Modern IT Developments in Healthcare: A Look Into Yesterday, Today, and Tomorrow In Oncology

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MSc in Public Policy and Management
2015

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Chapter One: An Introduction

The twentieth century has witnessed the rise of a multitude of challenges to humanity. Still, many of these difficulties have been solved, optimistically positioning humans today in the healthiest and most circumstance yet. Despite intense treatment and research advances, cancer prevails to be a clinical enigma and remains to be one of the most significant health challenges for modern society.

In a 2009 TED Talk, professor and author, David Agus, explains that until now, cancer research and treatment tends to find itself in a “reductionist” stature.\(^1\) During his presentation, he declares that there needs to “...a new strategy in the war on cancer,” and displays a graph (figure 1.1.1) to explain why. His graph demonstrates the gains medicine has made from 1950 to 2001 in various health ailments. Yet disproportionately, each of the causes of death have seen a reduction in their effect except one: cancer. Agus points out that roughly since the mid-1850s in France, physicians began describing cancer according to the body where it was first identified. Today, this inferior classification strategy remains the same.

![Figure 1.1.1 – Change in U.S. death rates by cause, 1950 & 2001](image)

The inspiration for this thesis was forged from the questioning of the deliveries of progress. If 1950 death tolls can be equated to 2001 death tolls, are researchers’

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\(^{1}\) Agus (2009)
claims of development valid? Naturally, the aims of societies are over simplified; it is the pathways towards solution that are often rife with complexity. To be fair, this reductionist perspective often blurs and omits a myriad of details that go into the production of these cancer death statistics, including the existence of a larger overall population, survivors of other diseases gaining a secondary affliction, or other still unknown—and increasing—risk factors. It is therefore reasonable to assume that gains made in the war against cancer could go largely unnoticed because of other elements deriding these advances, but the point of contention still remains: in fifty years, cancer death rates have not improved.

Meanwhile in the present tense, the terms “healthcare” and “explosion” seem to be a buzzword partnership escaping many a mouth in the IT industry. Indeed, there have been incredible IT advancements that readily spilled into other industries in that same fifty-year interval. Remember, the first commercially available computer—the UNIVAC I—only became available in 1951.²

Perusing the diversified offerings of the post-millennial age, eyes sparkle with amazement at the prospect of self-driving cars, 3D printing, of course, the Internet itself with all the associated expansions. Yet in the meantime, cancer treatment continues use of the prolific chemotherapy, which although undoubtedly has improved in nature since its first intravenous use in 1942,³ it remains to be an apologetically cytotoxic form of treatment.

This text will take the reader through a tour of simple developments that would theoretically form the building blocks of a fully digital hospital, which would begin to appropriately utilize the key technologies developed in recent years that have so far not seen ubiquitous usage. By examining a tri-part structure in the paradigm of yesterday, today, and tomorrow, an analysis on the impact that certain technologies will have on oncological care (in a gradually increasing manner) including: Health IT, data analysis, and mobile health (mHealth).

The information contained in of this research is positioned to be a primer to introduce nonprofessionals to important developments in the healthcare industry with the intention of using education to replace doubt and uncertainty with excitement and progressive thinking.

³ Fenn, J., & Udelsman, R. (2010, October 18)
In the pages that follow, an exploration is presented that attempts to answer a fairly straightforward question of what new technologies are available to improve cancer and healthcare and what are the benefits to the people of today, and those to come?
Chapter Two: A Theoretical Background

The true backbone or model of support for this thesis work is derived from Bardram, Mihailidis, and Wan’s 2007 textbook, *Pervasive Computing In Healthcare* (henceforth: PCIH). PCIH discusses—at considerable length—the various influences information technology will have on the health sector. Particular chapters of interest with regard to this thesis work are one and three through six.4

One cleaving variation between this thesis and the PCIH text is this paper’s heavily covered concept of data analysis, or Big Data analytics, as it is now titled en vogue. The rationale behind the choice to include was that as more and more systems are attached to an infinitely growing number of sensors, data will begin to pile up. When these colossal caches of information begin to wildly accumulate, the principal effectiveness for electronization is nearly lost unless essential organization is performed.

Overall, PCIH is a far more comprehensive work that should certainly be regarded as a key reading if one intends to bulk their health and information technology knowledge.

Beyond PCIH, a variety of medical, technological, and scientific journals are referenced and were almost entirely sourced via Google Scholar, and then retrieved from academic databases (e.g. ProQuest). The remaining non-formally academic resources were located via search engines and selected based on reputation of resource and value of content, specifically in that order.

The structure of this text is designed in three key aspects: a fixed internal structure to collect and organize data (e.g. EHR), a structure to process internal and external data (e.g. Big Data), and a dynamic external structure to collect data (e.g. mHealth). By employing this theoretical constructional framework, hospitals/clinics and individuals can leverage the eventual future high-speed data transfer and storage in the Cloud.5 It will also allow for more responsible scaling since medical facilities can first address internal needs and as server-side capacity is added, increased external support can be implemented.

5 Cloud data storage was specifically not discussed due to the still primitive nature of its development. Although commercially Clouds could potentially technically handle the huge streams of data storage and flow, there still persist far too many questions of privacy and data security to be considered an imminent mainstream technology.
As such, Chapter Three will cover health information technology (HIT) discussions describing various internal (fixed) electronic structures for managing patients and keeping track of their data; Chapter Four will cover Big Data and feature a look into data analytics, prediction and new developments with these technologies in oncology; Chapter Five will explore a world free of wire, where mobile technologies and treatment outside the typical hospital environment use wearables to empower individuals in their health choices and treatment.

The ultimate purpose of this thesis work is to explore a world that seems to be riddled with misconceptions, skepticism, and red tape. Mainstream healthcare here touches the very tip of its progressive frontier. In order to avoid costly mistakes, great health disasters, or stagnated improvement due to apathy, the potentials for progress must be strewn out and thus carefully examined.
Chapter Three: Health IT

3.1 What is Health IT? A foreword on HIT (Health Information Technology)

We live in the Information Age, but our healthcare industry is stuck in the Stone Age.

—Bill Frist, former Senate Majority Leader (2003-2007)

In March of 2001, the Institute of Medicine released a broadly positioned doctrine filled with concepts and details designed to greatly improve and repair the U.S. Healthcare delivery system.\(^6\) *Crossing The Quality Chasm* laid out ten essential “rules for redesign,” which ranged from fostering a greater patient-centric environment to extended transparency to reduced waste.

In the mix of discussion and suggestions, perhaps the most important recommendation described was that of the necessity of the system-wide implementation of modern information technology tools, or perhaps more descriptively known as the utilization of healthcare information technology (HIT/HealthIT).

HIT is defined by the U.S Department of Health and Human Services Office of the National Coordinator for Health IT (ONC) as “the application of information processing involving both computer hardware and software that deals with the storage, retrieval, sharing, and use of healthcare information, data, and knowledge for communication and decision making.”\(^7\)

As a blanket concept, HIT is generally expected to:

- Improve healthcare quality or effectiveness;
- Increase healthcare productivity or efficiency;
- Prevent medical errors and increase healthcare accuracy and procedural correctness;
- Reduce healthcare costs;
- Increase administrative efficiencies and healthcare work processes;
- Decrease paperwork and unproductive or idle work time;
- Extend real-time communications of health informatics among healthcare professionals; and

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\(^6\) Committee on the Quality of Health Care in America. (2001, March 1)

\(^7\) Anonymous C. (2015)
- Expand access to affordable care.
- Decreasing time for order confirmation and turnaround;
- Improving clinical decision support at the point of care;
- Making crucial information more readily available\(^8\)\(^9\)

As noted by Furukawa, Raghu, Spaulding and Vinzet, HIT as a term represents a variety of electronic technologies and systems used in the clinical sphere, including Electronic Medical/Health Record (EMR/EHR), computer physician order entry (CPOE), and clinical decision support (CDS).\(^{10}\)

Though there has been a steady flow of abhorrence from the paper-to-electronic transition, researchers are finding that in academic settings, scientists and practitioners alike generally declare the technological enhancements to be positive. In a 2011 article published by Buntin, Burke, Hoaglin, and Blumenthal, the collaborators set out to review modern literature (roughly covering years 2007-2010) to gather and gauge the typical sentiments surrounding HIT in the clinical space.

Their conclusions found that 92% of the 154 articles assessed spoke favorably of the new technologies.\(^{11}\) Figure 3.1.1 demonstrates specifically where the responses fell (positive, mixed-positive, neutral, and negative) and clearly shows an overwhelmingly positive result to most aspects of care.

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\(^{8}\) Anonymous D. (2015)
\(^{9}\) Steele, A., & DeBrow, M. (2008)
\(^{10}\) Furukawa, M., Raghu, T., Spaulding, T., & Vinze, A. (2008, May 1)
\(^{11}\) Beeuwkes Buntin, M., Burke, M., Hoaglin, M., & Blumenthal, D. (2011, March 1)
It’s interesting to note that the category with the highest level of positive response seems to be “efficiency of care,” which seems to dispute typical responses of professionals. Typically, “they want to stick with what they know works,” says Jaeyong Bae a researcher from Northern Illinois University studying Meaningful Use IT in hospitals. Still, Bae’s latest study resolves that, on average, a 14% increase in adverse drug events (ADEs) was found in hospitals “resistant” to adopting Meaningful Use IT standards.

It thus begs the question: if technical positivity exists and increased medical complications in environments sans HIT are likely, why the pushback? The clear answer seems to not be refutation of implementation, but rather a lethargic impulse to adopt, based on a misunderstanding of change.

In the event of a system meltdown, “everyone is ready to go on paper,” said Mayo Clinic’s Chief Medical Informatics Officer, Dr. Dawn S. Miliner. If paper is to be included into the digital revolution, why then switch in the first place? Can paperless be truly justified?

3.2 Computerized Physician Order Entry

By computerizing health records, we can avoid dangerous medical mistakes, reduce costs, and improve care.

—President George W. Bush, State of the Union Address, 2004

Surprisingly, digitalizing the clinical environment is not a drastically new concept. In 1971, El Camino Hospital in Mountain View, California branded itself as the first fully computerized hospital when it began demonstrating and using one of the earliest digital information systems in the hospital setting. The system that was instituted is now generically called computerized physician order entry (CPOE) and is perhaps the first major effort to create a digital hospital.

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12 Hrubec, A. (2015, March 5)
13 Encinosa, W., & Bae, J. (2015, March 1)
14 Freudenheim, M. (2012, October 8)
A case study designed by the Massachusetts Technology Collaborative and the New England Healthcare Institute concisely explains the basic premise of CPOE as “a computer application that is used by physicians to enter diagnostic and therapeutic patient care orders.” Researchers from the University of Washington and University of Virginia more describe at greater length a typical clinical routine and how a computerized system can be beneficial:

An intern attends rounds early in the morning with her team of residents and an attending physician. The group discusses each patient either at the bedside or just outside the room. During the course of the discussion, suggestions are made about what tests and medications to order for the patient. The intern writes some notes as a reminder about what to do later. At the conclusion of rounds, the intern is expected to enter orders into the computer for most patients. She seeks an unused machine, logs on and locates the first patient in the system. She may order labs and then begin to order medications. To order a medication, she first needs to find its name in an alphabetical list and select a dosage from a menu and then a schedule for administration from another menu. If the dosage or schedule desired is different from normal in some way [from the predefined list], she may need to type in exact instructions and be creative about abbreviating words because the space for free text may be limited. She sends the order for the first medication and, to order a second, goes back to the alphabetical list and starts again. If she orders something that might interact with another substance, she receives an alert when she asks the machine to send the order. When the intern is finished with the orders for the first patient, she pulls up the record on the second patient and starts again. She is pleased that the medication is received on the floor within an hour. Because the data are entered in a structured manner, and because they enter a large database, an accurate record of that order now exists for billing and other tracking purposes.

Without the computer, the physician would write a list of orders in longhand or check boxes on a form, one list per patient, and a ward clerk or nurse would take over the process after that. The clerk may need to clarify the order, especially if the writing is hard to read. It may take the intern ten minutes per patient to write the orders and answer questions.\textsuperscript{18}

Though many practitioners might feel that the paper method is upfront immediately more stable, simpler or faster, the reality is usually riddled micromanagement due to poor handwriting and incomplete entries.\textsuperscript{19} Still, time is not the only important consideration with regards to digitalization, the other is safety.

One of the most significant purposes of CPOE usage is to reduce accidents and injuries related to medical errors. In their seminal 1999 report, \textit{To Err Is Human}, the Institute of Medicine estimated that approximately 44,000 to 98,000 people die each year due to medical errors, which they define as, “adverse [prescribed] drug events and improper transfusions, surgical injuries and wrong-site surgery, suicides, restraint-related injuries or death, falls, burns, pressure ulcers, and mistaken patient identities.”\textsuperscript{20} The loss of life also does not include the financial costs (IOM estimates $17-29 billion per year) or the psychological issues, like population confidence in medicine, hospital setting or healthcare professionals. The Agency for Healthcare Research and Quality reports that nearly half of medication errors occur at the drug ordering stage.\textsuperscript{21}

A 2013 follow-up study by John T. James, writing from the Journal of Patient Safety, indicated even greater dismal results. In the years studied (2008-11), researchers found roughly one-sixth of all United States deaths were attributed to preventable adverse events (PAEs), or medical errors, each year.\textsuperscript{22} This translates to roughly greater than 400,000 deaths per year, which would rank deaths due to PAEs as the third largest killer in the U.S.\textsuperscript{23} James mentions the severe complexity at the provider, system, and national levels as the basic source of such errors. This can range from the improper usage and access to treatment guidelines to missing tools or improper handovers during shift changes.

\textsuperscript{18} Ash, J., Gorman, P., Lavelle, M., Payne, T., Massaro, T., Frantz, G., & Lyman, J. (2003, March 1)
\textsuperscript{19} Fumis, R., Costa, E., Martins, P., Pizzo, V., Souza, I., & Schettino, G. (2014)
\textsuperscript{20} Committee on the Quality of Health Care in America. (1999, November 1)
\textsuperscript{22} James, J. (2013, September 1)
\textsuperscript{23} Binder, L. (2013, September 23)
Although CPOEs alone could not completely resolve all of the above listed issues, a 2013 article from the Journal of the American Medical Informatics Association (JAMIA) cites that “electronic entry of medication orders through CPOE may reduce errors from poor handwriting or incorrect transcription. CPOE systems often include functionalities such as drug dosage support, alerts about harmful interactions, and clinical decision support, which may further reduce errors.” It is estimated that CPOE systems can decrease medication errors from 48% up to 55%.

Although there seemed to have been an early resistance to digitalization at the hospital-level, that trend now appears to be slowly withering. The Leapfrog Group, a consortium of large businesses, universities, and with U.S. government support, has been surveying hospitals nationally since 2000 in an effort to monitor and analyze CPOE implementation standards. Figure 3.2.1 shows the progress of CPOE implementation and subsequent full usage since 2009. Leapfrog’s “usage” definition

![Hospitals Meeting Leapfrog's Computerized Physician Order Entry (CPOE) Standard](image)

Figure 3.2.1 – Change in CPOE use over time

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24 Radley, D., Wasserman, M., Olsho, L., Shoemaker, S., Spranca, M., & Bradshaw, B. (2013, May 1)
requires that “at least 75% of medication orders across all inpatient units are ordered through a CPOE system.”

The Leapfrog Group has clearly shown over time that the adoption rate is indeed steadily increasing, with respect to the last few years. Though growth in usage should be considered a positive phenomenon, CPOEs are not free from deficiency.

There is a well-documented steep learning curve complementary to these systems, perhaps explaining why many individual professionals seem them slow and opposed to favor adoption—despite their benefits. Researchers Guappone, Ash and Sittig note one particularly irritating scenario:

One of the purported advantages of computerized order entry is that the user does not have to conceive the order to write, but is able to choose from a pre-constructed list. The user many times is not writing orders so much as picking from lists. Therefore, the task often changes from writing down words to finding and choosing items in the graphical user interface. Even if text is entered by typing into a blank box, it must correspond to a constrained list that the system recognizes, and the user must “find” the right word to enter. This category, by far, comprised the most common usability issues. Users spent a great deal of energy attempting to “find” what they were looking for.

... Users exposed other problems in locating items such as poor organization of forms or order sets, excessively long lists on menus, not enough default values, the lack of synonyms such that an item was not named the way the user expected, and the need to scroll to areas out of sight to see the needed items.

In the present tense, CPOE is best described as a precursory technology. Though the rough introduction to the digital hospital that CPOE helps to provide when implemented has value, it is often painfully restrictive. In an effort to improve these shortcomings, CPOE’s basic structure is preserved while a new type of system enhances usability, despite increasing overall complexity. In order to build on the

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successes of CPOE, hospitals must look forward to electronic health records (EHRs), the next step in care improvement and development.

3.3 The Electronic Health Record

I am so much more caught up on progress notes than I've ever been in my life. And I can read my own writing.\textsuperscript{28}

—Vanessa Jensen, pediatric psychologist at the Cleveland Clinic Children's Hospital

In a post for Hospital and Health Networks Daily, John Glaser, CEO of Siemens Healthcare Health Services, writes that society is very nearly in the midst of the fifth wave of the IT revolution.\textsuperscript{29} To reach this point, Glaser suggests there had to be a progression to pass through four precedential waves: mainframe computing, minicomputer (e.g. personal computers), networked personal computers, and the rise of the Internet.

It is likely that the digital hospital could already be defined early on in the mainframe-era. When Lawrence Weed introduced the idea of the problem-oriented medical record (POMR), suddenly then electronic input became possible in the 1960s.\textsuperscript{30} Through subsequent stages, new developments allowed for progressively more intuitive tools in the healthcare sphere began to crop up, including the creation of the first “computer-stored medical record” in 1972.\textsuperscript{31}

The Regenstrief Institute set out to accomplish a simple, but significant goal with their early electronic medical record (EMR): to improve treatment. Since records were expected to be stored digitally, the file theoretically could be accessed at any location, as long as somehow network-connected. This was anticipated to help reduce problematic diagnoses and treatments made by non-primary (non-treating) physicians. For example, in the case of emergency treatment far from the physical records, which

\textsuperscript{28} Anonymous F. (2012, May 1)
\textsuperscript{29} Glaser, J. (2011, June 14)
\textsuperscript{30} Jacobs, L. (2009)
\textsuperscript{31} McDonald, C., Overhage, M., Tierney, W., Dexter, P., Martin, D., Suico, J., Wodniak, C. (1999)
would normally detail a patient’s medical history, it would be extremely difficult to be completely aware of past treatments, allergies, or other hidden complications. By making records easier to access for a wide variety of authorized professionals, prevention, diagnosis and treatment were expected to be improved.

While EMRs were intended to improve tasks executed by healthcare workers, other entities were rather excluded from the picture. Insurance companies, market speculators, and most importantly, patients, could not directly benefit from these systems apart from the improvements to the care that they themselves received.32

In order to broaden the scope, a new type of platform was conceived: the electronic health record (EHR).

Although EHR is sometimes used synonymously with EMR, its identical nature is often disputed. The U.S. government’s Health IT website defines the difference with its claim that EMR is essentially useful for only one healthcare environment (i.e. where the system is used). In other words, EMRs can track data, maintain patient needs, and monitor the practice, but only in an isolated setting. EHRs, on the other hand, allow for the possibility of external coordination and communication. In this sense, EHR is a more openly comprehensive and robust form of EMR.33

Up to date EMR systems are expected to include features such as: digital patient record storage, automated physician-specific workflows (to aid professionals in working processes), more intuitive and simplified IT setup to allow smaller teams with less money and skills to setup and configure the system, integrated billing features and process audits, and interoperability (at least to some degree).34 EHR systems are also capable of collecting non-definitively clinical details about a patient that may have significance when analyzing rare diseases or population trends, as is elaborated in Figure 3.3.1 (following page).

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32 Anonymous G. (n.d.)
33 Garrett, P. (2011, January 4)
34 Tripathi, M. (2012, October 1)
The first industrial progressions of EHR implementation generally can be traced to Title II of the Health Insurance Portability and Accountability Act of 1996 (HIPPA Act), which intended to “adopt national standards for electronic health care transactions and national identifiers for providers, health plans, and employers” under the Administrative Simplification provision.\(^{36}\)

Then in 2004, President George W. Bush signed an executive order entitled *The President’s Health Information Technology Plan*, which aimed to press on with what the HIPPA Act began. Though absent of a fixed funding schematic, this new plan pointed out the common pitfalls of modern U.S. Healthcare and set a goal of ten years for “…most Americans [to] have electronic health records…”\(^{37}\) In the body of his order, the President highlighted common advantages such as: increased patient record access and convenience, improved treatment safety and effective and active population health

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\(^{35}\) Committee on the Recommended Social and Behavioral Domains and Measures for Electronic Health Records. (2014, April 1)

\(^{36}\) Anonymous H. (2013, April 2)

\(^{37}\) Anonymous B. (2004, January 20)
monitoring.

Figure 3.3.2 – Hospital EHR adoption rate over time 38

As a result, nearly ten years later (as shown in Figure 3.3.2), 38 EHR adoption has grown considerably—the U.S. government estimates five-fold growth since 2008. Though complete, comprehensive coverage has still not yet occurred. 39

A further initiative came in 2009, as part of the American Recovery and Reinvestment Act. The Health Information Technology for Economic and Clinical Health Act, or HITECH Act, was perhaps the first time the vision of cooperating healthcare networks was thought as viable. Whereas previously, ideas and funding remained divorced, HITECH proportioned approximately $30 billion in available funding (over ten years) to entice hospitals and professionals to input EHR systems. Non-compliant practices—those who forewent EHR adoption—would in turn also risk financial penalties associated to lack of use. With this, the U.S. government demonstrated a serious desire for structural development and care enhancement. 40 If financial incentive is not enough, penalties in the form of reduced reimbursement payment will begin in 2015. 41

“Information is the lifeblood of modern medicine,” writes David Blumenthal, “[and] health information technology (HIT) is destined to be its circulatory system.” 42 But having information is not everything; possession of an EHR system is not enough.

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39 Anonymous J. (n.d.)
40 Jha, A. (2010, October 20)
41 Anonymous K. (2009, March 1)
42 Blumenthal, D. (2010, February 1)
After the EHR system is installed, institutions must successfully achieve another required aspect associated to the criteria of the HITECH Act by achieving the necessary objectives of Meaningful Use (MU).

MU is quickly summarized by Blumenthal as achieving significant improvements in care.\textsuperscript{43} Though the reality is anything, but simple. MU criteria contains ten mandatory achievements, eight flexible choices from which five goals must be selected, and two further sets of two options each for either hospitals or clinics or healthcare professionals (refer to appendix Table A.1 for full list). These criteria can range from “[must collect] over 50% of patients’ demographic data recorded as structured data” to “over 50% of requesting patients [must] receive electronic copy [of their health information] within 3 business days.”

As daunting as these seem on paper, executing them in reality is more challenging and the amount of development for some hospitals is nearly insurmountable, especially in combination with the initial task of setting up the system. One of the best examples of a successful EHR, despite painfully quantifiable challenges, is the Kaiser Permanente (KP) model.

KP, founded in 1945, has amassed a modern staff of nearly 200,000 employees, including roughly 14,000 physicians, all in an effort to better serve and care for about 8.7 million individuals from nine states and Washington D.C. What sets KP apart from most other healthcare settings is its system-wide integration that “closely coordinates primary, secondary, and hospital care [and] places an emphasis on prevention [and] extensive use of electronic medical records.”\textsuperscript{44}

What is notably rare about KP is its full-scale connectability, combined with its network size. Yet, a patient exiting the KP realm may face the same pitfalls as any of connection-void treatment facility.

In the early 2000s, KP abandoned its efforts to create a custom EHR, instead opting for pre-designed solution because of a list of issues, called KP HealthConnect.\textsuperscript{45} With the selection of Epic, one of the largest EHR developers in the U.S., it hoped to also take advantage of de facto connection to other health providers by way of relation in the EHR manufacturer. As always, complexities arise when varying brand usage is employed.

\textsuperscript{43} Blumenthal, D., & Tavenner, M. (2010, August 5)
\textsuperscript{44} Richardson, B. (2009, July 1)
\textsuperscript{45} Chen, C., Garrido, T., Chock, D., Okawa, G., & Liang, L. (2009, April 1)
Lack of true interoperability, or flawless, non-related system to system patient data transfer, is a well documented issue, and one that the U.S. Congress hopes to eliminate with its MU guidelines. Epic, for its part, has introduced an interoperability feature (Care Everywhere), based on C-CDA, that has compatibility with over forty EHR vendors. From January to July 2014, more than twenty million exchanges occurred. Still, Epic admits that while transfers to other vendors are often possible, when both sides of the transfer are Epic products, “...a richer data set is exchanged and additional connectivity options … is available.”

At the beginning of this chapter, Bill Frist described the U.S. healthcare system as stuck in the Stone Age. Over the course of the last decade, much has been developed to segue today’s society towards its path of remaking the unique system that protects humans from the flaws ingrained in their own biology.

Consider that when a warehouse is filled with innumerable patient records, eventually it will grow to be pointless when the swathe of data becomes disorienting, so too is the absence of utility when the cache of digital data becomes too great.

With the advent and adoption of the personal computer, life has changed immensely for many: so then, what more can the computer do for healthcare?

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46 Butler, M. (2015, March 17)
47 Consolidated Clinical Document Architecture
Chapter Four: Data Analytics

4.1 What is Big Data Analytics?

Machines don't replace humans. They empower them.

—Inhi Cho Suh, Vice President & GM Big Data, Integration, & Governance, IBM[1]

Perhaps data was nothing until it became big; as in, what good is a baby until it becomes an adult or factories will not produce one car unless a thousand more follow in the line behind it? True, what good is knowing a single person’s biometrics without a suitable benchmark? In any case, while some managers today shirk the digital mountains of information amassing before them, others are climbing, faster and faster, increasingly curious as to what it all means, and how can it help them. Big Data has helped managers make money—but will it help doctors save lives?

In February 2001, Doug Laney, writing for META Group (now Gartner), discussed the imminent trends and changes businesses would soon have to adopt to stay competitive. In what he indiscriminately describes as “3D Data Management,” Mr. Laney gave a physicality to the then still undefined, but already sensed, data storage and analysis limitations rapidly approaching.[4]

The essence of 3D Data Management relies on the now classic concept, the 3 V’s: volume, velocity, and variety. Volume pertains to the mass amounts of data now available to modern businesses; velocity is attributed to the speed at which data can be accessed; and variety references data prioritization of critical or unique data.

In a 2012 rebuttal paper to himself entitled, “A Personal Perspective on the Origin(s) and Development of “Big Data”: The Phenomenon, the Term, and the Discipline,” Professor Francis X. Diebold writes: “The term “Big Data,” which spans computer science and statistics/econometrics, probably originated in lunch-table conversations at Silicon Graphics Inc. (SGI) in the mid 1990s, in which John Mashey

figured prominently.” Diebold had previously declared himself the creator of the concept.³³

The intersection of what Hilbert and Lopez describe as “the three basic information operations,” which has already opened a new frontier, enabling scientists and regular civilians alike to store and process huge archives of information—in a way—has birthed the Big Data era.⁴ These three characterized elements—highlighted in Figure 4.1.1—are: communication (origin of data), storage (data access point), and computation (data process point).

![Figure 4.1.1. – Various types of communication, storage, and computation](image)

It should indeed be noted that the three factors from Hilbert and Lopez also correlate with Laney’s 3 V’s: volume (storage), velocity (computation), and variety (communication); in other words, Laney is specifically discussing data as a concept, while Hilbert and Lopez are demonstrating machine ability and application. Thus,

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⁵² Diebold, F. (2012, August 1)
⁵³ Lohr, S. (2013, February 1)
⁵⁴ Hilbert, M., & López, P. (2011, February 10)
technical device limitations and a theoretical definition appear to have a mirror relationship with the construct in which the extents of data can exist.

In a 2010 Hilbert and Lopez study, they go on to note that from 1986 to 2007, total global storage capacity grew approximately 58% each year and was approximately 295 exabytes\textsuperscript{55} in 2007 (storage capacity increase seen in Figure 4.1.2, along with types of storage).

![Figure 4.1.2 – Large size capacity increases and types of storage entities\textsuperscript{54}]

Still, these growth numbers would not have been possible without price reduction per byte, which dramatically occurs continuously. Rockland IT Solutions estimates that one megabyte of storage in 1956 cost approximately $10,000; in 1988, $233; in 1998, $9; in 2000, $0.0118; in 2005, $0.0006 (prices not adjusted).\textsuperscript{56}

Hilbert and Lopez’ study, finally describes computational power as “…the repeated transmission of information through space [(communication)] and time [(storage)]…” and has also seen sizable gains since 1986. For the twenty years examined the research, beginning with a capacity of $3.0 \times 10^8$ (300,000,000) MIPS (million instructions per second) in 1986 to $6.4 \times 10^{12}$ (6,400,000,000,000) MIPS in 2007. Interestingly, in 1986 pocket calculators comprised about 41% of total power. By 2007, pocket calculators’ power input had become negligible and personal computers

\textsuperscript{55} 2.95 \times 10^{14} megabytes; for reference: a typical song = \textasciitilde 3 megabytes
\textsuperscript{56} Anonymous N. (2013)
made up 66%, but mobile phones/PDAs accounted for just 6%.57 This was also the same year (2007) that the first generation of Apple’s iPhone was released; by 2014 over 500 million iPhones have been sold.58

While the debate surrounding Big Data’s origin and significance—namely: has Big Data been around forever?—wears on, the eponymous title indeed seems to perplex and therefore intimidate both individuals and businesses alike. As Boyd and Crawford point out, “Big Data is, in many ways, a poor term,” possibly even a misnomer.59 Professor Lev Manovich also points out that while Big Data was once envisioned as a content so large that the usage of supercomputers was necessitated to perform appropriate analysis, many researchers today, armed with only a typical desktop PC, can confidently evoke powerful results from the hordes of data.60

It is critical to grasp that Big Data is, in fact, a sizeable cache of information. Whether focusing on wide or deep bodies of information (e.g. complete health records of a single person or a specific treatment result for a population), it seems certain that the tumult of texts and numbers do have an incredible value—but how to find it?

Still, today as of writing, many experts agree that Big Data as a concept is not solely a giant cluster of information; as knowledge without understanding exceeds its utility, but rather a comprehensive paradigm that includes large amounts of data, cost-effective information processing and then enhanced insight and decision making assistance, argues Gartner researcher, Svetlana Sicular.61

Despite the fact that Big Data holds the namesake of the process, it actually plays a much smaller part in the perceived cognitive process to generate value. In a Q&A session with Hal Varian, Google’s Chief Economist, Varian plainly describes the relationship:

“If you are looking for a career where your services will be in high demand, you should find something where you provide a scarce, complementary service to something that is getting ubiquitous and cheap. So what’s getting ubiquitous and cheap? Data. And what is complementary to data? Analysis.”62

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57 Hilbert, M., & López, P. (2011, February 10)
60 Manovich, L. (2011)
61 Sicular, S. (2013, March 27)
Mark Horowitz, of Wired, goes further: “The biggest challenge of the Petabyte Age won't be storing all that data, it'll be figuring out how to make sense of it.” So how to make sense of confusion? Study it, analyze it, and simplify to understand.

4.2 Analytics and Prediction

I propose to consider the question, “Can machines think?”

—Alan Turing, creator of the Turing Test

Toward the end of the first decade of the 2000s, General Electric (GE) realized that they, an industrial manufacturer, were selling software worth billions of dollars. Yet, they were and are still not typically regarded as a software company. It turned out that many of their industrial products required some software for operation, but the problem was that they were competing in a market with cutting edge exteriors and obsolete brains. Amidst shrinking market share, they needed an answer, and fast. Their solution was the Industrial Internet.

GE claims that Humanity is on the cusp (or perhaps already aboard) of the “third wave of innovation: the Industrial Internet.” Figure 4.2.1 demonstrates the three Waves: the Industrial Revolution, the Internet Revolution, and the Industrial Internet.

In a phrase, the Industrial Revolution created machines, the Internet Revolution greatly enhanced communication, and now the Industrial Internet will combine the two, allowing machines to communicate. For roughly a century, machines have been creating unending flows of content, now filling the Internet with asinine amounts of data, just waiting for technology to be able decrypt the mass.

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63 Horowitz, M. (2008, June 23)
64 Turing, A. (1950, October 1)
Yet, unlike those stories where sick people cryogenically freeze themselves until a future society has the knowledge to cure them, machines do not exactly have individuality. Standardized procedure is required for efficient industrial operation, so when old machines were decommissioned, new units were built, and the data just kept pouring in.

Perhaps in many ways, massive, disorganized stores of data is a lot like a sick patient, completely useless for productivity, but a short term cost seems to obscure the allure of long term benefits. Hence, the greater and greater expenditures for storage, communications, and computation offer value, but at a cost.

Yet today, the placid, overflowing data lakes can be unfrozen: society is on the brink of some huge discoveries.

While GE’s Industrial Internet operates largely on the concept only to benefit its own products—indeed their most flaunted examples of use (read: the buzzword is “connectivity”) are train locomotives that properly notify controllers before a part breaks causing downtime, planes that are aware of more efficient flight paths, and wind turbines that anticipate environmental change to enhance efficiency—a fellow, more general concept, the Internet of Things, seeks to excite all members of the societal spectrum to the benefits of interconnectedness.
The Internet of Things (IoT) seeks to connect all smart devices—devices with Internet connectability—to one another. Here, “Internet” is used generically to convey the significance of connectability. More formally, the Internet is “an electronic communications network that connects computer networks and organizational computer facilities around the world;” in other words, it is a gateway mechanism from one device to another.

Mark Weiser, a former researcher at Xerox’s Palo Alto Research Center (PARC), famously wrote in 1991 that, “the most profound technologies are those that disappear.” In his paper, he discusses the possibility of “Future networks [that] must be capable of supporting hundreds of devices in a single and must also cope with devices—ranging from tables to laser printers or large screen display—that move from one place to another.”

The concept is not at all innovative by now, but the point is that ubiquitous, “disappearing” computer usage, perhaps once a dream for Weiser, is quickly becoming a full-blown, modern reality. In 2013, Cisco estimated that roughly 10 billion devices were connected to the Internet, representing approximately only 0.6% of all global devices, or rather, 99.4% of all devices are not connected. Figure 4.2.2 (following page) demonstrates the actual and expected explosive device connectability growth

![Figure 4.2.2 – Progression (and expectation) of total devices connected to Internet](image)

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66 Anonymous O. (n.d.)
67 Weiser, M. (1991, September 1)
since 1995 and the corresponding era of connectedness.\footnote{Bradley, J., Barbier, J., & Handler, D. (2013)}

But connection—although an important element—is not the sole factor to make this paradigm purvey great potential, rather it is the devices that use analytics to take observations and turn them into useful data. Hermann Kopetz calls these devices smart objects and describes them as beyond what is normally thought of when describing smart machines. For example, “consider a smart refrigerator that keeps track of the availability and expiry date of food items and autonomously places an order to the next grocery shop if the supply of a food item is below a given limit.”\footnote{Kopetz, H. (2011, February 26)} A key aspect of the concept is autonomous device operation, such as the refrigerator ordering more supplies automatically instead of notifying the user and causing a distraction.

As smart object adoption rate becomes closer and closer to pervasive, society will enter the so-called Internet of Everything: an era where computers will be involved in every aspect of life, but generally occurring without user input. The possibilities, as presently perceived, extend beyond concepts and applications that are currently imaginable.

While the analytical, “smart” piece of the puzzle may simply appear as magic—it is not. Scientists have been investigating the premise of replacing man with machine for centuries. Descartes had already written of man creating “…various automata which move without thought…” in the 17th century.\footnote{Descartes, R. (1993)}

In 1950, years away from the basic personal computer age, Turing was considering existential capability of machines. It is easy to understand why—humans need an awful lot of help in unpacking the mysterious that envelope their existence.

In the last section, there was a discussion of the sheer stock of information. Though humans would like to know everything, it is simply not possible to find the time to discover the infiniteness of subtlety. At least, not without the computer.

In early 2011, IBM went on live TV to showcase its latest development in achieving human-like thinking contained in a machine: Watson. It had not been since 1997 when another thinking IBM creation, Deep Blue, had received such public attention because it had defeated Gary Kasparov in chess. The new challenge was to defeat two Jeopardy! champions, which it did seemingly effortlessly.
What Watson—a cognitive technology that processes information more like a human than a computer—did that year was far more than conquering a couple of game show success stories. For the first time in history, human-like conversation and intelligence was showcased by a computer to a mainstream audience.

It may be a fair point to highlight the high probability that Watson was developed for gameplay success in a period leading up to the contest, but was that any greater coaching or preparation than typical participants also employ? In short, Watson possibly embodies the most present mechanical threat to workplace redundancy, as Ken Jennings, Jeopardy’s most successful contestant, pointed out,

“Just as factory jobs were eliminated in the 20th century by new assembly-line robots, Brad [Rutter] and I were the first knowledge-industry workers put out of work by the new generation of "thinking" machines. "Quiz show contestant" may be the first job made redundant by Watson, but I'm sure it won't be the last.”

Outside of laboratories in the real world, it is also easy to get excited about widespread data collection. Deep Blue, Watson, and Jeopardy! critically have proven that. By taking a short moment to think about some of the devices on which are regularly relied, it is highly likely that soon sensors will appear as a component. Despite this, most devices today only take momentarily measurements, as Cisco discussed. The future car speedometer readings or thermometer measurements of an oven will not be simply forgotten. Instead, future devices will capture and save data for timely analysis.

It should be mentioned that the notion of constant measurement has gained the ire privacy advocates that counteractively call for reduced tracking and data collection. The basic fear seems to stem from an obvious eventual loss of complete anonymity, which, to be fair, is an apt concern.

Yet, perhaps little to no privacy as a concept could also have great benefits. After a large earthquake struck Haiti in 2010, the country was left rather destitute. In order to help the local population with increased efficiently, aid workers and researchers from the Karolinska Institute and Columbia University began monitoring

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72 Jennings, K. (2011, February 16)
almost two million SIM cards to track migration patterns. This proved quite beneficial, as the researchers were able to properly guide government and humanitarian organizations more accurately to where the most effective use of their resources could be directed.\footnote{Anonymous Q. (2012)}

From 2009-12, the EU VIAJEO project collected and analyzed a large amount of traffic patterns by tracking vehicles operating in Athens, Beijing, Sao Paulo, and Shanghai to understand how to improve transport and reduce roadway congestion. Thanks to this research, more logical traffic distribution networks can be designed, helping to facilitate less pollution and more efficient point-to-point travel.\footnote{Anonymous R. (2012, December 18)}

And now, the healthcare sector is poised to take full advantage of the benefits of intelligently analyzed data, as long as managers are willing to make the necessary investments.

4.3 Big Data & Healthcare

What can happen in a year?

—University of Texas’ MD Anderson Cancer Center (from Moon Shots Program promo video)\footnote{Anonymous S. (2013, October 18)}

“In the fall of 2012, MD Anderson launched the Moon Shots Program with the goal of saving as many lives as possible, as quickly as possible,” says MD Anderson’s president, Ronald DePinho.\footnote{Anonymous T. (2013)} The Moon Shots program covers a wide variety of cancer research, including: melanoma, breast, ovarian, Acute Myeloid Leukemia (AML) and Myelodysplastic Syndrome (MDS), Chronic Lymphocytic Leukemia (CLL), lung, and prostate cancers. Patient records are drawn from the hospital’s EMR and then processed with their proprietary platform, Oncology Expert Advisor (OEA), which is powered by IBM’s Watson.

The hospital’s jewel of their Moon Shot program is a large-scale Leukemia research project that, since its inception in Fall 2013, has recorded over 1,300 newly
diagnosed patient records and includes over 3,000 non-new patient samples and reports. It is expected that the results will generate important findings and make important contributions to the Watson system as it learns its way through processing.

Memorial Sloan Kettering Cancer Center (MSKCC) is also tapping the power of Watson to benefit their research and treatment. “What our role is, is that we are MSK/Watson’s teacher; and just like we would teach a trainee in medical oncology or surgical oncology, we’re teaching the MSK/Watson system,” said Mark Kris, Lead Physician of the Watson/MSK collaboration.77

For roughly two years, MSK, IBM and WellPoint (a giant managed care provider) have collaborated to teach the system how to properly and rapidly analyze data and assist medical professionals to choose the best treatment plans for lung and breast cancers (expected later expansion to blood, colon, prostate, bladder, ovarian, cervical, pancreas, kidney, liver uterine, melanomas, and lymphoma cancers).78 IBM estimates that Watson “…has ingested more than 600,000 pieces of medical evidence, two million pages of text from 42 medical journals and clinical trials in the area of oncology research.” 79 This is critical. MSKCC estimates that the average doctor simply cannot stay completely current on the latest findings from medical journals causing professionals to sometimes reference anecdotal knowledge rather than evidence-based, updated information when making decisions.80 For Watson and other computer systems, this is not a problem as data is simply regularly uploaded.

Watson then can apply this knowledge to the estimated 1.5 million modern and historic patient records to which it has access and make recommend evidence based treatment options rapidly, all while using natural language processing (NLP) to simplify medical professional to system communication.

The consortium’s research and development with Watson is intended to produce a commercial product to support professionals in the healthcare setting in the near future. Already, the Maine Center for Cancer Medicine and WESTMED Medical Group have signed on as early testers to provide feedback for the system’s performance.

77 Bassett, J. (2014, April 11)
78 Kris, M. (2013, April 8)
79 Saxena, M., & Kris, M. (2013, February 8)
80 Anonymous U. (2013)
The Cleveland Clinic is also experimenting with Watson both as a teaching tool and also as an advanced EMR data-mining tool. Watson EMR Assistant is aimed to use its NLP ability to parse through disorganized patient records to find the pertinent information, thereby generating efficiency and saving time for the medical professional.81

Watson proposes action by giving multiple possibilities with higher or lower probability of success scores. In order to test the efficacy of the machine, Columbia researcher, Herbert Chase, performed mock scenarios. “Watson has done incredibly well,” Chase said. “You say ‘fever, weight loss, joint pain, skin rash’ and Watson comes up with three or four suggestions [of a diagnosis] which are incredibly accurate.”82 Specific results have so far not been published.

Watson and other platforms like it are called clinical decision support systems. Using information retrieved from EMRs and other imported data, these systems help medical professionals make appropriate choices regarding diagnosis, treatment and possibly also assist in managing resources (like available beds), unused devices (like MRIs) and speeding up the decision approval process that can sometimes delay the treatment process.83 Additionally, these systems could be highly useful to track actions to maintain quality assurance and prevent unnecessary treatment or fraud.84

Researchers from the Mayo Clinic created a prototype CDSS specifically to study the effect on treating cervical cancer. Figure 4.3.1. (following page) shows what and how their CDSS takes data from their EMR system. By analyzing 169 cases, the researchers found that the CDSS gave “suboptimal” for only twenty-two cases, as assessed by blind experts, for 87% accuracy.85 Human providers, on the other hand, fared worse with about 66% accuracy.

81 Kelly, J. (2013, October 15)
82 Uhl, J. (2011, March 21)
83 Berner, E. (2007)
84 Patkar, V., Acosta, D., Davidson, T., Jones, A., Fox, J., & Keshtkar, M. (2011)
85 Wagholikar, K., MacLaughlin, K., Kastner, T., Casey, P., Henry, M., Greenes, R., Chaudhry, R. (2013, July 1)
However, a system’s overall effectiveness is also reliant on its ability to function with all different types of EMR/EHR systems, as today’s market has hundreds of choices, in order to have access to examine the maximum amount of data. The American Society of Clinical Oncology (ASCO) has developed their own CDSS, called Cancerlinq, which they hope can tap into the vast patient data archives from as many willing hospitals as possible. Using their established network, they have contact with over 35,000 oncology professionals with whom they hope to gain access to many presently isolated hospital networks.

ASCO points out “close to 30% of patients with cancer are seventy-five years old or older, yet they represent fewer than 10% of patients on clinical trials.” For instance, consider a 77-year-old man with stage 3 colon cancer, heart failure and diabetes. That patient wouldn't have been included in a clinical trial, but those are the folks we take care of in the real world all the time,” said Tennessee Oncology doctor, Charles Penley.

In this case, systems like Cancerlinq and other similar concepts will fill many data holes and allow any decision made by a professional to have real weight because their decision will be supported by relevant evidence. A Google-backed start-up,

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89 Winslow, R. (2013, March 26)
Flatiron, seeks to do the same thing as ASCO with decision making in oncology: connect and fill in the data gaps.\textsuperscript{90} So far, Cancerlinc has approximately 130,000 breast cancer cases loaded into it prototype.\textsuperscript{91} Flatiron has not reported their statistics to date.

SAP’s HANA platform is also aimed at mining EMR/EHR data, but will also include integration with wearable devices, “.... tracking, wearable technology that most of us are using to track our vitals, our calories, and our daily exercise.”\textsuperscript{92}

Figure 4.3.2 – CDSS adoption rate in the post-2000s U.S.\textsuperscript{93}

As seen in Figure 4.3.2., CDSS adoption rate in the U.S. is moving at dramatically fast pace since 2007, thanks to the U.S. Government’s strong, incentivized push for nationwide EHR/EMR adoption. Progress is being made and the widespread implementation will help connect disparate records and data and is expected to yield a higher level of care.

\textsuperscript{90} Anonymous V. (2012)
\textsuperscript{91} Sledge, G., Miller, R., & Hauser, R. (2013)
\textsuperscript{92} Singh, E. (2013, October 15)
\textsuperscript{93} Anonymous LL. (n.d.)
With the adoption of EHR, data cloud connectivity, use of Big Data analytics and decision support, the clinical environment is largely covered, but, in fact, it is not where most patients spend their time. So what happens to all the information when the patient is on the go?
Chapter Five: Telehealth

5.1 Telecommunications and Healthcare

The doctor of the future will give no medication, but will interest his patients in the care of the human frame, diet and in the cause and prevention of disease.

—Thomas A. Edison, prolific inventor and thinker

“People have been communicating over considerable distances by sounds or visible signals for centuries,” the Institute of Medicine’s 1996 report on telemedicine begins. Using sound, light, or smoke, early humans clearly understood the power of long distance communication. Over the course of history, the ability to communicate over long distances has allowed people to save time, money, or avoid disaster.

Of course, while the circumstances and ultimate ramifications of modern communication hold much greater accuracy and possibility, the base rationale of usage remains essentially the same. Telehealth today represents a modern execution of a vintage problem: how to maintain the patient while out of reach of the physician?

In the Telehealth Start-Up and Resource Guide (2014) distributed by the U.S. Department of Health and Human Services, telehealth is defined as possessing tools to allow for assessment, monitoring, and communications in order to diagnose and treat illness or injury and encourage prevention and education.

The 2012 Institute of Medicine’s follow-up report notes that remotely-based, in home treatment has been relevant since at least as early as the telephone early in the late 1800s when physicians sought to use “...the telephone to reduce unnecessary office visits.” Later, during space expeditions, NASA needed an appropriate method to measure and maintain astronauts vitals from a centralized location while the workers were flying thousands of miles away.

In the last two chapters, an investigation into the developments in the process of implementation in hospitals were strictly analyzed; meanwhile, when not in these clinical environments, patients seem to be left to their own devices, where they

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95 Anonymous W. (2014, October 1)
96 Nesbitt, T. (2012)
deteriorate just enough until direct, hands-on professional care is necessary. Besides, inherent cost savings as a result of less unnecessary doctor-to-patient meetings, telehealth services can also reduce patient anxiety.

Kaiser Permanente’s (KP) My Health Manager (launched in 2005) is an extremely straightforward platform that allows patients to communicate with their physician whenever they feel urgency and seek answers to questions. Though the suite of tools was first accessed via the hospital’s website, a smartphone application that functions in exactly the same manner is now available. From 2004-2007, KP saw a 26.2% decrease in hospital visits while scheduled telephone “visits” increased by nearly 9 times.\textsuperscript{97}

The website platform and application offer KP patients accessibility to see their health plan, contact their doctor (via phone or secure in-app messaging), schedule appointments, refill prescriptions, and view their personal medical record, including reviewing lab results.\textsuperscript{98} Since the introduction of the platform, patients sent roughly 3,000 messages in 2005 and later grew to 51,000 in 2007. Of note, these messages would have occurred before the mobile application’s introduction, since the age of smart phones was very nearly dawning in 2007. By 2013, KP estimated at least 13 million messages had been sent.

Figure 5.1.1 (following page) visibly demonstrates the drastic alteration currently transforming the concept of visiting the doctor. Also important is that interactions per member are not dropping over time despite fewer in-person meetings.

\textsuperscript{97} Chen, C., Garrido, T., Chock, D., Okawa, G., & Liang, L. (2009, April 1)
\textsuperscript{98} Wardell, A., & Poorsina, R. (2013, July 18)
Naturally, the in-person visits may drop steadily until a plateau point is reached when the efficiency of the call or message reaches zero. Still, remote live conversation with doctors or other healthcare professionals appears to be diversifying in its forms of application. For those living in urban areas, a few clear motivations for these developments are convenience and cost reductions, but for those located far from their care professionals, meaningful remote access may prevent harm or save lives.

In rural Georgia, remote consultations accounted for upwards of 40,000 virtual doctor visits in 2011. Paula Guy, CEO of the non-profit Georgia Partnership for TeleHealth, which runs and maintains the telehealth system for rural Georgians, expects that number to exceed 100,000 by 2013. The sizable increase could be attributed to rising health fees for in-person visits.

Thomas Nesbitt, University of California Davis’ associate vice chancellor for strategic technologies and alliances, mentions that the first videoconferencing tool his school purchased in 1996 cost $100,000, while modern comparable devices might cost as little as $5,000 (in 2012). In 2015, most laptops are equipped with a respectable video chatting camera; high performance smart phones often come with two cameras.

A simple Google search can render pages full of seemingly sensationalist stories detailing how Skype and other related video conferencing software have saved individuals’ lives. Still, early stroke victims do, for example, clearly stand to benefit greatly from teleconferencing tools, which put patients in front of highly specialized professionals.

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99 Flinn, R. (2012, August 23)
physicians and nurses from afar before real damage takes place. This is especially true in the rural environment where hospitals or clinics are unlikely to be specialized or outfitted with critical technologies.\textsuperscript{100}

In the event of an absence of KP access for some, there are similar technology providers also filling the void. HealthTap operates much like KP’s My Health Manager interface, except that anyone can join as a patient or a doctor. Right now they have roughly 68,000 professionals.\textsuperscript{101} By signing up on either a PC-based portal or via smartphone application, doctors are able to generate extra income and also work remotely, enabling less time spent in the office while still maintaining consultations. A few extra features beyond KP’s product make this appealing; namely, in platform video teleconferencing and wellness advice. Plus, it is also possible to sign up for a strictly free account where one can anonymously consult with doctors via email-like messages.

Although there are a variety of ways a physician can perform routine check-ups on a patient, some holes still do exist. One company, Theranos, is aiming to make noteworthy strides in the telehealth environment by offering remote lab testing.\textsuperscript{102}

Users arrange all details electronically, including patient data and test selections. The equipment is then shipped to the recipient to extract a needle-free, micro sample of blood to be returned for analysis. The results are then posted on a secure website as soon as available. Theranos is betting on the convenience of flexible lab testing that works around the patient’s schedule, not the labs. Currently hundreds of tests are available from calcium content to cancer antigens.

For some, telehealth also represents the opportunity to avoid entering nursing homes—which would also require additional staff for monitoring—and continue to live independently at home. The U.S. Department of Veteran Affairs’ Telehealth Services’ program offers eligible seniors an essentially parallel environment of care and security thanks to accessibility of medical tracking tools connected to VA hospitals.\textsuperscript{103} In study measuring efficiency for the VA program, researchers found patients that utilized telehealth devices while undergoing chemotherapy treatment held a wide advantage over the non-using control group. Overall, telehealth patients visited clinics 97% less,

\textsuperscript{100} Demaerschalk, B., Miley, M., Kiernan, T., Bobrow, B., Corday, D., Wellik, K., Richemont, P. (2009)
\textsuperscript{101} Anonymous X. (2015)
\textsuperscript{102} Anonymous Y. (2015)
\textsuperscript{103} Anonymous Z. (2014, January 16)
including preventable visits after chemotherapy treatment. Since physicians or other healthcare professionals were able to see health status decline before clinic or hospital environment care was required, many drastic issues were prevented, leading to less unnecessary and costly visits.

Researchers have also found another useful component of telehealth: potential for community development. Far out in tiny rural villages, many cancer patients may find no equal with whom they can discuss the various details of their disease. This lack of support may lessen the benefits of treatment and also lead to depression or posttraumatic stress disorder (PTSD).

By creating virtual networks where individuals can share their experiences and learn from others dealing with synonymous symptoms and pain, quality of life can dramatically increase. Patients’ comprehensive understanding of what is being faced can be both culturally sensitive in rural communities and difficult to explain for external medical professionals, but with the help of like-minded individuals—despite being separated by great distances—fellow cancer survivors can more appropriately prepare for next steps.

Telehealth has addressed a multitude of difficulties faced by some users who are typically unable to access standard forms of care or others simply looking for convenient methodologies to inject a greater level of health coverage in day-to-day life.

For many individuals, fixed location monitoring and interaction is a perfectly acceptable scenario, but for other highly mobile users, being regularly fixed to some location is often not acceptable, perhaps even impossible. Yet, as personal computers both shrink in size and grow in potency, the future of the hospital does not necessarily need to be in the living room—it could be anywhere.

In a lot of ways, the personal hospital has already arrived.

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5.2 mHealth: Wearables and Remote Monitoring

My spidey-sense is tingling.

—Spider Man

When Apple introduced their take on the smartwatch early last Fall, to which their CEO, Tim Cook, billed as “...the most personal device yet,” mainstream consumers were effectively introduced to the novelty and future medical value of mobile health, or mHealth.107

The World Health Organization (WHO) defines mHealth as “...medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices.”108

Today, most people can identify mHealth in a huge variety of applications and environments. From non-intrusive items like a wearable to monitor breathing patterns, which reminds you how to properly inhale and exhale,109 to incredibly tiny sensors—smaller than a penny—that can be implemented in the body to measure vital activity, options are essentially endless and waxing toward infinity.110 One creative retailer has put an outline of a human body on their homepage and allows you to click on different regions to learn more about (and purchase) wearables for those specific areas.112

The idea of a wearable is, in fact, about as old as the first wristwatch. Yet these days, wearables combine movement and technology that permit immersive new opportunities.

Pew Research Center identifies three main actions that have influenced the current technological state of development: broadband Internet, mobile devices, and social networks.113 The fact that this quintessential triumvirate of today has only just ascended to prevalence

109 Duffy, J. (2014, June 17)
110 Keller, M. (2014, September 11)
111 Frost, M., & Meyerhoff, M. (2002, October 1)
112 Anonymous AA. (2015)
113 Anonymous BB. (2015)
quite rapidly should provide users an even greater sense of wonder for the future. As visualized in Figure 5.2.1., while cellphone ownership percentage of Americans in 2014 was 90% (83% in April 2011), smartphone usage already represented 64% (35% in April 2011). Gartner reports approximately 1.2 billion smartphones were sold in 2014 alone.\textsuperscript{114}

Broadband and social networks are also key, without them, there would be no manner to rapidly transmit large packages of information and no one with whom to share data.

Pollack and Peintner describe the current wave of computing as the third, or “automatic” stage.\textsuperscript{115} In this stage computers are meant to enable users to enhance their abilities all while becoming uninhibiting. Whereas previously, a user would have to give attention to the computer in order to guide its function, devices today are meant to perform tasks autonomously. This allows the user to perform their desired task, while using a computer that is out of conscious focus.

Yet, despite such early days of creation, wearables seem to be already becoming key aspects of many people’s lives. “People are no longer content hopping on a scale in

\textsuperscript{114} Goasduff, L., & Rivera, J. (2015, March 3)

\textsuperscript{115} Bardram, J., & Mihailidis, A. (2007)
an effort to shed a few pounds. We’re measuring calories, individual steps, and blood glucose levels, and those who get obsessed with tracking start wrestling with bigger questions: How well do I know myself? Who do I want to be?” writes Sean Brennan for an op-ed Wired piece.\textsuperscript{116}

Brennan goes on to note that while, for now, technologies seem to be constantly growing in complexity, eventually the goal of all this learning about the self should lend a steady hand in actually knowing what is thyself. The patterns that people learn about the body, with the initial help of sensors, will eventually allow for an intuitive knowledge of what is happening, in spite of the absence of the seemingly complex sensors that exist today.

To that end, the wristwatch might have been an incredibly forward thinking tool some 500 years ago, but humans have at no time in history been more poised to adopt the benefits of mHealth with arms wide open.

5.3 Wearables’ Implications On Oncological Healthcare

Imagine a future where you can know yourself best.

——Scanadu Scout device slogan\textsuperscript{117}

“The vast majority (84%) of Americans over 65 live independently in single-family homes or apartments,” begin Mihailidis and Bardram in their \textit{Pervasive Computing in Healthcare} text.\textsuperscript{118} They go on to mention that these 65+ year-olds spend most of their time at home where they usually discover and battle illness. Couple this information with the fact that this age group also represents the second largest population for incidence of cancer in the U.S. and clarity surfaces on the necessity to improve continuous tracking.\textsuperscript{119}

To date, there have not been a great number of strides made by wearables to allay or outright treat cancer, but there are some important early developments.

\begin{flushleft}
\textsuperscript{116} Brennan, S. (2015, March 1) \\
\textsuperscript{117} Anonymous CC. (2015) \\
\textsuperscript{118} Bardram, J., & Mihailidis, A. (2007) \\
\textsuperscript{119} Anonymous DD. (2014)
\end{flushleft}
Google, naturally, is one of the early players with a wearable-nanoparticles combination that works to identify cancer before it begins to cause harm. “The idea is that this pill will contain magnetic nanoparticles that can latch onto certain cancer-related molecules in the bloodstream—and that a wearable device could then use magnetic properties to recognize when this happens,” writes Wired correspondent Cade Metz, while performing an interview with Stanford University and Google’s Sam Gambhir.\textsuperscript{120} The method is intended to occur in a non-disturbing manner so that those individuals at risk can be monitored without causing unnecessary stress or dramatically altering their lives.

Another company, Cyrcadia Health (formerly First Warning Systems), has designed and produced an early detection sport bra to identify breast cancer with promising results while undergoing testing at Ohio State University and El Camino Hospital (CA).\textsuperscript{121} With Flextronics to produce the sensors that are woven into the material, Cyrcadia used its technical knowledge to create the algorithm that powers the iTbra, as it is called. By measuring temperature levels in the breasts, changes can possibly point to tumor growth, in which case, the user is warned and a doctor visit scheduled. In one study at Ohio State University, the iTbra performed 70% or better when detecting breast cancer later corroborated by a mammogram.

For those patients suffering from tumors associated with brain cancer, Novocure has developed a wearable device that is now approved by the FDA as a treatment alternative to chemotherapy and/or radiation.\textsuperscript{122} Optune, as it is known commercially, is comprised of four electrodes that are worn on the head and which generate “‘wave-like’ electric fields called Tumor Treating Fields (TTFields).\textsuperscript{123} The system is specifically aimed to treat glioblastoma multiform (GBM), or the most common type of brain cancer in adults.

Boston University researcher Darren Roblyer, has designed an early stage imaging pad that is worn directly above a tumor to monitor the effects of chemotherapy treatments on tumor size. Roblyer is utilizing diffuse optical spectroscopy (DOS) to quickly “…detect rapid changes in tumor blood supply and oxygen content in breast

\textsuperscript{120} Metz, C. (2014, November 5)\textsuperscript{121} Anonymous EE. (2014)\textsuperscript{122} Walker, E. (2011, April 15)\textsuperscript{123} Anonymous FF. (2014)
tumors using patient-safe, infrared light.”

He has received a four-year grant (beginning in 2014) from the American Cancer Society to continue to develop his work.

One application and wearable designed to coerce users to drop bad habits is called Pavlok. The system works by giving the user a minor electric shock (administered by wearing a special wristband) each time they are about to partake in an action they wish to quit. Using the device in conjunction with quitting smoking, for example, is a meaningful way to reduce a few different types of cancer and avoid potential future issues and costs.

Besides these examples, there are many non-cancer-specific wearables being developed that are increasingly powerful. Ignoring the typical examples, such as distance trackers for running, many companies have so far sought to tackle the general health market space by releasing products that may be appropriate for a variety of ailments. Their developments will perhaps one day enable greater coverage for oncology patients.

GenieMD is one of these applications that, when coupled with appropriate sensors, can be a powerful aid to monitor risks for illness and disease. If the premium license is purchased, a user can upload their personal health record to the software where it will be analyzed in combination with the sensory inputs to define the quality of health. What sets this particular offering apart from the rest is its affiliation with IBM’s Watson supercomputer. Of course, the smartphones of today do not possess the technical power of Watson, so it is unclear if the application takes advantage of similar algorithms or operates through a data cloud’s computing potential.

Another notable example is PhysIQ. This application, with wearable sensors, intends to provide users with a basic health score (called a wellness index) that is personal and based only on individual data inputs. After spending a short time analyzing personal data like heart rate, blood pressure, respiration rate, and other information, the application creates a dynamic wellness score that when connected to the contact information of a treating physician, can warn them of possible upcoming issues like a heart attack or stroke before they occur.

124 Dwortzan, M. (2014)
125 Anonymous GG. (2015)
126 Anonymous HH. (2014, October 7)
The founder, Gary Conkright, previously created a similar company called SmartSignal that was later sold to General Electric (GE) to monitor airplane engines and warn of impending part or systems failure. A similar application called mMR Predictive Analysis, which aims to notify individuals or healthcare professionals before disaster strikes is also available from KloudData.

Perhaps the most exciting of these developments are the crowdsourcing opportunities for data analysis. Apple (HealthKit), Samsung (Sami), and Google (Google Fit) have all released their own platforms to collect sensor-to-smartphone sourced data where users can choose to silo or anonymously release their information into a giant pool of other consenting users. These health data collection applications are/will be included in the mobile software for each company to allow users a straightforward approach for sharing their records.

One particularly interesting partnership has occurred between Apple and IBM, which will inject Apple users’ data into the IBM ecosystem where it will be analyzed in the cloud by Watson. Bloomberg reports that Apple has also linked with Cedars-Sinai Medical Center in Los Angeles to provide HealthKit with an additional 80,000 unique patient entries. A similar application, called ResearchKit, empowers researchers to create their own studies in which Apple users can participate, all completed right from their smartphone.

A previously mentioned company, Flatiron, also has unveiled their own cloud-based analytical tool that is specifically aimed at cancer research data compilation. They believe that “...oncology needs its own "big data" software approach.”

Telehealth is indeed still in early days. The Center For Connected Health Policy writes that “the “tele-" descriptor should ultimately fade from use as these technologies seamlessly integrate into health care delivery systems.” In other words, it someday might be compared to the now archaic usage of mobile and phone—as in, mobile phone—whereas today it is simply an indistinctive phone. As technologies ease into the population, their denotation relaxes to expose mainstream adoption. Indeed, this

127 Anonymous II. (2014)
128 Anonymous JJ. (2014)
129 restricted, hidden, or individualized data repositories
130 Olson, P. (2014, June 19)
131 Douglass, C. (2015, April 13)
132 Higgins, T. (2015, April 26)
133 Anonymous V. (2012)
134 Anonymous KK. (n.d.)
widespread adoption is critical with the consideration that some people have yet to fully engage with the Internet and related technologies.

Finding users on the road or at home may be one of few places where vital signs and other notations can still not be continuously monitored, while the user goes about their daily life. If these devices are to be effective, simplicity, unobtrusiveness, and general likeability are all key factors representing success.
Chapter Six: A Conclusion

We aren’t yet ready to put cancer on the extinction list along with “simpler” diseases like smallpox and polio…

—Craig B. Thompson, CEO of Memorial Sloan Kettering Cancer Center

By now, the text has covered the basic framework needed to arrange and support the digital hospital of the future. By first implementing an internal data collection system, then supporting it with effective data analysis, and finally, mixing in external data collection, a true picture of the health of a population and the individual may come to light. It is not to say that healthcare today does not yet improve lives, but often solely saves them. Instead, the idea, new today, retro tomorrow should here pointedly apply. Of course, the additional onus of improving life is often on the patient as much as the physician.

Despite the hopefulness and optimism often evident in this text, it should come with a fair warning that effectiveness (or: ineffectiveness) is far from fully known. It is entirely possible that the technologies just discussed could be half-step progressions that might be inane or even wasteful to implement. In other words, before some technologies are developed to their full capacity, early adoption may lead to disappointment, which may inspire lethargy for further related acceptance.

It is also absolutely vital to note that this paper is not designed as a comprehensive guide to understanding. As mentioned, it is instead aimed to broadly introduce the topic in order to inspire further study. Compared to the PCIH text, for example, the scope of this work is quite secondary. Everyday new information and new materials are released, frankly necessitating a full time team’s review efforts in order to stay completely up to date.

As data under this system is expected to move about extraordinarily freely, it is simply unconstructive to write about big data without discussing privacy. In an era of growing government surveillance capability and regular reports of health data breaches, patients may have legitimate concerns. To date, industry-standard security protocols are still not completely effective at keeping data safe, as witnessed in the recent

\[135\] Thompson, C. (2015, April 26)
\[136\] Weil, A. (2014, July 1)
Anthem Health Insurance attack.\textsuperscript{137} This notion of certainty of security will hamper development until either significant provable security metrics become available or data simply becomes available in the public domain—where anyone can search anyone.

Especially regarding the mHealth and wearables section, much of the future development should come from the general public’s desire for rapid consumption—an interest in new, but unproven devices—and the progress of the Internet of Things (IoT) and Internet of Everything (IoE). To further complicate matters, the next generation of wireless data transfers—theoretically called 5G—will be necessary for large data transfers, but perhaps widespread and free WiFi networks can sidestep this infrastructural development necessity.

At the beginning of this text, David Agus was quoted pondering why researchers have failed to make considerable gains in limiting cancer in the last half century. Although Agus must be optimistic for the future, as surely he is already aware of the possibilities for improvement in what is defined in this paper, and perhaps well beyond it, he must continue to fight. Any society would do well to always maintain an outspoken group who sees a problem of today and the solution of tomorrow, and thus clamors for it.

To conclude: whereas yesterday cancer existed in a treatment paradigm that was largely focused on extermination of the disease in the most direct manner (e.g. chemotherapy or radiation therapy), assuredly, the most brilliant minds are endlessly toiling to not only stunt the strength of cancer, but to improve the paradigms of care. So that treatment is a little less staving off the inevitable and a little more continuously working towards healthier, more productive lives.

\textsuperscript{137} Brandeisky, K. (2015, February 5)
Works Cited


38. Anonymous HH. (2014, October 7). IBM and GenieMD Tap the Power of


## Table A.1 – Summary overview of Meaningful Use Objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record patient demographics (sex, race, ethnicity, date of birth,</td>
<td>Over 50% of patients' demographic data recorded as structured data</td>
</tr>
<tr>
<td>preferred language, and in the case of hospitals, date and preliminary</td>
<td></td>
</tr>
<tr>
<td>cause in the event of death)</td>
<td></td>
</tr>
<tr>
<td>Record vital signs and chart changes (height, weight, blood pressure,</td>
<td>Over 50% of patients 2 years of age or older have height, weight, and blood pressure recorded as structured data</td>
</tr>
<tr>
<td>body-mass index, growth charts for children)</td>
<td></td>
</tr>
<tr>
<td>Maintain up-to-date problem list of current and active diagnoses</td>
<td>Over 80% of patients have at least one entry recorded as structured data</td>
</tr>
<tr>
<td>Maintain active medication list</td>
<td>Over 80% of patients have at least one entry recorded as structured data</td>
</tr>
<tr>
<td>Maintain active medication allergy list</td>
<td>Over 80% of patients have at least one entry recorded as structured data</td>
</tr>
<tr>
<td>Record smoking status for patients 13 years of age or older</td>
<td>Over 50% of patients 13 years of age or older have smoking status recorded as structured data</td>
</tr>
<tr>
<td>For individual professionals, provide patients with clinical summaries</td>
<td>Clinical summaries provided to patients for over 50% of all office visits within 3 business days; over 50% of all patients who are</td>
</tr>
<tr>
<td>for each office visit; for hospitals, provide an electronic copy of</td>
<td>discharged from the inpatient department or emergency department of an eligible hospital or critical access hospital and who request</td>
</tr>
<tr>
<td>hospital discharge instructions on request</td>
<td>an electronic copy of their discharge instructions are provided with it</td>
</tr>
<tr>
<td>On request, provide patients with an electronic copy of their health</td>
<td>Over 50% of requesting patients receive electronic copy within 3 business days</td>
</tr>
<tr>
<td>information (including diagnostic-test results, problem list, medication</td>
<td></td>
</tr>
<tr>
<td>lists, medication allergies, and for hospitals, discharge summary</td>
<td></td>
</tr>
<tr>
<td>procedures)</td>
<td></td>
</tr>
<tr>
<td>Generate and transmit permissible prescriptions electronically (does not</td>
<td>Over 40% are transmitted electronically using certified EHR technology</td>
</tr>
<tr>
<td>apply to hospitals)</td>
<td></td>
</tr>
<tr>
<td>Computer provider order entry (CPOE) for medication orders</td>
<td>Over 30% of patients with at least one medication in their medication list have at least one medication ordered through CPOE</td>
</tr>
<tr>
<td>Implement drug–drug and drug–allergy interaction checks</td>
<td>Functionality is enabled for these checks for the entire reporting period</td>
</tr>
<tr>
<td>Implement capability to electronically exchange key clinical information</td>
<td>Perform at least one test of EHR’s capacity to electronically exchange information</td>
</tr>
<tr>
<td>among providers and patient authorized entities</td>
<td></td>
</tr>
<tr>
<td>Implement one clinical decision support rule and ability to track</td>
<td>One clinical decision support rule implemented</td>
</tr>
<tr>
<td>compliance with the rule</td>
<td></td>
</tr>
<tr>
<td>Implement systems to protect privacy and security of patient data in the</td>
<td>Conduct or review a security risk analysis, implement security updates as necessary, and correct identified security deficiencies</td>
</tr>
<tr>
<td>EHR</td>
<td></td>
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<tr>
<td>Report clinical quality measures to CMS or states</td>
<td>For 2011, provide aggregate numerator and denominator through attestation; for 2012, electronically submit measures</td>
</tr>
<tr>
<td>Objective</td>
<td>Measure</td>
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<tr>
<td>Implement drug formulary checks</td>
<td>Drug formulary check system is implemented and has access to at least one internal or external drug formulary for the entire reporting period</td>
</tr>
<tr>
<td>Incorporate clinical laboratory test results into EHRs as structured data</td>
<td>Over 40% of clinical laboratory test results whose results are in positive/negative or numerical format are incorporated into EHRs as structured data</td>
</tr>
<tr>
<td>Generate lists of patients by specific conditions to use for quality improvement, reduction of disparities, research, or outreach</td>
<td>Generate at least one listing of patients with a specific condition</td>
</tr>
<tr>
<td>Use EHR technology to identify patient specific education resources and provide those to the patient as appropriate</td>
<td>Over 10% of patients are provided patient specific education resources</td>
</tr>
<tr>
<td>Perform medication reconciliation between care settings</td>
<td>Medication reconciliation is performed for over 50% of transitions of care</td>
</tr>
<tr>
<td>Provide summary of care record for patients referred or transferred to another provider or setting</td>
<td>Summary of care record is provided for over 30% of patient transitions or referrals</td>
</tr>
<tr>
<td>Submit electronic immunization data to immunization registries or immunization information systems</td>
<td>Perform at least one test of data submission and follow up submission (where registries can accept electronic submissions)</td>
</tr>
<tr>
<td>Submit electronic syndromic surveillance data to public health agencies</td>
<td>Perform at least one test of data submission and follow up submission (where public health agencies can accept electronic data)</td>
</tr>
</tbody>
</table>

**Additional choices for hospitals and critical access hospitals**

<table>
<thead>
<tr>
<th>Measure</th>
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<tbody>
<tr>
<td>Record advance directives for patients 65 years of age or older</td>
</tr>
<tr>
<td>Submit electronic data on reportable laboratory results to public health agencies</td>
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</tbody>
</table>

**Additional choices for eligible professionals**

<table>
<thead>
<tr>
<th>Measure</th>
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<tbody>
<tr>
<td>Send reminders to patients (per patient preference) for preventive and follow-up care</td>
</tr>
<tr>
<td>Provide patients with timely electronic access to their health information (including laboratory results, problem list, medication lists, medication allergies)</td>
</tr>
</tbody>
</table>
The underlying theme in this text is an investigation into how modern developments in information and communications technology can be safely, strategically and progressively implemented into the healthcare structure at large. Beyond that there is a lingering question as to why oncological care continues to lack the improvements (in terms of reducing death totals) seen in other forms of disease.

The backbone of the analysis was constructed with the text assistance of Mihailidis and Bardram’s *Pervasive Computing in Healthcare*. PCIH definitively examines various IT technologies and their probable corresponding functions in healthcare. Notably, this thesis work is not nearly as complex as PCIH, but instead covers a three-tiered structure in the technological paradigm of yesterday (already implemented), today (partially, or entering implementation), and tomorrow (expected to be implemented).

Using this structure as a rough schematic for a comprehensively digital clinical environment, particular concepts are identified and analyzed in this specific order: Health IT, data analysis, and telehealth (including wearables). This series was crafted by necessity of a logical buildup: first internal data will be collected, next data will be heavily analyzed, and finally, external data collection will be added to analysis. If external data is added before analytical tools can safely and appropriately handle internal flows, scaling may not be manageable and data will drift towards worthlessness.

The first chapter covers internal data collection tools, including computerized physician order entry (CPOE), electronic health record (EHR), and more. The second chapter offers an entry-level approach to data standards and trends and examines concepts like Big Data analysis and how it can benefit healthcare. The final chapter surveys external data collection methods and treatment outside of the typical clinical environment in telehealth and wearables.

Naturally, much of the text relies on the exploration of nearly effective medical tools that still reside in a largely novelty-esque sphere, until massive study and further development can render them highly efficient and useful.

Concepts for future consideration and organic shortcomings of this text are highly rooted in the fact that this paper is simply not all encompassing. Healthcare is an incredibly complex institution and change is not to be taken lightly. After all, new
technologies can sometimes lead to unexpected scenarios that may cause unfortunate consequences. Therefore, to properly understand how the new and rapidly advancing tools can best fit into this system, it is first necessary for papers like this one to be released in order to initiate interest, then extremely specified investigations will follow to carefully make recommendations and suggestions based on safety and efficiency.

This paper is designed to inform those less industrially knowledgeable individuals and to inspire optimism for new, promising ideas, which with many more hours of research and development, could perhaps save at least one more life today than yesterday, all while improving quality of life and convenience.