.

The IT adoption lag in the healthcare industry is not the result of Luddite physicians. Healthcare is a

unique industry. Unlike most of the rest of the economy, decisions about services provided are not

made directly by the organization paying the bills. The classic healthcare value chain includes purchasers

of healthcare services – such as employers and self-funded insurance companies; prescribers and

specifiers of healthcare services, such as physicians; and the ultimate recipients of those services –

patients. Each group has imperfect information and may have very distinct incentives. The government

functions as a major purchaser but is constrained by political considerations, as has been demonstrated

in the 2009-2010 round of healthcare reform discussions. The provider market is extremely fragmented, with hundreds of thousands of physicians and physician groups practicing more or less autonomously.

Against this background, the financial benefits of Health IT, which will underpin any investment decisions, are questionable for any single actor. Electronic Health Records, which are seen as the bedrock of an interoperable healthcare network, must be deployed at the level of the individual provider. The costs of deploying a full EHR system for a single ambulatory care provider, including lost productivity during the ramp-up phase, have been estimated to exceed $50,000.[15] While benefits do accrue to provider offices, their overall impact has not been well quantified as a positive or a negative. [16]

Discussions of Health IT to date have focused on the Return on Investment expected for the entire healthcare system ("systemic ROI"). This is essentially unique among industries, as IT in airlines, financial services and retail has been driven primarily by investments made by single companies for their own benefit. Even where multiple service providers were eventually involved – such via the SABRE system developed for American Airlines by IBM in the 1950s and 1960s – the initial investment was made by a single entity for direct competitive reasons. [17] In the financial services industry, which is often cited as a model for where healthcare *should* go, development of common standards for Automated Teller Machine (ATM) networks was made possible because of smaller banks' needs to provide their customers with more places to withdraw their money. Small banks needed large networks of "friendly" ATMs to keep up with their larger competitors, and due to the relatively simple nature of the transactions involved the integration between institutions was fairly straightforward. Indeed, most of the work had already been done for inter-bank check clearing. Consumer online banking was likewise driven through the rise of a single dominant personal finance package, Quicken, which led to the development of a standard programming interface for retrieving personal transaction data from banks.

It can easily be argued that the healthcare industry, when faced with such simple investment decisions, has adopted new information technology at an equivalent rate. Medical billing software is present at many healthcare providers, and most have eliminated paper billing entirely with an eye towards reducing the number of days that claims made to insurance companies remain outstanding. But the HIT investments that would have a substantial effect on overall healthcare spending do not fall into this category. Reduction in duplicate laboratory testing, often cited as a major driver of savings,[2] removes a major source of high margin revenue for smaller hospitals. Likewise, easily portable records will make it easier for patients to switch providers, increasing the competition faced by individual practices.

Perhaps most telling of all is the fact that "Health IT" has a name that has entered the national dialog. No other industry can make a similar claim.

1.3. Understanding the Landscape

Health IT is very much a distinct discipline, although it is related to – and largely overlaps with – biomedical and clinical informatics. The latter is, however, focused on the direct clinical and research applications of technology. [18] Health IT as a discipline is focused on integrating the results of clinical informatics research with delivery of care in real-world settings. It therefore encompasses fields – such as medical billing – that are often ignored in academic practice (Health Information Management has emerged as its own discipline). The level of overlap varies by institution. At the Massachusetts General Hospital, the Laboratory for Computer Science founded by Dr. Barnett has played a major role in the deployment of clinical systems, including the OnCall Electronic Health Record used by over 300 physicians as primary driver of clinical care.[19] At another Harvard teaching hospital, Children's Hospital Boston, meanwhile, there is minimal overlap between the work of the Children's Hospital Informatics Program and the hospital's internal information technology staff, although the two groups do occasionally collaborate.

Effective Health IT decision making mandates that decision makers have a clear understanding of the complex environment that they face. [20] Years of the author's personal experience in the Health IT industry has shown a remarkably low level of general HIT literacy among practicing physicians, hospital managers, investors and policy makers. Individuals focus on areas that map to their own clinical specialty or to their past exposure to particular facets in the healthcare industry. Practicing physicians may have almost no exposure to clinical research or consumer focused healthcare applications, while policy makers may tend to oversimplify in their search for easy analogies to other industries.

1.4. Mapping Healthcare Information Technology

This thesis is an attempt to cut through some of the confusion. I present a method for developing a high level taxonomy of healthcare information technology applications – a "map" of the industry. A map, at its most abstract, is a translation of an aspect of the "real world" into a schematic format that is useful for solving particular categories of problems. Most examples, of course, come from the world of geography, where maps are used to represent everything from political boundaries to natural resources to trends in migration and population and even the impact of popular culture.[21] The real world is complex, messy and nuanced, but a map allows an analyst or decision maker to make sense of key trends without being unnecessarily bogged down in the sheer scope and scale of the domain of interest.

1.4.1   Why an HIT Map?

Healthcare Information Technology requires its own map because it is an incredibly complex domain, and absent years of study it is almost impossible for one individual to appreciate its full scope. Even then, the material studied at the beginning is likely dated by the end, given the rapid pace of 21st century technology and policy development. There has been no systematic attempt to build a robust map of the HIT landscape to date; while taxonomies of information technology and medical terms developed for other purposes occasionally touch on Health IT issues, they are minimally detailed and in

all cases designed to categorize academic research papers, rather than to provide the useful attributes of a map to parties interested in advancing the healthcare agenda. [22] It is common to encounter physicians who have practiced medicine for years but have only the faintest idea of the processes by which a new drug is approved by the FDA, or of the processes by which their own back-office support staff process billing requests. In the healthcare industry, many stakeholders focus exclusively on a very small part of the overall delivery system.

A successful map will be a tool for researchers, policy makers and other decision makers seeking to understand their investment options in HIT or to understand how HIT may influence future strategic decisions. It should categorize the "IT toolbox" for a 21st century healthcare system.

An emerging theme in the national HIT dialog is the idea of a "platform" for healthcare applications. In brief, a software platform provides a common basis on which independent software developers can create consumer focused applications. Platforms are ubiquitous in modern technology – from Microsoft Windows, to Microsoft Word (which provides a platform for document exchange between multiple computer users), to the SAP architecture for Enterprise Resource Planning, SalesForce.com's platform for Customer Relationship Management applications, and Apple's iPhone (the top platform for mobile applications, which has enabled hundreds of thousands of developers to build applications that can easily be deployed to a consumer's mobile phone). Platforms encourage competition – they provide substitutability of applications, allowing each user of the platform to configure it to meet their own needs. A sports-minded user of the PlayStation 3 can install football simulations, whereas other users might prefer action-adventure. In both cases, the developers of applications are freed from the core engineering required to create the user experience. [23] HIT is notable in that it currently lacks platforms of almost any kind – vendors instead build the "entire stack" from core clinical data management all the way through a user interface. [24] Changing this model requires development of shared services that can

support a variety of applications, as well as identifying points where the individual workflows of physicians and other healthcare providers overlap and where they may differ. An effective map of these workflows and application requirements is critical to designing the underlying architecture of a platform for HIT applications, and such a platform would accelerate the development of critical new HIT tools by removing much of the redundant (and often poorly implemented) infrastructure work that currently characterizes the industry.

1.5. Developing the Map

This thesis is a first attempt at developing the map described above – a high level representation of the key components of the HIT landscape. I first develop a basic methodology for organizing the broad scope HIT applications available today within the healthcare system using a method of categorization that relates sensibly to the workflows that currently dominate the delivery of care. By focusing on applications rather than underlying technologies and standards the map has the potential to orient a non-technical reader to the various opportunities presented by IT across the spectrum of the healthcare industry.

In addition to presenting the basic method for assembling a mapping of HIT applications related to specific actors and workflows within the healthcare system, I have applied that method to a body of literature, direct research and experience to produce an annotated first version of the map of the HIT space. It is my hope that this iteration of the map will, for at least the next two or three years, provide a useful working snapshot of this dynamic industry.

1.6. Statement of Hypothesis

I hypothesize that it is possible to take a very complex, dynamic component of the healthcare industry – healthcare information technology - and create an internally consistent framework (a map) within which one can categorize the wide range of information technology tools available to healthcare practitioners.

To validate this hypothesis we must establish as set of criteria that are essentially reproducible. In theory, if multiple experts were to attempt to build a map using the methodology described in this paper the maps produced should be more or less consistent. As it was not practical to have the work recreated by a second, independent analyst, other approaches that approximate this form of validation are discussed in Chapter 4.

1.7. Summary

A map of the Healthcare IT landscape matters because the healthcare system is in crisis and technology is frequently cited as a savior – but often by policy makers who lack the basis to understand what options HIT provides and how effective HIT may be at achieving those policy goals. The intent of this introductory chapter is to provide a high level overview of the HIT landscape, to describe the uniqueness of HIT as a set of industry-specific problems in IT, and to outline the current policy issues and the key development issues around interoperability. I have described the need for a mapping of HIT applications to real-world workflows. In the following chapters I begin by describing a methodology for creating that mapping. I then apply this methodology to generate a first approximation HIT map in order to provide the types of guidance discussed previously. Next I analyze the results, including potential objections, methodological alternatives, and scenarios which may invalidate the map. Finally, I summarize the conclusions and discuss a few of the immediate implications of the map's description of the HIT universe, as well as next steps for further research on this topic.

2. Methodology

In this chapter I describe a methodology developed to create a "map" of Healthcare IT applications. I start by exploring a general approach to organizing complex families of information and then describe a process for gathering a knowledge base on the HIT industry and a sorting algorithm for the information assembled.

2.1. Taxonomies and Maps in Healthcare

Healthcare is rife with taxonomies[i]. Beyond the Linnaean taxonomy of organisms that founded the genre, taxonomies of genes, medications, biological samples and proteins have filled important tactical roles in life sciences research. Also at the very tactical level, detailed taxonomies have been developed for healthcare providers [25] to support the billing process. In the policy community high level taxonomies intended to support public debate have been informally proposed for different categories of payment systems. [26] One obvious benefit is that they allow identification of items that are closely related to another. An expert in mice is much more likely to be able to assist in research on rats than in research on salmon – and the Linnaean taxonomy allows researchers to identify other experts whose experiences might have relevant value.

With one exception, however, no formal taxonomy has been proposed for HIT. Likewise, formal taxonomies of information technology applications have not been developed for other industries. The most notable taxonomy of IT applications as a whole may be the Association for Computing Machinery's Computing Classification System, which was developed solely to organize content in the ACM's flagship journal. [27] The ACM classification includes a single entry for healthcare applications, and focuses instead

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[i] A taxonomy is a system of categorization. One of the first taxonomies in medicine was the Linnaean taxonomy, which organized the plant and animal kingdoms into a hierarchy based on degrees of similarity.

on computer science topics and core technologies, as well as enterprise applications common to many

industries.

The one formal IT taxonomy within healthcare is the Medical Subject Header taxonomy, which was

developed by the National Library of Medicine to support indexing of the PubMed database. [28] MeSH

includes a number of topics relevant to clinical informatics research. The MeSH headings, however, are

insufficient to provide a lay user (or policy maker) with a sense of how health IT applications are used in

practice and of how they relate to each other.

Given the lack of work in this area, there remains a place for a taxonomy of healthcare IT applications.

To be useful, the taxonomy must provide the user with a broad overview of the HIT field, organized in a

way that supports decision and policy making. Accordingly, I refer to the product of this effort as a

"map" of the HIT space.

2.1.1   Creating Categories and Identifying Workflows

As with any complex system, HIT can be divided in a number of meaningful ways, most of which cross-

cut each other. It is possible to look at HIT through the lens of technology: tablet PCs, mobile phones,

and laptops, but this approach is unhelpful for the decision maker as virtually every type of application is

available via every potential technology platform, and the optimal decision will depend as much on local

environments and support as on any external criteria. In an attempt to create the most broadly useful

set of categorizations possible, in this project I begin by attempting to describe the HIT universe in terms

of workflows.

I envisage each workflow as essentially "personal:" based on the tasks performed by one individual.

Rather than encompass the complete inpatient experience as a single workflow (which, again, would

preclude meaningful distinctions), I focus on activities performed by a single individual or a small team

in a constrained time period (not more than one or two days). An office encounter, therefore, consists of a workflow for the physician and nursing team, a workflow for scheduling and billing in the back office, a workflow for the patient, and a workflow for an outpatient pharmacy. What is critical is that each of these can be viewed independently. Even if a physician in a micro-practice is handling scheduling and billing by herself she is operating in a different role and a different setting when dealing with billing as opposed to care delivery.

2.1.2 Exclusion Criteria

There is a subset of IT applications that are applied across most enterprises, and it can be argued that a truly complete taxonomy of HIT will by definition include all information technology used in the healthcare system. Obvious examples include email systems, enterprise calendar system, general register systems, expense account management tools, phone systems, content management systems for web sites, operating systems, relational databases and enterprise anti-virus systems. Including all of these technologies in a taxonomy would be unwieldy at best. Therefore, in this project I exclude systems that meet either of the following criteria:

1. Are common to most industries and are generally deployed in healthcare with minimal industry-specific adjustment.
2. Serve primarily as enabling technologies for building applications that are subsequently used by healthcare providers or administrators (and are therefore not directly interacted with by the clinical user).

Examples of the first category include email systems and computer operating systems. Both of these may require special configuration to meet the regulatory needs of the healthcare industry. HIPAA, for example, strongly encourages the use of various encryption technologies which can be implemented in both email servers and operating systems through add-on software or special configuration options.

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These requirements exist in other industries as well, and are therefore not healthcare specific. Examples

of the second category of excluded applications include databases like Oracle or Microsoft SQL Server.

Again, while many include features that are very helpful to meeting regulatory requirements in

healthcare, they are not specifically HIT tools. Even in the event that a tool is used almost exclusively in

healthcare (such as the Intersystems Cache database engine, which implements a programming

language, M, designed and used almost exclusively for building EHR systems), its status as a

development tool keeps it from being included here.

2.2. Defining the Map

In developing the map, I begin with a broad literature review of the health informatics community,

including the clinical informatics journals (The Journal of the American Medical Informatics Association)

and the health information management literature (the Journal of the Health Information Management

Systems Society), as well as other PubMed resources. This research is supplemented by the HIT

"popular press" including Healthcare IT News, Modern Healthcare, the California Healthcare

Foundation's iHealthBeat, and the FierceHealthIT newsletter, which together provide a general overview

of the products available at the large hospital level. I attended the 2008 HIMSS conference to further

study the tools available to hospitals, the 2008 Drug Information Association meeting to investigate

pharmaceutical IT, the 2009 AMIA Annual Meeting to review key themes in clinical informatics, and

Microsoft's 2009 Healthcare Solutions Conference to research Personal Health Record platforms and

health-system level data warehousing tools. While researching consumer directed healthcare tools I

attended HealthCamp Boston in March 2009 and immersed myself into the "Healthcare Social Media"

community on Twitter, as well as conducted interviews with prominent "ePatients". To investigate HIT

in developing countries and in the context of medical tourism I visited Bumrungrad International

Hospital in Bangkok, Thailand, and spent two days meeting with hospital and IT leadership and

observing systems in use. Finally, I monitored several key blogs in the Health IT space over a two year

period to gain further qualitative insight into companies and applications that are active in HIT (including

blogs by the CEO [29] and CIO [30] of Beth Israel Hospital in Boston, and of the Managing Director of

Chilmark Research in Harvard Square [31], who is a frequently cited commentator in the personal health

and HIT policy arena), In addition to this formal research, I served as Chief Technology Officer of

Invantage, Inc., a Clinical Trial Management Systems company from 1998 to 2002, as the eHealth Policy

Staff Lead on the CMS Office of Policy from 2006 to 2007, and as Director of the Informatics Solutions

Group at Children's Hospital Boston from 2007 to the present. In these roles I gained substantial

exposure to major projects and issues across the HIT spectrum from medical billing to clinical research.

In 2006 and 2007 I co-chaired the Harvard Medical School meetings on Personally Controlled Health

Record Infrastructure (www.pchri.org), which convened 100 industry experts to discuss the future of

personal health record platforms.

In constructing this map I have excluded applications that, while healthcare specific, exist at more than

one degree of remove from a patient or clinical trial subject. This primarily eliminates claims

management systems run by insurance companies and similar systems deployed by Pharmacy Benefits

Management companies. Classifying the applications in these verticals – or extending this classification

to include them – is a potentially valuable future exercise.

Based on this information and within these constraints, I developed a list of applications that fall under

the umbrella of Health IT. I then categorized each application on four axes: *Principle User, Locus,*

Novelty, and *Clinical Support.* Principle users are clinicians, support staff (such as medical billing

specialists), patients, and non-provider caregivers. For the locus of use I defined four areas where an

HIT application could be deployed. Some packaged applications are used in more than one of these

areas – however, deeper investigation shows that in those cases the individual functions are almost

always also available as separate, "best of breed" applications (for example, most electronic health

record systems, used during the patient encounter, include optional billing and practice management tools).

The remaining two categorizers are more subjective. For novelty, I assessed whether or not the core application was widely present in the market in 2002. This provides a marker of market accessibility for new, innovative firms, as well as an indicator that policy development work may be required. A "No" should not be taken to indicate that the application area itself would not be attractive to an entrant with a novel offering – merely that existing firms have been working in the area. Likewise, "Clinical Support" attempts to separate applications that streamline the process of running a medical practice (such as managing patient charts) from "practice of medicine" applications that hope to change provider behavior (e.g. clinical decision support tools that warn physicians away from particular activities).

Table 1: Categorizers for Health IT Applications

Principle Users	Locus	Novelty	Clinical Support
Clinicians Support Staff Patients Non-Provider Caregivers	Direct Patient Encounter Clinical Research Billing and Practice Management Health Management	Pre-2002 Post-2002	Practice Process

After assembling an initial list, I arranged the list into a set of initial categories for the industry map, corresponding to collections of workflows led by one or at most two categories of principle users. This map was then refined through consultation with experts[ii] on different aspects of the HIT industry and refined still further based on their suggestions.

[ii] In addition to Dr. Teo Dagi, my thesis advisor, the map was reviewed with Dr. Blackford Middleton of Partners Healthcare and with Omid Moghadam, the founder of the Dossia Personal Health Record initiative and the Intel Genomics and Digital Health Group. Additional feedback was received at various points during the process from a range of experts in the field.

2.3.Summary

In this chapter I document the lack of accurate, useful , up-to-date taxonomies of Health IT that are capable of providing guidance for decision makers and those new to the study of HIT. I suggest that extensive information gathering followed by a sorting process that incorporates provider workflows, novelty, user types and clinical support role will produce a more effective map of the HIT landscape, which in turn will allow for both more effective exploration of Health IT as a research subject and the identification of key trends in software and workflow organization that will have implications for future investment and research. In the next chapter I will apply this methodology to produce a functioning map.

3. Results

In this chapter I present a mapping of healthcare IT, based on the methodology discussed in the previous section. The intent is to provide a set of distinct categories of HIT applications such that any particular healthcare workflow can be decomposed into a set of distinct actions carried out by particular categories of healthcare worker.

Table 2 provides a high level summary of the results. Novelty scores have been mapped Low, Medium and High, based on a subjective assessment of the aggregate of the various applications involved.

Table 2: A Map of Health IT Applications

Title	Locus	Primary Users	Novelty	Examples
Practice Tools	Direct Encounter, Billing and Management	Clinicians, Support Staff, Non-Provider	Medium	Electronic Health Records, Picture Archiving and Communication Systems, electronic prescribing tools, automated registration kiosks, enterprise master patient indexes, clinical data repositories, lab information management systems
"Advisory" or "Decision Support Tools"	Direct Encounter, Health Management	Clinicians	High	Medication Adverse Event Warnings, Computerized Provider Order Entry rule sets, radiology expert systems, Computer Aided Diagnostic Tools, Patient Population analytics, formulary support
Financial Tools	Billing and Practice Management	Support Staff	Low	Revenue Cycle Management tools, automated billing systems, practice management tools
Remote Healthcare	Health Management	Clinicians, Patients	High	Electronic office visits, office-based telemedicine, remote ICU monitoring, disease management platforms
Clinical Research Tools	Direct Patient Encounter,	Clinicians	Medium	Electronic Data Collection Tools, Electronic Patient Diaries,

	Clinical Research			Results Data Repositories
Patient Tools ("Health 2.0")	Health management	Patients	High	Personal Health Records, online disease communities, patient portals, online health information sites, goal-oriented wellness web sites, recreational genomics
Enterprise Clinical Analytics Tools	Health management, quality reporting, public health	Hospital and practice administrators	High	Quality-oriented data warehouses integrating clinical and administrative data for reporting purposes

For example, the standard patient visit workflow for an EHR enabled practice can be broken down into several sub-workflows:

1. Patient Registration (using a Practice Tool: Practice Management System)
2. Nurse/Clinician Chart Pull (using a Practice Tool: Electronic Health Record)
3. Consultation (not electronic)
4. Patient Management
   a. Review medication list (from EHR)
   b. Review medication conflicts (using an Advisory Tool: Automated Clinical Decision Support)
   c. Order labs (using a Practice Tool: Computerized Provider Order Entry)
5. Prescription Management
   a. Review formulary (using an Advisory Tool)
   b. Transmit Prescription (using a Practice Tool: ePrescribing gateway)
6. Practice checks insurance eligibility and submits claim for payment (using a Financial Tool: medical billing gateway)
7. Patient retrieves lab results and looks up interpretations (using Patient Tools: a Personal Health Record and an online health research)

Readers familiar with the normal conduct of an evaluation and management visit will notice that some workflow steps combine advisory and practice tools. In each case this is because the relevant functionalities are available separately although they are also often integrated. For the remainder of this chapter I will describe each category of application in greater detail in order to make these divisions more clear.

3.1. Practice Tools

"Practice Tools" are tools that support the mechanics of practicing medicine. This category includes practice management systems, electronic health records that replace paper charts, tools for gathering information required for regulatory purposes (such as the outcome measures required by the Society of Thoracic Surgeons[iii]), and electronic prescribing systems, which replace the standard paper prescription with an electronic version that is automatically routed to a pharmacy. More recent entries into this arena include systems that allow patients to automatically register themselves at kiosks or via tablet PCs which can collect detailed medical and family histories and provide patient educational materials in the waiting room.[32] Other tools manage the generation and documentation of informed consent documents for patients, integrating relevant clinical data into the document creation process.

As the front-line instruments of current Federal HIT policy, EHRs deserve special attention (a related term, Electronic Medical Record, is essentially synonymous at this point, although "EHR" was originally intended to connote a wider range of applications beyond charting in an office or hospital setting). EHRs have been defined as a longitudinal record of patient care, allowing the reconstruction of any given patient encounter and encompassing a full range of supporting data, including laboratory results, medication lists, radiology reports and pathology results. [33] Some early EHRs served as digital equivalents of the "classic manila folder based record." Physicians would interact with them after an encounter, occasionally by scanning paper documents. As the technology has advanced, EHRs have become more integrated into the physician's encounter workflow, providing a platform for decision support and improved decision making although not without imposing new challenges for physicians. [15]

[iii] A complex set of reports covering the results of individual procedures, which can take hours or days of time to compile manually through nursing reviews of patient charts and operative notes.

All of these systems can be, but need not be, implemented in a way that exactly mimics non-digital (paper) processes. In some cases, these tools may themselves facilitate the deployment of new technologies. For example, increased utilization of MRI, PET and CAT scanners has fueled radiological decision support companies providing interpretive services on top of imaging data, as well as the introduction of PACS (Picture Archiving and Communication Systems) for organizing, storing and retrieving images, without which the huge quantities of data produced by new imaging modalities would be practically unusable. The introduction of other imaging modalities, whether hospital or imaging center-based, or point of service-based, has led to an interest in storing, retrieving, indexing and displaying other kinds of imaging data (*e.g.,* mammograms, retinal scans, foetal ultrasounds, whole body skin imaging for melanoma screening) alongside patient narratives, the results of examinations, and laboratory tests.

Practice tools, along with several other categories of systems discussed later in this chapter, promise to play an important role in quality improvement within the healthcare system. Quality improvement initiatives focused on the delivery of care according to best practices require substantial data about the state of a particular practice. In order to define quality improvement targets (for instance, associated tight glycemic control in diabetics with better or worse long term outputs) a large patient sample with consistent, high-value clinical data is required. Electronic health records, if well designed, support querying over large populations of patients. A researcher or practice manager can ask the system for all female diabetics between the ages of 40 and 55 with co-morbid hypertension. That panel of patients can then be used to answer clinical questions –did the more tightly controlled patients have better cardiovascular outcomes over time? Likewise, once the standards of care are established, a practice manager can use the same system to identify the patients in the practice or at the hospital who have not received care appropriate to their disease status. This reporting is extremely time consuming to do by hand, but is increasingly called for by Federal and private sector healthcare payers. The 2010 round of

Federally Funded Community Health Center Grants, for instance, focus mainly on data collection for diabetes, hypertension and other high prevalence, high cost chronic conditions.

3.2. Advisory Tools

"Advisory" or "Decision Support" tools are tools that support the provider in the medical decision making process. A second category of Health IT tools exists primarily as "add-ons" to practice tools. Advisory tools may provide much of the proposed financial benefit from Health IT, because better decision making is linked to reduced utilization of resource. More effective drug dosing within hospitals, for instance, may lead to a reduction in costly adverse drug events. Medication administration in the hospital setting is a common example: a study at the Brigham and Women's Hospital, an early adopter, showed $16.7 million in new savings over ten years from the reduction in inpatient drug costs after the introduction of an order entry system that provided guidance on appropriate dosing levels. [34] Clinical Decision Support Systems, which provide point of care advice to physicians based on a combination of patient-specific data and a database of clinical rules, are often cited as an ideal way to reduce the rate of medication errors in the US healthcare system. [35] Advisory tools can also provider "softer" guidance to the physician: for instance, an overlay of the patient's insurance carrier's formulary over an electronic prescribing screen, indicating alternate or generic medications that may save the patient (and the system) substantial amounts of money. They can also prompt for follow-up according to specific guidelines, such as reminding physicians to ask questions about depression when faced with a higher risk patient.

The mapping differentiates between practice tools and advisory tools because it is possible to deploy practice tools without an overt decision support layer. Electronic prescribing, for instance, can be implemented entirely as a process support tool, enabling more efficient writing and renewal of prescriptions. Drug interaction checking and formulary support are essentially optional features, and are

not nearly as widely deployed. [36] Interaction checking depends on the availability of an accurate high

quality, up-to-date medication list for the patient and such a list is not often available. In radiology,

vendors such as Medicalis and Sage HMS provide decision support that allows providers to order studies

based on up-to-date guidelines. Critically, these systems can lead to improved relationships between

providers and insurance companies, sometimes even reducing the need for prior authorization of

certain types of studies, as in the case of at least one of the major Boston teaching hospitals[iv]. None of

this implies that practice systems that do not incorporate specific advisory capabilities are incapable of

improving the quality, as well as the efficiency, of clinical medicine. A well designed electronic patient

record, for instance, will integrate and present information that otherwise might be buried within a

paper chart, allowing the clinician to make better decisions on that basis alone.[37]

At the farthest extreme, clinical decision support tools can start to look very much like clinical

interventions in their own right. Computer Aided Diagnosis software (CADx), for instance, is capable of

examining digital or digitized mammograms for incipient neoplasms and achieving results that are

consistent with – or even slightly more sensitive than- a panel of trained radiologists. [38] These systems

are already being used to provide a secondary screening of mammograms at many hospitals. That said,

the technology has been deployed cautiously, and studies have shown little difference in the recall rates

and detection rates for patients screened with and without computer assistance,[39] although potential

efficiency gains for radiologists remain to be studied. The FDA has recognized that there is a need for a

regulatory pathway to address CADx as part of the medical device approval pipeline [40], although

progress on a consistent set of guidelines has been slow. It should be noted that "aided" is an important

word. In my research, there have been no systems approved by the FDA that perform meaningful

diagnosis followed by treatment without physician intervention. Automated blood glucose readers, for

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[iv] Personal communication. Through implementation of an automated order entry system this hospital has been able to eliminate previous required prior authorization

instance, are approved only as an additional data point for physicians, and patients must rely on more traditional finger-stick methods for adjustment of therapy, rather than relying on automated adjustments. [41]

Like practice tools, advisory tools are expected to play an important role in quality improvement initiatives. Once a set of standards of care have been developed and agreed upon between providers and healthcare purchasers, advisory tools integrated with point-of-care workflows can help assure that those standards are met consistently. Use of advisory tools to support the decision making process also allows practices to commit to a more complex set of care guidelines than would otherwise be practical with a paper-based system, as standards can be set for relatively rare conditions where the appropriate procedures would not necessarily come immediately to mind for the treating physician.

3.3. Financial Tools

Financial tools streamline the financial process for healthcare providers. The billing process consumes a large amount of what would otherwise be clinical time in all practice settings. Payment and administration costs contribute up to 26% of overhead costs, over twice the equivalent in Canada (which, with a single-payer system and privately run hospitals and clinics, provides a useful proxy for the overhead of the US insurance industry).[42] Many Revenue Cycle Management (RCM) companies integrate software into a proprietary database of claims rules provided by or derived from payers, in order to improve reimbursement. They assist practices in payer disputes, practices and hospitals in reducing unrecovered receivables. Ultimately, so long as healthcare reimbursement continues to require co-payments and deductibles, so long some services remain uncovered, and so long as different insurers offer different benefits, the goal would be to convert such databases into real-time reconciliation applications. Real-time reconciliation applications would allow patients, providers and insurers to predict, using appropriate algorithms at points of service, the reimbursed or covered costs and the

unreimbursed or out-of-pocket costs (for patients, insurers and employers) and the financial risks

imposed and assumed by providers and institutions. Integration will play an important role, as some

rules require knowledge beyond the current clinical encounter. If an insurance carrier pays for no more

than one primary care well visit in a six month period, a real-time reconciliation system must have

access to the claim for a prior visit before authorizing the current visit. If that earlier claim was

submitted on paper the system cannot make a final determination, regardless of the quality of the

algorithms.

While only 1.5% of hospitals deploy a comprehensive EHR as of 2009, and only 17% use some sort of

Computerized Provider Order Entry (CPOE) tool, [43] patient scheduling , registration, billing, and claims

submissions systems are much more frequently used.[v] A 2006 Frost and Sullivan study estimated that

roughly 40% of provider organizations used a billing and claims management software package. The

same report suggested that the products available in this sector are fairly undifferentiated.[44] Since 2006

use of billing and claims management tools has likely increased dramatically, although more recent

surveys are not available. Since that point innovative companies like athenaHealth and Kareo have

brought a software-as-a-service approach to the medical billing space. The athenaHealth offering alone

is now used by 20,000 physicians, or roughly 4% of the total market. [45]

3.4.Remote Healthcare Tools

"Remote healthcare" tools enable care outside the hospital or provider office. Telemedicine promises

fundamental changes in our approach to the delivery of preventative and acute care services. [46] Remote

healthcare fall into three broad categories – patient focused electronic visits (eVisits), provider office-

based telemedicine, and disease management.

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[v] This is not a typographical error. Comprehensive EHR systems are defined as encompassing CPOE and a range of
other systems. CPOE is often the first clinical application deployed at a medical center. Therefore the 17% figure
encompasses all hospitals that have made use of CPOE in at least some clinical areas.

Patient focused electronic visits replace a traditional provider contact with an electronic one. In most cases the replaced encounter would not be a consultative visit, but rather a phone call or other minor provider contact, although small scale evaluation and management visits can be accomplished via these tools. RelayHealth, Kryptiq and Zix Medical all provide infrastructure for electronic encounters. The software is often deployed by an insurance company that wishes to make eVisits available for their customers, with the goal of reducing overall utilization.[47] This creates challenges for providers, including a requirement for multiple systems (in the event that they accept multiple insurance carriers) and poor or inconsistent integration with other aspects of physician workflow. An example of a new breed of eVisit vendor is American Well, which combines Personal Health Records, video conferencing and payer/provider integration to provide an online consultation environment for customers of participating insurance companies. At a simpler level, TelaDoc provides patients with the ability to contact a doctor (not their own) with questions at any time.

Provider based telemedicine involves bringing the patient to a fixed location where they can receive care from a provider located in another location. CMS regulations have limited reimbursement for telemedicine to this setting (Medicare patients are not, as of 2010, eligible for eVisits). A key application is the delivery of specialty care in rural settings, which began with a 1960s program to provide psychiatric care in Nebraska. [48] A second application for provider telemedicine is remote monitoring of Intensive Care Units, using technology developed by companies such as Visicu. Remote monitoring promises cost savings and improved outcomes (decreased length of stay and mortality have been associated with the availability of intensivist physicians in the ICU), but the complexity of ICU care makes study design difficult enough that the actual benefits of this technology have not been conclusively proven. [49]

The IT component of disease management initially focused on building analytical systems for identifying at-risk patients based on existing insurance databases. Follow-up with high risk patients was conducted by nurses or secondary providers working in a call center setting. [50] Companies like StatusOne (now part of American Healthways) and Health Dialog pioneered this approach. A second generation of disease management companies have incorporated personal health records and web-based outreach tools in support of phone based nurses. A leading example is HealthString, which provides online employee health coaching managed by registered nurses. Some of these companies have stepped back from the patient segmentation approach and instead provide their service to an entire employee population and in some cases their dependent beneficiaries. [51]

3.5. Clinical Research Tools

Clinical Research Tools support academic and industry sponsored clinical research. The clinical research enterprise exists in parallel with the classic care healthcare system. While clinical research plays a major role in the healthcare system, many physicians not directly involved are unaware of its mechanics. Briefly, biopharmaceutical and medical device companies conducting clinical trials for new products are required to collect large amounts of highly structured clinical data, under FDA supervision. The rules for clinical trial data collection, including regulations aimed at ensuring the integrity of information from initial clinician entry through FDA submission are more stringent than the requirements imposed on normal clinical record keeping by HIPAA.[52] In addition, the need for consistency across study sites mandates customized data entry forms for each study. The result is specialized Electronic Data Collection (EDC) software from vendors such as PhaseForward and Medidata, as well as open source alternatives such as RedBook. These tools are deployed alongside the electronic or paper health records that drive the clinical care of the patients in the study.

Since clinical trials can support a higher degree of per-patient investment than normal clinical care, direct monitoring of patients between visits is often feasible. Electronic Patient Reported Outcome (ePRO) software, or "electronic diaries", is usually based on a handheld computing platform, and is used by patients to record qualitative or quantitative data on a daily basis. ePRO systems can provide a higher level of data validation than traditional paper research diaries, mostly due to their ability to timestamp data, which prevents patients from filling out weeks' worth of study data while in the waiting room preparing for a follow-up visit.

In addition to EDC, a category of software, the "Research Data Repository" has appeared at academic medical centers over the last few years. These systems integrate electronic data (including clinical notes, demographics, observations and laboratory results) from multiple sources within a provider enterprise into a consistent view that can be queried to answer research questions or at least, identify potential subjects for future research. In addition to allowing users to implement data warehouses, these tools also provide support for managing patient privacy in accordance with the requirements of local Institutional Review Boards and the HHS Office of Civil Rights. A notable example is the Informatics Integrating Bench to Bedside (i2b2) project. Originally launched at Partners Healthcare, i2b2 now connects three hospitals within the Harvard Medical School system using a federated architecture that provides IRB approved patient protections.[53] This open source software has been deployed at an additional 17 independent institutions. Several major meetings on i2b2 have been sponsored by the NIH. [54]

The FDA and NIH have launched a variety of other tools aimed at pharmaceutical companies to streamline regulatory processes. The eCDA system allows for electronic submissions of new drug applications. The ClinicalTrials.gov site sponsored by the National Library of Medicine allows pharmaceutical companies to meet various mandates for public listing of clinical trials. Since these

systems are used primarily by pharmaceutical companies and not by clinical end users we will not

explore them further.[vi]

3.6. Health 2.0 and Patient Tools

"Health 2.0" and "patient tools" are software systems that engage the patient directly in a Consumer

Oriented Healthcare context. Advocacy of consumer oriented healthcare has shaped much recent

healthcare reform discussion. The emphasis on consumer involvement and consumer empowerment

has been present at some level for years and been a plank in the platform of groups such as the

American Association of Retired Persons (AARP) and the American Diabetes Association (ADA). Over the

last five years, however, the emergence of a number of so-called "Health 2.0" applications ("Health 2.0"

is a derivative of the term "Web 2.0" coined in 2004 to describe the new generation of interactive,

"social" web sites such as Facebook and Twitter), [55] allow and encourage patients to engage directly in

managing some components of the care. The precise definition is still under a subject of community

debate, but "Health 2.0" is generally distinguished from "eHealth" or "Health IT" by an emphasis on

individually directed care with direct patient involvement. [56]

In simplest form, these tools allow patients to assume some of the roles previously filled by the

physician's back-office: organizing the flow of care, ensuring the completeness of the clinical record

including the result of radiological and laboratory investigations, and avoiding redundancy. At a more

sophisticated level, they facilitate integration of care for the patient and for family members, sometimes

remotely. Examples of this genre include personal health record platforms, such as Microsoft's

HealthVault and Google's Google Health; disease specific tools like meal planners for diabetics, disease

management applications that link home monitoring devices such as sphygmomanometers,

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[vi] ClinicalTrials.gov does have a potential patient application, allowing individuals with a disease to identify trials
they can participate in. For this reason it could also be classified as a Patient Tool, below.

glucometers, atrial pressure monitors and coagulation monitors to physician extenders for feedback, optimal drug control, and prevention of complications; community tools such as PatientsLikeMe, Inspire.com and WeAre.us, online sites allowing patients with a range of conditions to interact with each other and share treatment experiences and strategies; general health and well-being sites such as FitBit.com that help individuals lose weight, exercise, or improve their psychological health; clinical trial enrollment sites such as TrialX that allow patients to search for clinical trials based on their current disease state; consumer-driven provider rating sites such as DrScore and Vitals.com that purport to rate physicians and institutions; community support sites such as CaringBridge hosted independently or by hospitals that allow families to post news about hospitalized or chronically ill patients; and family-centric sites, also hosted either independently or by providers and healthcare institutions that allow family members, often widely dispersed, to coordinate and communicate needs, events and efforts on behalf of elderly parents or other dependent or semi-dependent individuals.

Electronic patient tools are available, but not yet in effective widespread use as of 2009. The Manhattan Institute, a market research company, conducted a survey in summer 2009 showing 35% of American adults had used some form of online health resource in the preceding year. [57] The same survey, suggests, however, that only seven million Americans make active use of a personal health record containing their own clinical information. Despite low usage, interest in these tools is high,[58] and they will likely become increasingly important interfaces between patients and providers, and patients and the healthcare industry more broadly, if only because they are capable of conferring a level of efficiency and control that patients increasingly find desirable.[59] Personal Health Record Platforms like Microsoft Healthvault are capable of supporting the mandate that hospitals release medical records to patients in electronic form meeting the regulatory requirements of the HIPAA and ARRA. HealthVault, to that end, has been deployed at the New York Presbyterian Hospital, among others. [60]

Pharmaceutical companies and medical device manufacturers have discovered the potential value of the patient information contained on medical social networking sites, and have begun a number of programs to recruit patients for clinical trials via targeted advertising on these sites. [61] Patients participating in disease specific social networking sites will often provide extremely detailed information on their clinical condition, both in highly structured formats and through narrative descriptions of their conditions that allow better and more rapid recruitment for clinical trials. [62]

Finally, the last few years saw the creation of several "Recreational Genomics" companies, of which 23andMe, co-founded by the wife of one of the founders of Google (and seed funded by her husband) has received the most publicity (Navigenics and DecodeMe are two other competitors). These services will perform SNP analysis on a saliva sample provided by the patient, and provide feedback on relative risk factors for particular diseases. 23andMe also provides informational content linked to genealogical databases. To date these services have had no noticeable impact on healthcare delivery, and in conversations with clinical geneticists at Harvard Medical School there were no anecdotes of any patients having sought more detailed testing or counseling based on the results of a consumer-directed SNP analysis. The impact of consumer-directed genetic testing on the practice of medicine is otherwise well beyond the scope of this thesis.

3.7. Enterprise Clinical Analytics Tools

"Enterprise Clinical Analytics" (ECA) tools allow integration of data across the clinical enterprise to address quality improvement and reporting beyond the point of care. ECA is a relatively new category that goes beyond the reporting capabilities embedded in a conventional EHR. As electronic data is generated in more and more areas of the healthcare enterprise (particularly in hospitals), a need has arisen for systems that aggregate clinical data for use by higher level officials in the hospital, such as medical directors and directors of quality improvement. This data can be used to support government

and insurance carrier reporting requirements. Typically, an ECA will accept data feeds from multiple clinical systems (such as EHRs, CPOE tools, image and lab management systems, financial systems and PHRs) and use them to assemble a centralized, easily queryable data warehouse, which in turn allows for data analysis in either batch mode or near-real-time.

The i2b2 system described in the previous section, while designed for clinical research applications, has been occasionally applied towards quality improvement reporting instead, making it an ECA system as well as a clinical research tool. The leading commercial example is Microsoft's Amalga UIS ("Unified Information System"), which was based on software developed at MedStar Health in Washington DC and acquired by Microsoft in 2006. Amalga UIS has been deployed at several hospital systems, including New York Presbyterian, and provides the technology basis for various quality improvement initiatives.[vii]

ECA functionality is also provided by at least two companies using software as a service model. Humedica, founded in 2008 by executives from a variety of HIT firms, accepts data feeds from hospitals and provides them with reporting in exchange. The data received are also incorporated into other product offerings the company plans to make available to pharmaceutical companies and other clients in the future. Likewise, AnvitaHealth has packaged their clinical decision support products into a service offering in which they will analyze EHR and administrative data to identify patients not receiving fully guidelines-compliant care.

3.8. Summary

Application of the research methodology in the previous chapter divides Healthcare IT applications into different categories based on the principle users, the locus of care and the workflows involved. Workflow divisions focus mostly on direct clinical practice, administrative activities, research, quality

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[vii] I discussed this system extensively with Aurelia Boyer, CIO of New York Presbyterian, at the 2009 it.health conference at Harvard Medical School, and am grateful for her time and insights.

improvement, and patient-directed health management. Thus, the universe of HIT applications can be

divided into seven categories: Practice Tools, Advisory Tools, Financial Tools, Remote Healthcare Tools,

Clinical Research Tools, Patient/Health 2.0 Tools and Enterprise Clinical Analytics. The approach used

here provides a set of categories into which any HIT application can be classified in a reasonably

unambiguous way.

4. Further Discussion

Having laid out the general results of the research, in this chapter I will discuss the results and methodology in more detail. In particular, I will explore applications of the research and discuss its resistance to errors and applicability to decision making, even when not one hundred percent complete or accurate.

4.1. Why a Map? Applying the Map in the Real World

The purpose of this exercise was to create a map that would help different stakeholders understand the health IT landscape, using a semi-structured approach that will support ongoing decision making without forcing the user to make arbitrary assignments of technology to one category or another. As a way of quantifying the "health IT toolbox", this model should prove useful to researchers, policy makers, and providers considering both their investments in HIT to support current processes, but also their overall strategic directions.

4.1.1 Research Considerations

The division of Health IT into seven application categories should allow future researchers to focus on integration between categories and between systems in a category. The logical workflow distinctions between different providers imply that in order to meaningfully drive adoption of Health IT, development should focus on improving the performance of products in each category, as the result will be consistent, optimized workflows for individual healthcare providers. Likewise, connection points between the various categories obviously present a range of opportunities. To take a concrete example, advisory tools are currently predominately packaged as part of a practice tool. There is no obvious reason why this has to be the case – advisory tool vendors may focus on providing a knowledge base as their core competency, while developers of practice tools are likely to focus increasingly on building smooth, coherent, well-designed user experiences. As the user interaction requirements will likely vary

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substantially in different settings, researchers will find it useful to begin to focus on standard

mechanisms for representing advisory knowledge bases that can be integrated into a variety of different

applications.

The development of a high level map of HIT applications obviously creates an opportunity for additional,

targeted refinement of the taxonomy. This should be pursued with care, as the marginal value of a

highly detailed map compared to the more abstract form presented here is questionable. The diversity

of HIT applications has led to a range of slightly differing software addressing the same core workflows

in a similar way, and accommodating the marketing desires of each vendor would complicate the

taxonomy to no purpose.[viii] The taxonomy can also be extended by relaxing the patient contact

constraint used in this project: for instance, extending the enquiry into payer and PBM applications.

Each category, however, is amenable to separation into multiple sub-categories, which can then be used

in combination with additional data to address other resource questions related to the structure of the

HIT industry. Specifically, where is the innovation? Which categories of applications are most likely to be

deployed in concert? How do different bundles of application functionality (for instance, decision

support systems and clinical record keeping) compare from a user acceptance perspective? The

taxonomy will allow one to frame these questions, which will not be simple to answer – although the

answers may prove quite valuable to the private sector, as well as government payers and standard

setters.

4.1.2 Policy Considerations

A map of HIT applications has considerable applications for policy making. The taxonomy can be used to

allocate stimulus funds both to research projects along the boundaries between application categories,

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[viii] As an example, QuadraMed refers to their EHR product as a "CPR" – "Computerized Patient Record" but does not include functionality that is notably distinct from their competitors.

and towards development of high quality applications within particular categories. For example, by identifying specific kinds of advisory tools that could be integrated into practice tools, policymakers can allocate funds to generating content that can be incorporated in different ways into different workflows, such as using the same drug-drug interaction checking database in an electronic prescribing application and a consumer-focused personal health record.

The map also provides a tool for reviewing policy assessments. This works in two directions. First, policy initiatives that are not addressed at HIT per se are still going to be supported by HIT tools, whether for data collection or implementation of new payment policies or standards of care. Collection of quality metrics data is a time consuming process if performed manually through reviews of paper charts, but can be quite efficient if managed through an EHR.[63] Quality reporting initiatives should therefore be pursued in parallel with financial incentives for HIT adoption. The map also provides a quick way to check that major areas of HIT are not ignored during the policy making process. Clinical trials and the FDA are often the poor relation in Federal HIT promotion – the American Health Information Community, the HIT advisory body for the Bush administration, did not add a clinical research workgroup until very near the end of its existence. The result, in the author's view as a participant in the workgroup discussions, was an investment in standardization that ignored the requirements of a sector of the healthcare industry that could otherwise have made a major contribution to cost containment and outcomes improvement.

The financial impact of P4P remains relatively small, but Medicare's current move towards "value based payments," including medical severity related diagnosis resource groups (MS-DRG) will place new requirements on hospitals and other providers to justify claims around patient severity.[64] We can therefore expect that Pay for Performance incentives will also drive HIT adoption among existing providers, provided that the incentives are sufficiently valuable to warrant the investment in money and

time. EHRs have been shown to be substantially more effective than claims data at identifying patient

populations of interest to providers, and only marginally less effective than manual chart reviews [63].

4.1.3 Provider investments in HIT

On the provider side, the HIT industry map will provide hospital administrators and healthcare providers

with a blueprint for planning their HIT strategies. Its ultimate value here is as an educational tool.

Hospital CIOs can use the map, and potentially extended versions, to inventory existing applications,

identify gaps, and prioritize ongoing investment. The methodology may also prove helpful in this setting,

as the workflow oriented approach to defining HIT applications (and therefore projects within an IT

setting) is intended to focus resources on high-value areas, and to identify potential trouble spots where

initiatives attempt to cross multiple application categories or require workflow changes from

stakeholders who may not benefit from the proposed initiative as designed.

The importance of HIT in strategic planning at the hospital level cannot be overstated. HIT is an

important component of new modes of healthcare services delivery. Retail clinics, such as MinuteClinic,

provide rules-based care for a small number of common conditions that can be treated in a standardized

way. In a population setting, these programs have been shown to reduce overall costs, primarily through

reduction in Emergency Department visits, while patients treated at retail clinics experienced overall

care quality measured via standard quality measures that was as good as, or better, than that received

by patients who saw conventional primary care providers for the same conditions.[65] Advanced IT

systems allow these clinics to implement a rules-based diagnostic and treatment approach. In the

future, interoperable exchange of visit summaries will allow a more seamless integration of care

delivered in retail settings with traditional hospital and outpatient settings. This may lead to a gradual

increase in services that can be delivered via the retail clinic model, and potential improvements in

follow-up care as well. For instance, if properly integrated with primary care physician practices, a retail

clinic could play a substantial and cost-effective role in the management of chronic disease, allowing

patients more frequent provider interaction while preserving the physician's coordinating role in

patient's care.

4.2. Visualizing the Map

In most cases (Computer Science being the notable counter-example), maps are represented visually.

The methodology in this project used a taxonomy-driven approach to develop a map, which does not

always lend itself to meaningful visualization. In this case, however, the map categories and the criteria

used to develop them can be combined in at least one useful way. Figure 1 overlays the seven

application categories with four key activities: clinical care, practice management, financial

management, and patient interaction. The same individual may play multiple roles, but generally will
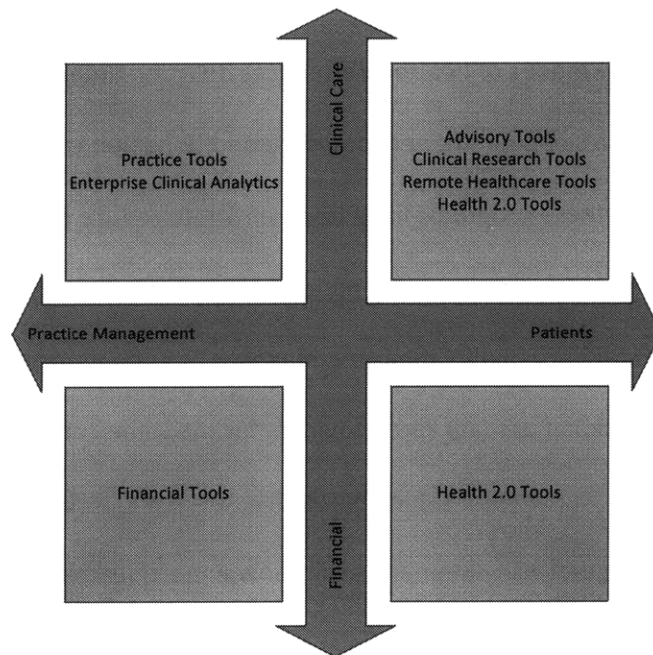
not do so simultaneously.

Figure 1: Map Categories and Expected Users

In Figure 1, Health 2.0 tools appear twice, as patients will use them to address both clinical and financial issues (Intuit Corporation's Quicken Medical Billing Manager is an example). The visualization exercise raises the question of whether an eighth category (perhaps "Patient Financial Tools") is required. In this project, the patient's workflows were defined as including both clinical and financial concerns. As the Health 2.0 space evolves the results of the mapping exercise may differ.

4.3. Choice of Project Methodology

The methodology described in Chapter 2 was driven partially by the scope of this research project. Smaller problems have been addressed with much larger budgets. In 2007 the Office of the National Coordinator for Health IT awarded a $500,000 contract to BearingPoint and the now-defunct National Association for HIT to define just five phrases : "electronic health records," "electronic medical records," "personal health records," "regional health information organization," and "health information exchange." [66] The project included multiple rounds of public meetings and had no long-term impact on the industry.[ix] This thesis is, accordingly, a bargain.

An alternate approach to generating the taxonomy content would have involved an outreach process to develop lists of applications, and an expert panel to organize those applications into categories and subcategories using a Delphi process, which is a traditional library sciences approach for taxonomy development. [67]

The approach used in this paper has the advantage, however, of internal consistency. The assignment of categories was performed by a single expert with over fifteen years of constant exposure to nearly every IT related aspect of the American healthcare system. Category definitions were therefore cleanly understood. Additional validation was nonetheless required, and is described below.

[ix] Searching for evidence of the project on Google produces scant results, as HHS has removed the relevant announcements from the ONC web site, and NAHIT is now defunct.

4.3.1 Validation of the Map

I have taken several approaches to validating the map. The first was an internal check embedded in the initial categorization process, based on the heuristic that each HIT application discussed needed to fit within one and only one category. This resulted in the elimination of several proposed categories, including a "Business Process Tools" section that was subsumed into "Practice Tools" and "Financial Tools". Intuitively, the map aligns with divisions in the market itself regarding vendor project lines, and with the key areas if research undertaken by members of AMIA and HIMSS, respectively the "research" and "implementation" arms of the HIT industry.

For external validation, I have presented the contents of Table 2 and selected supporting narrative to a number of experts in the HIT field. Based on their feedback, the contents of the categories were extended. In no case did this involve changes to the seven core categories, but rather the addition of new examples in each case[x].

Based on these checks, I conclude that the map is a valid one, but not an exhaustive one. This is at least partially by intent. An exhaustive map would sacrifice the ability to rapidly orient a new user to the broad scope of Health IT activities. A small, but clearly defined set of categories will allow users to categorize new applications as they are developed.

4.4.Sources of Error

Taxonomies are fundamentally subjective. As a result, errors – or simply variability – may be introduced via several avenues. First, the initial assignment of application categories to taxonomies was done by a

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[x] The three outside experts asked to review this taxonomy were Dr. Blackford Middleton, Director of Corporate Information Services at Partners Healthcare, Omid Moghadam, formerly of Intel Corporation and the Dossia Consortium, and Dr. Isaac Kohane of Harvard Medical School's Center for Biomedical Informatics. In addition, Dr. Teo Dagi provided extensive commentary during the development of the taxonomy. Subsets of the taxonomy were reviewed by other experts during the course of the project. The addition of recreational genomics was suggested by Mr. Moghadam.

single expert, with occasional input from others. While the enumeration was fed by a wide range of research over several years, it could easily be missing application categories that are limited to particular specialties or that are not in widespread deployment (particularly if there has been no peer-reviewed publication or conference presentation). The lack of niche application categories is probably not a critical flaw of this study, although an exhaustive survey of "occasional use" HIT applications would likely surface several candidates for commercialization or more widespread adoption.

Another source of error is in definitions. The definition of an EHR (or EMR) varies considerably depending on the authority. [68] In the particular case of an EHR, I have dealt with the problem by using a very constrained definition that separates "Practice Tools" from "Advisory Tools" (which contain the clinical decision support capabilities included in some definitions of an EHR). An historical example has been the Personal Health Record. Personal Health Record applications have been defined as including remote medicine capability (specifically, doctor-patient messaging), [69] or patient portal features. The idea of a "pure" patient record, with Personal Health Applications on top of it, has recently gained some acceptance.[xi]

4.5. Weaknesses of the Map

The methodology used here produces a taxonomy that is vulnerable – indeed, amenable -- to change over time. HIT is a fast moving field, as was seen in my discussion of financial tools (where between 2006 and today the market has been revolutionized by companies like athenaHealth). Systems coming to market today are based on web standards, and, for the first time, pay serious attention to the interoperability issues discussed in Chapter 1. The Software as a Service Model for clinical applications

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[xi] The author's own contribution to this mess is the acronym PCHR, for "Personally Controlled Health Record", in the preparation for the PCHRI conference in 2006 and intended to represent the pure patient record. The term itself was coined by Dr. Peter Szolovits of MIT's Computer Science and Artificial Intelligence Laboratory but never previously rendered into an acronym.

(where a vendor hosts a clinical system for a customer in a HIPAA compliant data center) was practically a non-starter in 2005, which saw the collapse of Amicore, a well-funded startup that proposed to build a SAAS-style ambulatory medical record. By 2009, leading vendors were citing SAAS as their major growth area.

Disease management is an area where one can reasonably expect the map to change dramatically. The parties to a disease management program have traditionally been the patient and an independent disease management vendor. In most cases the primary care physician has not played a major role. It seems likely that trends towards Accountable Care Organizations and similar shared-responsibility payment models will create incentives for provider offices to become more directly involved in remote health management.

The map is also US and first-world centric. Its US centric nature is not a major issue, even for international use. By and large, clinical healthcare systems function similarly, although different countries have widely diverging adoption rates, in turn partly driven by variations in healthcare systems organization. The differences center on financial systems, due to different healthcare payment systems in each country. These differences are likely to manifest themselves at least one level below the one at which this project took place. A map of developing world HIT would look substantially different, and would also be substantially less populated.

Nonetheless, the map is useful even despite errors in assignment of applications to categories. HIT policy issues are not deterministic – experiments will be required across the policy spectrum, and the primary goal – core education – remains valid.

4.6. Alternative Mapping Strategies

Health decisions, like all business strategy are inherently multidimensional. The classification approach taken in this paper provides a single map, based primarily on core clinical workflows. By focusing on workflows that are followed by a single actor in a single context, we obtain a fairly fine grained set of application categories. Depending on the task at hand, other divisions are potentially useful. An organizational scheme based on provider type (by specialty) and provider size (particularly for ambulatory practices) would have surfaced a large number of niche applications that do not appear in our results. Such an approach would have allowed us to identify applications that, while superficially similar across provider types, in fact differ substantially in requirements and implementation. Picture Archiving and Communications Systems are one example: the needs of radiology PACS and ophthalmology PACS are quite different in terms of workflow and integration requirements.

Reviewers also suggested stratifying Health IT by "underlying IT" – specifically, the technology platform (mobile, client/server, web-based, stand-alone, tablet PC, etc.). This is a useful lens through which to view the landscape, but only as a cross-cutting way to examine the current map. Electronic Health Record applications, for instance, are available on all of the platforms just mentioned. Accordingly, a platform decision will be based on provider preference and availability of local support infrastructure.

A third approach would be to organize systems exclusively by primary user. This is initially appealing, as many practical problems in HIT deployment require assessments of the needs of particular provider types. However, this form of organization does not account for the shared nature of many healthcare activities. Health 2.0 tools may be accessed by both patients and providers, and Electronic Health Records exist to be a source of coordination between multiple providers and provider types. Thus this approach would lead to classifying the same system under multiple headings.

Yet another approach would be to classify IT systems according to their FDA regulatory status. Unfortunately for this approach, the FDA has not established clearly its expectations of jurisdiction around many of the areas of HIT I have discussed. Clinical trial tools are subject to FDA regulation through a set of regulations around clinical trial data collection, most notably 21 CFR Part 11, which governs the integrity of data delivered as part of a new drug application. [70]

4.7. Summary

A map of the HIT industry map is and will be useful for researchers, policy makers and providers as a tool to allocate stimulus funding and other investment, and to fully educate decision makers about the scope and complexity of information technology in healthcare. The methodology used in this process is imperfect, as it has been forced to accommodate resource limitations during the research process. It has produced a taxonomy that is vulnerable to change over time, leaves some uncertainty about the boundaries between individual workflows, and may lack the necessary granularity for some applications. Despite these concerns, the map as it stands provides a high level of utility. Alternate approaches to building a taxonomy of HIT focus on distinctions that do not helpfully support a decision making or strategic planning process.

5. Conclusion

In undertaking this project, I hypothesized that it would be possible to take a very complex, dynamic component of the healthcare industry and create an internally consistent framework within which one could categorize the wide range of information technology tools available to healthcare practitioners. After developing a list of core HIT applications, I was able to resolve seven broad categories of applications:

1. Practice Tools
2. Advisory Tools
3. Financial Tools
4. Remote Healthcare Tools
5. Clinical Research Tools
6. Patient Tools/Health 2.0 Tools
7. Enterprise Clinical Analytics Tools

This hierarchy captures attributes that are important in strategic decision making and long range planning related to HIT: workflow, activity type and principle users. Unlike the handful of other attempts at creating HIT taxonomies, this division incorporates the idea of novelty – separating, for instance, tools that automate the paperwork of medicine (Practice Tools) from those that augment the healthcare provider's medical decision making (Advisory Tools) and that reshape the relationship between the patient and the provider (Patient Tools). The seven categories also acknowledge the different user communities for particular tools, rather than focusing purely on the information management problems involved.

While fundamentally somewhat subjective, the categorizations were robust to an internal consistency check by the author, and each application considered was strongly associated with the definition of a particular category. This check itself is somewhat validated by the fact that it eliminated a proposed eighth category, "Business Process Tools." The taxonomy also stood up to review by several external experts.

The map demonstrates the workflow divisions present in the healthcare system. In particular, it reveals a gap in the standard approach to defining the HIT landscape, which generally focuses on a smaller number of divisions – "provider tools" and "payer tools" – or focuses tightly on particular settings of care. As the benefits of HIT emerge through improved integration of information in the healthcare system, along with improved medical decision making and increased patient involvement in their own long-term wellness, any comprehensive view of HIT *must* be workflow oriented.

There are at least three reasons for this focus: First, any other approach will produce different categories of applications depending on the particular setting in which the methodology is implemented. Second, integration requires a substantial amount of investment and development which must be targeted carefully. An understanding of critical workflows illustrates the natural integration points between systems. Finally, workflows in healthcare are well entrenched, and applications that support existing patterns of practice are more likely to achieve acceptance by physician users than those that require radical change.

The seven categories also point towards the future evolution of the HIT industry. In particular, the split between Patient Tools and Advisory Tools creates a set of new market opportunities which are slowly being explored by creative startups. Companies like AnvitaHealth are providing "knowledge products" that have no user interface of their own but can be integrated into practice tools developed by a variety of vendors. On the non-profit side, initiatives like the Clinical Groupware Collaborative seek to develop standards for "pluggable" HIT components that can be mixed and matched at the practice level. [71] The implication is for dramatically increased competition around certain common features of HIT systems – if AnvitaHealth's rules engine for care guidelines is more effective than Cerner's, customers may demand the ability to substitute the Anvita software. Despite this, while the idea of an "HIT Platform" has gained some attention in the last year, [24] actually implementing a system where individual providers

can easily swap out HIT applications based on their specific needs requires a concrete understanding of the individual workflow components performed by providers on a daily basis. This has not yet occurred. It is my hope that healthcare informaticists will be able to use the map developed in this project to design improved technical interfaces to support seamless integration of information across application categories.

Ample scope remains for future study. As discussed in the previous chapter, the taxonomy can be extended down a level in each of the seven categories to account for application sub-types. This additional level of detail will allow for further definition of particular application types by provider and care setting for each HIT application. This will also allow analyses based on HIT for nurses, inpatient and outpatient settings, physician assistants, extenders, and disease management roles. Further research into public health reporting and population health research may also extend the top-level categorizations.

Health IT, in the end, is complex. It does not encompass one or two workflows within the healthcare system – it encompasses all of them. While individual pieces of information technology may be used by a single provider, the tapestry of information flows connecting the healthcare system is pervasive. To be successful in healthcare, IT must live up to its two grand promises – to make information available anywhere and at any time, and to allow the users of that information to interpret it more effectively than they would be able to do without technological support. The map generated in this research should help us prioritize our HIT investments in a way that supports both of those goals.

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