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DEPARTMENT OF SUPPLY CHAIN AND INFORMATION SYSTEMS

TECHNOLOGY GAP IN HEALTHCARE'S VALUE BASED PAYMENT MODEL

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ABSTRACT

The misalignment between cost and quality of healthcare in the United States has prompted the players in the industry to reevaluate dated systems and begin to innovate. A common approach to change is the shift in payment models from Fee-For-Service (FFS) to an alternative design; this thesis will focus on the alternative payment model of Value Based Care (VBC). VBC aims to restructure payment by linking payment to quality of care rather than volume; aiming to encourage an improvement in health, care, and costs. However, given the complexity of requirements to execute VBC, significant technology implementation will need to occur. While the required technology exists in other industries, it is not yet integrated in the lagging healthcare industry. Obtaining the proper resources for achieving VBC will have significant investment costs, amplifying the need to correctly identify the proper technology. This thesis will address how investments in blockchain will eliminate the technology gap in VBC.

To arrive at blockchain as the solution, the background of payment model shifts will be analyzed through various healthcare player perspectives. The design of VBC operation along with relevant policy and legal constraints will create evaluation criteria to determine the technology needed in effectively executing a VBC payment model. With proper investment and design, the implementation of a VBC model will drive value and innovation in healthcare.

The data driven VBC model will require data management systems focused on scalability, interoperability, ease of use, security. The system will need to perform the key functions of information aggregation, analytics, and reporting for both health and financial data. VBC will require digital platforms to be ubiquitous across the care continuum.

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Chapter 1

Introduction

In 2016 the United States' healthcare spending as a percentage of gross domestic product (GDP) was the highest of all thirty-five Organisation for Economic Co-operation and Development (OECD) countries, reaching eight percentage points more than the OECD average of 9.2 percent (OECD, 2017). The $9,892 per capita spending did not result in improved health outcomes as the U.S. life expectancy at birth reaches 78.8-years compared to an 82-year OECD average. As the gap between cost and quality of care remains significant, the United States has experienced both government and private attempts to revolutionize the healthcare system.

United States healthcare initiatives have gained intense political attraction within recent years, with the 2010 installment of the Patient Protection and Affordable Care Act (PPACA) and resurfacing with the attempted proposals of acts to repeal or change the PPACA. However, as these initiatives face political gridlock, changes are occurring outside of government control. Primarily, the healthcare system is transforming the current payment Fee-for-Service (FFS) payment model to several alternative payment models. This thesis focuses on the technology requirements of the value-based care (VBC) payment model and proposes blockchain technology as the primary solution to current technology gaps in the healthcare industry. The design of VBC operation along with relevant policy and legal constraints will be utilized to determine the technology needed to effectively execute a VBC payment model. With proper investment and design, the implementation of a VBC model will drive value and innovation in healthcare.

This thesis is organized as follows. Chapter 2 introduces the key differences between a FFS and VBC payment model in the U.S. healthcare system. Chapter 3 displays how FFS has contributed to the rising costs and stagnant quality of care and health indicators within the U.S. Chapter 4 discusses how the inefficiencies and failures within FFS have created the need and underway transition to VBC being the prominent payment model in the United States. Categories of FFS cost waste in Chapter 3 will be mapped to how VBC operates to solve current issues. The technical requirements of a successful VBC payment model will be formally explored in Chapter 5 to argue the inability of VBC operation of the current technology landscape in healthcare. Chapter 6 creates the case of blockchain being the optimal technology to properly execute VBC. Mainly, the interoperability, scalability, and policy compliance requirements will be analyzed. Finally, Chapter 7 offers a series of remarks about how these ideas about blockchain technology in relation to VBC can initiate a positive movement in the United States healthcare system.

Chapter 2

United States Healthcare Payment Model Shift

The importance of change within the healthcare system grows along with the increasing spending in this industry. Without reform, health spending is expected to reach twenty-five percent of the U.S. GDP as of 2037. Along with this rise, federal spending on healthcare will increase from twenty-five percent to forty percent of the total federal spending (Center for American Progress, 2012). However, cost reduction is restricted by the fear of reducing healthcare quality or access. The value provided by healthcare is often referred to as the *Iron Triangle*, with quality, access, and cost each representing a vertex of the triangle (Carroll, 2012). With the structure that an improvement in one vertex will detract from another, historically health reform focus has emphasized optimizing the balance between the three vertices. However, recent advances in thinking have attempted to restructure the healthcare system to not have these aspects be as interdependent as they have been in the past.

Fee-for-Service

The healthcare system has three major stakeholders; patient, provider, and payer. A patient can be defined as the individual receiving care; a provider as the health system providing the care; a payer as the intermediary of payment between the patient and provider. The interaction between these three stakeholders form the complexity of the United States' current healthcare system. Healthcare was built in the United States with the intention of providing accessible, quality, and cost-effective healthcare to Americans. As the percentage of Americans who desired healthcare grew, the management models became more complex and costly. While the main priority of healthcare is delivering health, this goal has been impeded by the administrative and financial constraints of delivering health on a national scale. Ultimately, the FFS payment model is used to combat those complexities and create a direct link between cost and service provided. FFS operates where a, “predetermined amount is paid for each discrete service provided. FFS payment puts the provider at risk for the number and cost of processes within each service, but there is no limit on the number of services, and providers get paid regardless of quality or outcomes” (Miller H. , 2009).

FFS has become the most popular payment model within the United States for logical reasoning. FFS allows parties to understand and more accurately predict costs, bill for all services provided, incentivize the care of ill patients, obtain low overhead cost, and promote ease of administration. Overall, FFS is a payment model built to balance the simplicity of its execution with fairness of payment and treatment. This payment model first began in the United States with the formal start of Blue Shields Plan (BSP) in 1930 as BSP began, “providing reimbursement for physician services” rather than paying a flat-fee for each person on their plan (Lichtenstein, 2012). This model is integral to the cost of healthcare and has faced criticism recently as it has been unchanged within nearly ninety years. Critics of FFS have deemed it to be a payment model which leads to, “overprovision, inefficiency and uncontrollable health expenditures” (Ikegami, 2015). However, as technology improves and administration capabilities are enhanced, healthcare has often been neglected to receive any industry innovation or disruption. FFS is behind the capabilities of modern day and leaves all parties questioning how such a flawed system can now be improved.

The total cost to treat a patient can be calculated from the number of conditions by number of episodes of care per condition by number of services per episode by number of processes per service by cost per process, FFS only considers the latter two. While a provider has influence across this entire cost spectrum, the provider's resulting pay is only influenced by the cost per discrete service they provide (Miller H. , 2009). This is illustrated below in Figure 1.

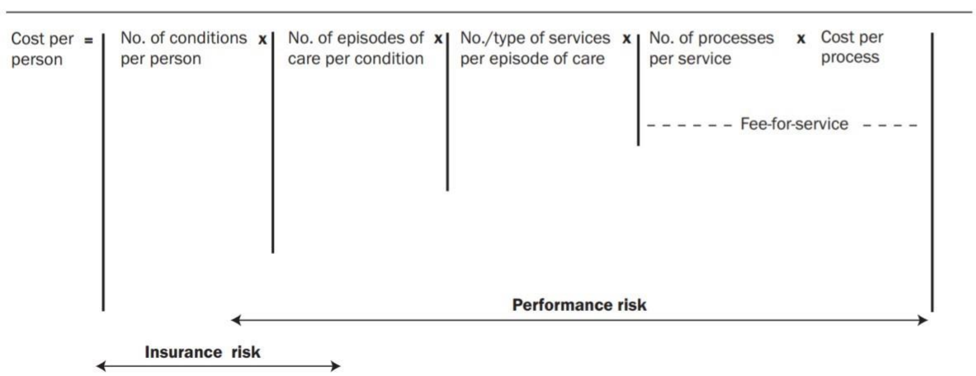

Figure 1. Risk Accountability in Payment Models

To further illustrate, take the example of a patient with heart disease who has just been emitted to the emergency room for a hip fracture. While at the hospital this patient is not only treated for his hip fracture, but also receives testing surrounding his heart disease although he just had a check-in with his cardiologist several days ago. The patient is discharged to a nursing home for further rehabilitation and must continue to travel to and from the nursing home and hospital for daily check- ups. Under the FFS model there is no incentive for coordination or care quality optimization. The providers in this example experience different payment incentives. A physician is paid per diagnostic testing, decreasing the coordination between cardiologist and emergency room physician. Each physician has been incentivized to conduct their own in-house diagnostic testing as they are directly paid per test performed. A patient is charged per night in inpatient stay, prompting a quick discharge and repeated transportation. . Under FFS there is, “no financial downside to…provide unnecessary care. And without coordination between each of the different providers, it is even more likely that the patient received duplicative services, all of which are paid for separately” (Calsyn & Lee, 2012). When operating independently, each stakeholder has a minimal effect on the cost and quality of care provided. However, the introduction of alternative payment models has prompted coordinated efforts between stakeholders.

Value-Based Care

FFS has created a zero-sum approach in health care competition. Providers and payers alike are competing for one-off financial gains, working to push cost to a different player and profit where they are able to. Healthcare competition does not effectively eliminate providers and payers who do not provide value for the patient. Rather, competition has promoted an environment where payers and providers who can shift costs succeed. Other industries, such as airlines, entertainment, or manufacturing, experience innovation and growth from competition, but healthcare competition has caused a reduction in access and quality of care. Healthcare has grown into a dysfunctional system whose issues have been exacerbated by its clear lagging in technological and strategic improvement. Modern medicine has made enormous strides since the inception of healthcare, but these changes have yet to be fully reflected in the United States system due to systematic error.

At the root of healthcare issues is the indicator of healthcare success. Optimistically, each player is working towards increasing the value per patient per dollar. However, under FFS providers and payers are working towards decreasing dollar per value per patient. Redefining healthcare success to be based on value delivered, rather than volume performed, will transform the entire healthcare system. The idea to shift from fee per service to value per patient has created an alternative payment revolution in healthcare. The focus of this thesis is on the value based care payment delivery model. Value based care aims to realign competition with "value for patients" rather than short term profits (Porter & Teisberg, Redefining Healthcare, 2006).

VBC holds many different titles such as pay for performance, value based payment, or value based contract, but will be referred to exclusively as value based care under the acronym VBC in this thesis. VBC is defined as, a "payment model that incentivizes providers for meeting performance goals for care quality and efficiency" (McKesson , 2016). Similar to FFS, VBC has many dynamic and interdependent parts which complicate its operations. These complications of dynamic parts are not mitigated by the broad definition of value, which must be assessed to appropriately create a VBC payment model. Value must be analyzed at an individual patient level. Based on the inherent characteristics of a patient, how healthy is a provider able to keep this individual compared to standard? This measure of health should be measured throughout a lifetime, rather than discrete points in treatment or check-ins.

To illustrate the idea of lifetime value, take the example of a patient with breast cancer. Value of care can be measured by dimensions of health throughout the time of a patient's lifespan. These dimensions, including survival, degree of recovery, time to recovery, disutility of care, sustainability of recovery, and long term consequences of care can be combined to create an overall metric of health. In Figure 2 below, these dimensions of lifetime value in a VBC model are shown in parallel with the example of a breast care patient. VBC works to benefit these dimensions through best measures, whereas FFS would encourage duplication and excess of care (Porter, What is Value In Health Care, 2010).

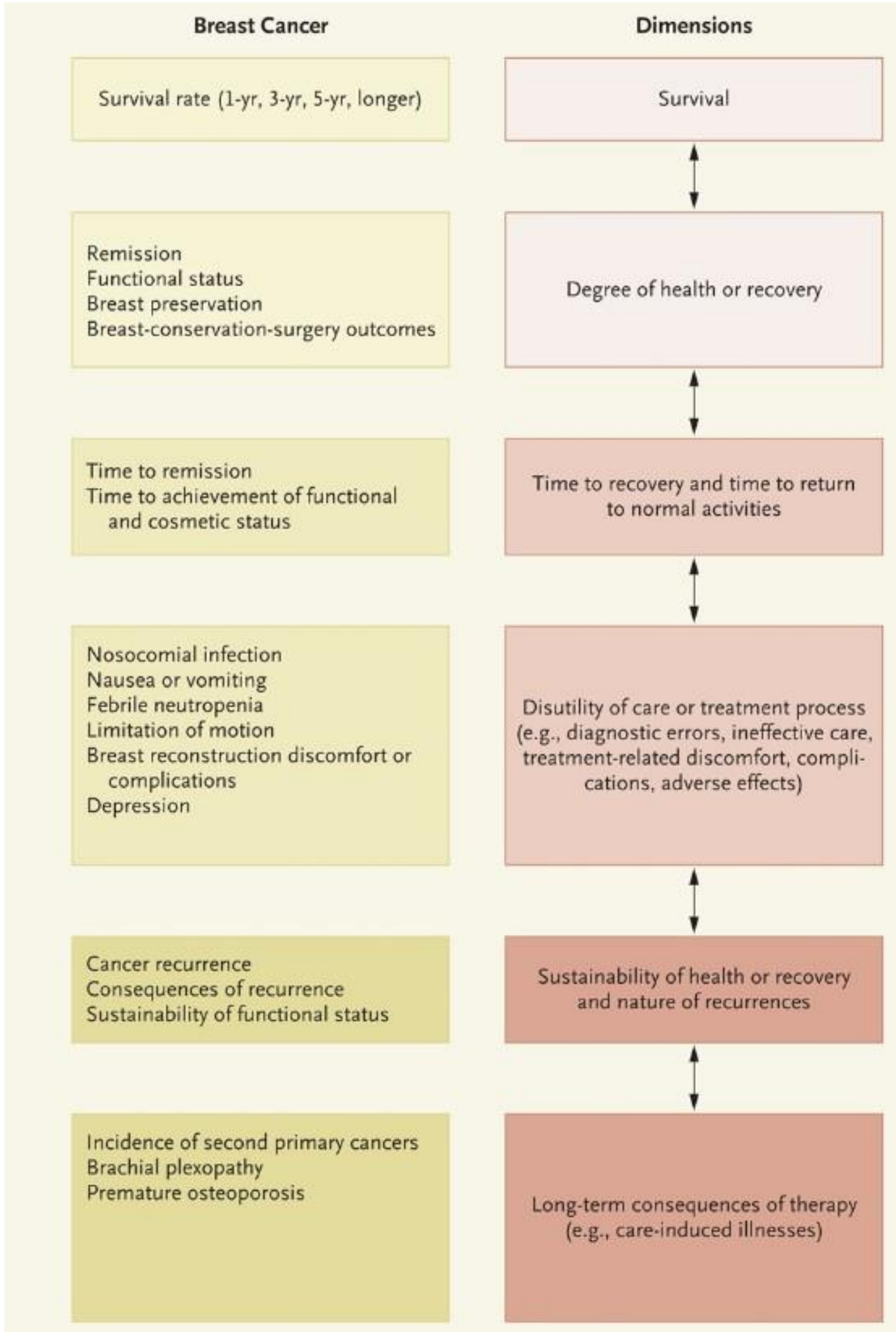

Figure 2. Dimensions of Quality in VBC

Traditionally, when a patient undergoes a lumpectomy or partial mastectomy, lab screenings are performed after the surgery to ensure 100 percent of the cancerous tissue has been removed. In a shift from reactionary to preventative care, the Mayo Clinic has begun performing Frozen Section Analysis (FSA) on breast tissue to test for complete eradication of cancerous tissue while the patient is still in surgery. Under FSA, results of cancerous tissue presence is obtained within twenty minutes and can then dictate the continuation or completion of the surgery. An additional twenty minutes in the operating room is costly for providers and causes the profitability of the initial surgery to decrease. However, the Mayo Clinic in Rochester, Minnesota performs lumpectomies with a 3.6 percent, thirty-day reoperation rate compared with the 13.2 percent national average (Theimer, 2014). This reduction in reoperation leads to overall less medical costs for the lifetime of the patient, although the initial surgery cost to the provider is greater.

The trend towards value based care is apparent in both payers and providers quickly progressing away from FFS and towards alternative payment methods. Although FFS is currently the dominant payment method, it is predicted for VBC to become the majority by 2020. A survey conducted by McKesson with support from ORC International in 2016, including the participation of 465 payers and providers, estimated the transition of payers and providers to VBC. (McKesson Health Solutions, 2016). This estimation is displayed in Table 1 below.

Arrangement Type	2016	2019	2022
Providers in a VBC arrangement	36%	47%	60%
Reimbursements tied to a VBC arrangement	32%	42%	54%
Membership tied to VBC arrangements	32%	42%	55%

Table 1. Estimation of Progression in Shift to VBC

Chapter 3

Relating Healthcare Waste to Fee-for-Service

On the precipice of the payment model revolution, the main categories of healthcare waste were analyzed to help create new models to improve on these inefficiencies. These categories, while highlighting the flaws with previous models, helped to create the organization and priorities of where the United States healthcare system should head. While there has always been competing alternative payment models to FFS, as technology, medicine, and culture has progressed, these alternative payment models have attempted to grow with the times. As healthcare moves forward, it is important to understand how FFS has failed the system and how these issues will be mitigated.

The prominent sections of healthcare waste fall in to the categories of care delivery failure, care coordination failure, overtreatment, administrative complexity, pricing failures, and fraud and abuse. In 2011 this waste for these main categories was estimated to be thirty-four percent of U.S. healthcare spending for a total of $910 billion (Berwick & Hackbarth, 2012).

Care Delivery Failure

A care delivery failure either is generally referred to as the ineffective or lacking implementation of best care practices. Care delivery errors are made when the issue could have been avoided through proper distribution of previously known information. For example, a patient may be prepped for a colonoscopy surgery before being confirmed to receive the operation by a specialist who then later cancels the surgery. Whereas, care delivery problems are made when a provider is unable to execute on planned care due to an unavailable resource, ranging from time and proximity to operation tools or supporting staff (Edmondson, 2004).

Care Coordination Failure

Care coordination failure is the lack of communication and planning between physicians to provide a patient with the optimal level of care. For example, a patient may see their primary care physician and be referred to a lab for imaging of tissue as well as a specialist for the injury. However, at the time of the specialist appointment, the lab images are not available and the specialist must conduct the same imaging in-house. The lack of communication between the primary care physician, image lab, and specialist caused the need for repeat procedures.

Overtreatment

Overtreatment is defined as, "the waste that comes from subjecting patients to care that, according to sound science and the patients' own preferences, cannot possibly help them—care rooted in outmoded habits, supply-driven behaviors, and ignoring science". An example of this can be the prescription of unneeded or unwanted drugs.

Pricing Failures:

Pricing failures of the U.S. healthcare system stem from the "absence of effective transparency and competitive markets." (Berwick & Hackbarth, 2012). The cost of MRI or screening procedures in the U.S. is more costly than that of identical procedures in other countries. With FFS, providers make money on individual procedures, thus driving the cost of common procedures.

Fraud and Abuse:

Fraud and abuse is not only the cost of scamming of a few within the healthcare system, but also the resulting cost it must take to effectively parole the legitimacy of a system which is susceptible to fraudulent activity. For example, a provider may submit fake claims to an insurer to gain profit. Due to this issue, now payers must employ departments to detect fraudulent claims.

Administrative Complexity

Healthcare, while an industry often restricted and guided by strict regulations, also faces an issue of immense complexity and differences between all providers, payers, patients, and involved government entities. This causes all players to focus on adhering to guidelines and corralling any discrepancies rather than allocating all focus and resources to delivering health. For example, when a provider is in the network of multiple payers, they must file forms in a way standardized for each payer rather than their needs, often duplicating or prolonging administrative work.

While not all six of these categories are direct results of continuing the FFS model, they are each important when developing a better payment model. For instance, both administrative complexity and fraud and abuse are not attributed to FFS. Specifically, administrative complexity has been a source of reason to stay with the FFS model. FFS has existed the longest of any payment model and is the most developed throughout the healthcare system. A one to one match of service and fee helps to alleviate the need for intense data aggregation and infrastructure. Care delivery, care coordination, and pricing failures and overtreatment have direct ties to FFS. Care duplication, cost inefficiencies, and unnecessary care are all prevalent due to the rewards they create in FFS model.

Chapter 4

The Call for Value-Based Care

By identifying the six prominent categories of waste within healthcare under a FFS model, the significant changes under a VBC model are also identified. VBC will address the categories of waste, as well as redefine the culture of healthcare. The future outlook of healthcare under VBC is summarized in Figure 3 below. (Grube, Kaufman, & Pizzo, 2012). The remainder of this chapter will depict how the identified major categories of waste will be affected by VBC.

Element of Change	Today →	Future
Care focus	Sick care	"Healthcare," wellness and prevention, disease management
Care management	Manage utilization and cost within a care setting	Manage ongoing health (and optimize care episodes)
Delivery models	Fragmented/silos	Care continuum and coordination (right care, right place, right time)
Care setting	In office/hospital	In home, virtual (e-visits, home monitoring, etc.)
Quality measures	Process-focused, individual	Outcomes-focused, population-based
Payment	Fee-for-service	Value-based (outcomes, utilization, total cost)
Financial incentives	Do more, make more	Perform better on measures, make more
Financial performance	Margin per service, procedure (bed, physician, etc.)	Margin per life

Figure 3. Dimensions of the VBC Transition

Care Delivery

Proper care delivery is achieved when best care practices are ubiquitously implemented. According to a 2012 Ponemon Institute survey, thirty percent of the world's data storage resides in the healthcare industry (Huesch & Mosher, 2017). With this decade's revelation in big data, much of this data is being underutilized in relation to current technology capabilities. Under VBC, this large magnitude of data would be shared across a network of care providers and payers to gain insight to the results of health outcomes. Kaiser Permanente, an integrated managed care consortium, consisting of Kaiser Foundation Health Plan, Kaiser Foundation Hospitals, and Permanente Medical Groups has implemented an in house data exchange system, HealthConnect, to promote data exchange across all facilities. This system has allowed physicians to better understand cardiovascular disease outcomes and achieve an, "estimated $1 billion in savings from reduced office visits and lab tests" (Kayyali, Knott, & Van Kuiken, 2013). This example illustrates the use of proper data sharing and analysis of 10.7 million Kaiser Permanente members when used internally (Kaiser Permanente, 2017). Value based care would incentivize payers and providers under separate mother companies to share in the benefits of improved care delivery.

Care Coordination

FFS incentivizes providers to perform and even duplicate high margin services, while shifting low margin services to other providers. Often care is a silo of each unique provider in the care delivery model, rather than a coordinated effort to provide the best care. . Despite an awareness of the benefits of integrating care providers, a 2016 study conducted by NEJM Catalyst Care Redesign, surveying 375 providers showed only seven percent of respondents declared themselves as fully coordinated, thirty percent as mostly coordinated, fifty-three percent as somewhat coordinated, and ten percent as not coordinated (Compton-Phillips & Mohta, 2016). VBC aids to blend the silo between providers and increase communication between the parties. VBC reimburses providers based on the lifetime value of health for a patient rather than discrete services provided. This continuous effort to achieve lifetime health must be delegated across various providers and, "because providers often share financial and clinical risk with health plans under VBC, it is essential that all parties also share information about patients' clinical conditions and the services patients receive" (Optum, 2013). Care coordination is best performed when necessary information is shared, accurate, and readily available.

For example, Figure 4, below, displays the preferred level of care coordination for the process of a patient going to an ER or similar establishment for care. Information is passed through multiple providers and will ultimately be available to the primary care physician of the patient. As providers become more financially concerned with the lifetime health of their patients, they will be incentivized to promptly share necessary information and coordinate care (Marzoug, 2017).

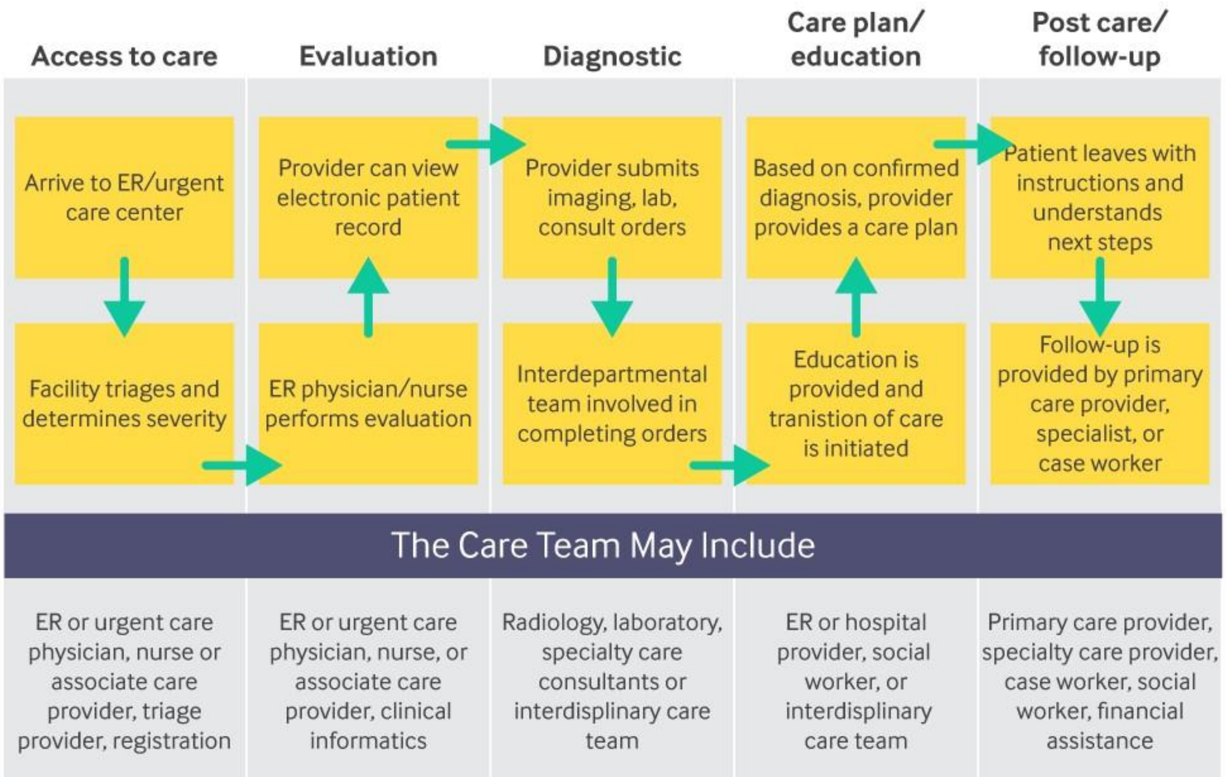

Figure 4. Care Coordination in VBC

Overtreatment

The cause of overtreatment differs with each case and patient, and although FFS creates an environment where overtreatment is rewarded, there can be a variety of reasons for this to occur. A 2016 study conducted by the National Institute of Health with 2,106 physician respondents, found the culmination of malpractice fears, patient demands, information access constraints, and communication barriers can cause a physician to over treat a patient. Figure 5, below, shows the physician's view of what percentage of treatment is in excess of needed quantity (Moise, et al., 2017).

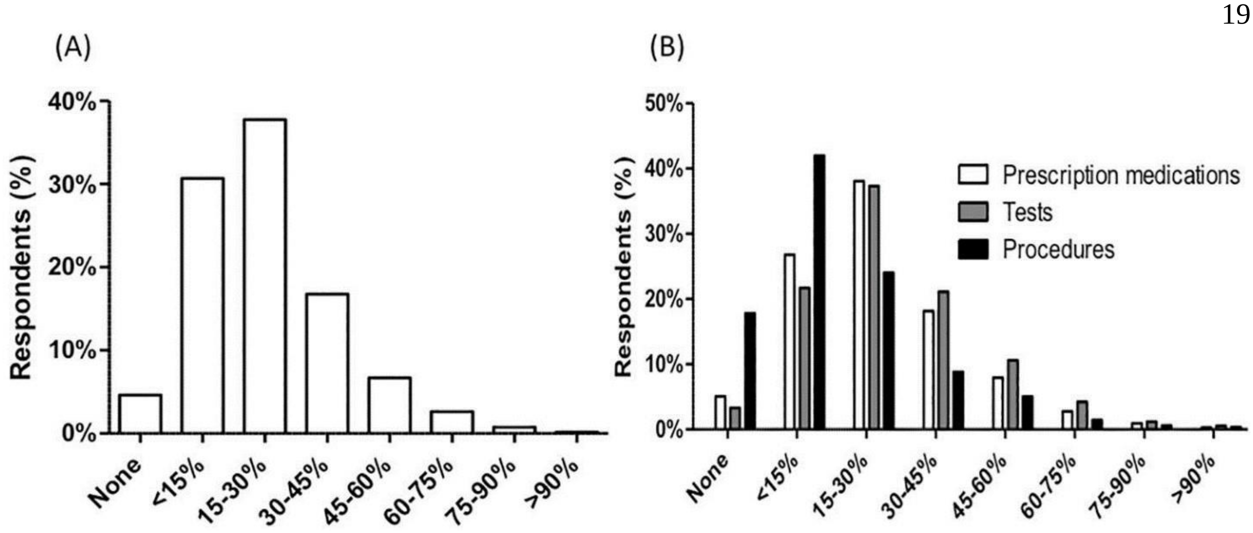

Figure 5. Physician's View on Overtreatment as Percent of Total Cost

Physicians, the individuals overprescribing and over-treating, have cited the need for a cultural shift in healthcare for overtreatment to be sufficiently reduced. FFS has left healthcare exchanges to feel transactional rather than as a unified effort towards health. With the specifics of VBC left largely undefined, VBC has the opportunity to be implemented in a way that reduces the pressures providers feel to give their patients volume of care, rather than value. VBC aims to combat overtreatment, not only by eliminating the financial incentive, but also by giving providers access to information necessary to make an informed treatment decision and by building a cultural environment that encourages high value health procedures over volume.

Pricing Failures

Pricing discrepancies in healthcare account for fifty to eighty percent of the annual rise in healthcare costs. (Braunstein, et al., 2015) This price is tied to the increasing cost to administer and provide healthcare, illustrated through the other cost inefficiencies, as well as the fundamental differences between health pricing compared to other consumer goods. Healthcare pricing inefficiencies have been led by “third-party payment for insured consumers and a fundamental imbalance in information, clinical knowledge and understanding between patients and clinicians" (Braunstein, et al., 2015). When an insured has fulfilled their contribution to their healthcare costs (their deductible), they no longer share in the risk of keeping their healthcare costs low. A consumer without price sensitivity allows the provider to drive costs. Lack of understanding of healthcare services and procedures paired with limited transparency to available prices also contributes to rising prices. Similar to overtreatment, VBC will combat pricing failures through both a technical and cultural shift. The promotion of information sharing will allow for transparency into prices for both physicians and patients. Culturally, the shift to compensation based on value, will allow for patients to trust in the decisions of their providers. Pricing will now be predetermined based on health status and physicians will receive payment upon maintenance of a specific health trajectory. The available information from VBC will allow payers a transparent look at pricing and the ability to compete on their offerings for combination of health and price provided.

Fraud and Abuse

As mentioned in Chapter 3, fraud and abuse within healthcare is not specifically attributed to the environment created by a FFS payment model. Due to the long standing presence of FFS, those committing fraud have developed methods to systematically abuse the healthcare system. Parties protecting against fraud have also had the same advantage in building a defense for a static payment system. Developing a new payment model would require new regulation, prevention techniques, and strategies to preventing fraud and abuse. Current national fraud and abuse laws, Stark, Anti-Kickback, and the Civil Monetary Penalty, were all built upon the FFS payment model structure. It was presumed to be suspicious if various providers had any shared financial incentive. These laws were created to keep hospitals and physicians in the silos that FFS placed them in (American Hospital Association, 2017). VBC will require its own set of laws and regulations surrounding potential fraud and abuse by all payers, providers, and patients. This transition to VBC should serve as an opportunity for infrastructure to help enable fraud protection rather than enable fraud itself.

Administrative Complexity

Administrative complexity does not serve as an immediate reason for transition from FFS to VBC, but rather has stunted the rate of transition. “Transitioning to a VBC approach involves added infrastructure, training, and complexity of delivering care” (Bailey, 2017). Changing from FFS to VBC requires an intense investment of both finances and human capital. Similar to other industries implementing new policies or procedures, this transition will at first disturb the healthcare environment before it is successfully integrated. Although most certain further administration complexity will be faced with VBC, supporters of the transition indicate greater payoff once start up difficulties fade.

In theory, VBC is able to deliver a higher quality and more accessible healthcare for lower cost, but as this transition becomes reality the industry must move away from the utopia view of a new payment model and recognize the requirements for implementation. If operating as imagined, VBC will deliver best practices of the proper amount of care to a patient across the continuum of their life. There must be defined metrics, linked to health outcomes, which can be tracked and utilized to determine reimbursement. Proper availability, analysis, and security of healthcare data must be achieved for VBC to become operational.

Chapter 5

The Healthcare Technology Gap

"The sheer volume of health care data is growing at an astronomical rate: 153 Exabyte (one exabyte = one billion gigabytes) were produced in 2013 and an estimated 2,314 Exabyte will be produced in 2020, translating to an overall rate of increase of at least 48 percent annually" (Stanford Medicine, 2017). With the increasing presence of technology throughout the United States, data creation and availability in all industries has grown rapidly in the 21st century. Great strides have been made to make this data easier to transform into information and insight. Specifically within healthcare, this has created optimism around major advancements of preventative care, and quality and cost of care. The steps of VBC for each disease/ailment are as follows (Shah, 2016).

1) Identify patient cohorts based on similar risks

Cohorts are sets of patients with the desired range of characteristics used to perform a retrospective analysis of a clinical hypothesis. Cohort formation can be based on all available information on the population of patients. What data should be used for cohort selection (Bucur, et al., 2016)?

2) Define outcome measures that are tied to health and meaning for patients

Based on the defined cohort and expected results of best known practices, what indicates a healthy outcome for a patient? This question can be analyzed through the information gained from an individual's medical history.

3) Define timeframe required to achieve optimal outcome

Based on the defined cohort and expected results of best known practices, what is the expected timeline for the proper health outcomes to follow? This question can be analyzed through the information gained from an individual's medical history.

4) Quantify baseline outcomes and costs for each patient cohort

Through reference of procedures and care used to treat individuals in this cohort, compared to available pricing information, what is the expected cost to deliver proper care?

5) Determine value proposition, prospective performance and cost objectives

Given the cost of proper care, how should the payer, provider, and patient share risk to ensure execution of optimized health delivery?

6) Continually refine and improve process with data

As more data is collected throughout a patient's lifetime and throughout the population, how can best practices be improved to reflect the discoveries of new information?

Data is the key to accomplishing these six steps. Collecting and analyzing this data cannot be performed manually and requires a technology based solution. The proper infrastructure will allow for the healthcare industry to have access to the right data to make informed decisions and drive value. Data will reduce the fragmentation caused by FFS and allow a provider to get the complete view of a patient. However, this immense amount of data must be handled appropriately to lead to insight. To make the case for a specific technology, the necessities for healthcare analytics will be mapped to technology capabilities.

VBC healthcare analytics primarily deal with population health to address the six steps above. To assess population health measures in VBC, large amounts of data are required. The volume of data is most typically associated with the term 'big data', however data can be deemed 'big' given an extreme volume (scale of data), variety (different types of data), velocity (analysis of streaming data), or veracity (uncertainty of data) (IBM, 2014). Aside from increase in patient and claims data, data surrounding healthcare research and medical literature increases by nine percent annually, doubling roughly every eight years (Geurriero, 2016). This amount of information is impossible for a physician to decipher and effectively act on. Not only is the volume of data large, but the sources of data are widely varied. Data can include, but is not limited to, machine to machine, web and social media, big transaction, biometric, and human-generated data (Raghupathi & Raghupathi, 2014). The velocity of data within healthcare has largely been increased by the use of wearables and personal health devices. The veracity of data is of prominent importance in the healthcare industry. Keeping accurate information on a patient's health or financial status is foundationally important to the patient's care experience.

Data within healthcare has been considered "big data" under a FFS structure, but FFS does not require aggregation, integration, or actionable insights of data in the same way as VBC. Technology infrastructure for the FFS model was designed to relay claim codes and financials between a payer and physician but was not built to create a holistic view of any individual patient. The 2010 Affordable Cart Act incentivized health systems to make the transition from paper to Electronic Health Records (EHR) and penalized those who did not. This mandate was effective, with 86.9 percent of health providers adopting EHR by 2015, an improvement from the

20.8 percent adoption rate in 2004. However, "in 2015 roughly only thirty percent of office-based physicians had electronically sent, received, integrated, or searched for patient health information from other providers" (Jamoom E, 2016). This low number compared to the adoption of EHR systems can be attributed to the lack of fundamental capabilities of functionality and interoperability within the EHRs. A 2015 study conducted by the Journal of the American Board of Family Medicine (JABFM) found EHRs allowed for proper data capture, but had difficulty tracking these records, coordinating between integrated teams, and exchanging information with other EHRs (Miliard, 2015). The data and analytics required of FFS are far behind that of VBC. The failure to use existing EHRs for care coordination and delivery demonstrates the existing technology gap between the healthcare industry's current technology landscape and the technology requirement of VBC. As populations increase and data grows, physicians, providers, and patients must work together to build an interoperable, scalable, and policy compliant technology infrastructure to facilitate VBC.

Chapter 6

The Case for Blockchain

In 2008 Satoshi Nakamoto, an anonymous person or group, published a paper titled Bitcoin: A Peer-to-Peer Electronic Cash System, to introduce blockchain, a transformative digital currency. Bitcoin, a blockchain application, would move digital payments from a trust based model to one validated by cryptographic proof (Nakamoto, 2008). Typically, financial transactions are made with the assistance of a trusted third party. However, as Nakamoto argues, the facilitation of a third party allows for disputes, security weaknesses, and higher transaction costs. The fundamental idea of Nakamoto's Bitcoin is to create a transaction to be validated by the public rather than by a subjectively trusted third party. Blockchain would soon find itself being used outside of Bitcoin or other cryptocurrencies and being the focus of technology experts across the world.

Blockchain began with financial purpose; originally intended to be used solely as a distributed transaction ledger. The strong and flexible foundation upon which blockchain has been built allows it to transform to meet the needs of various industries. A blockchain can simplistically be thought of as a chain of blocks, where each block will represent a transaction or piece of data and each chain represents the hashes linking the blocks together. Hashes are functions that map data to another piece of data. The blocks will be maintained on a distributed, decentralized database (Rai, 2017). Each block consists of the following components listed in Table 2 (GitHub, 2018).

Component	Purpose
Previous Block Hash	Identifies the chain the current block belongs to. Verifies the integrity of the chain of transactions
Index	Identifies the block's number
Data	The information being stored
Timestamp	When the block is created
Current Block Hash	Built off the previous block hash. Creates immutability; hash of block (n) will be changed based on hash of block (n-i)
Nonce	The number of transactions sent from a given address. Eliminates transactions from being skipped or double counted, as they must be processed in order of the nonce number.

Table 2. Components of a Block

A blockchain and its components can be visualized as below in Figure 6 (Hartikka, 2017).

Figure 6. Blockchain Visualized

Given the foundation of blockchain there are many possible applications of the technology. The remainder of this chapter will discuss the ability of blockchain to achieve interoperability, scalability, and policy compliance in a VBC healthcare setting.

Interoperability

"Interoperability of healthcare records is the extent to which the clinical intent can be conveyed across institutional boundaries". (Peterson, Deeduvanu, Kanjamala, & Boles, 2016). As discussed in Chapter 4, interoperability plays a crucial role in facilitating care coordination and execution of proper care delivery. Physicians must have necessary data easily accessible to both understand a patient's current status and dispense the most up to date best care procedures for the individual. For the necessary data to be available it must not only be shared between parties, but also understood by both parties.

The 21st century has been filled with effort to bring health records to the digital age, but legacy strategy and technology has hindered the healthcare industry from reaching its goal. Under the FFS model, healthcare payers and providers do not benefit from a collaborative model. Hesitant to share their data, companies participate in 'information blocking' to share some, but not all data with other players. Companies have done this for competitive strategy. While a new technology may not change this competitive reasoning, the reward structure of VBC will encourage healthcare companies to invest in a technology solution to help the flow of all data.

From a technology perspective, the current use of EHRs is inadequate to operate a VBC model. Although there has been an increased presence of EHRs, payers and providers have faced issues with data security, structure, and semantics. Current healthcare data is difficult to share with others due to the data's complex and heterogeneous nature. Because of the heterogeneity of current healthcare data standards, companies run into issues with communicating with other companies with differing data. With concern of data quality and consistency, blockchain provides an opportunity for healthcare companies to reset their data quality standards and create a new structure. The use of EHRs was the first trial of creating operating standards. Now with lessons learned from the failures of EHRs, blockchain has the opportunity to begin a new age of homogeneous data standards

Given the security measures caused by the importance of medical records and complexity of data stored, it is difficult to achieve needed levels of interoperability. Lack of security is a large issue preventing both payers and providers form utilizing the benefits of

EHRs. Health records are sensitive and personal information can be resold on the black market at a higher price than financial information (Humer & Finkle, 2014). Health records typically contain enough information to effectively steal a patient's identity. A study conducted by the Penenom Institute in 2016 found "The healthcare industry was the victim of eighty-eight percent of all ransomware attacks in the U.S. industries last year…and eighty-nine percent of studied healthcare organizations have experienced a data breach" (Mulero, 2017). To evade security concerns, health companies have avoided the use of EHRS, also avoiding the benefits. Blockchain is immutable and therefore less likely to be breached. Blocks are each unable to be changed or tampered with once created because of the previous hash stored in each current block. If a block in the chain is changed then all the following blocks must also be changed. Blockchain is a public ledger and blocks are verified through public consensus of cryptographic algorithms. A malicious change in a previous block can never be made because it would require the consensus of those on the network. The feature of immutability allows for confidence in data quality. Figure 7 below shows how a data breach will in turn effect the remaining length of the blockchain. (Nakamoto, 2008)

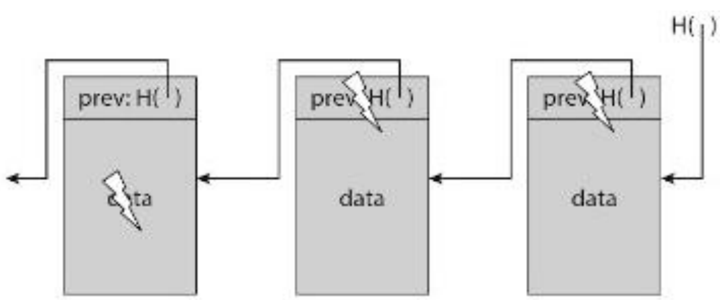

Figure 7. Blockchain Immutability

Although the benefits of blockchain are derived from its public consensus, availability to the public may also be seen as a negative for sensitive health data. However, above immutability, blockchain also provides anonymity of the data. Transactions and information are separated from the identities of those who own the chain. Figure 8 below, displays the reformed anonymity model under a blockchain technology (Miller, Narayanan, Felten, Bonneau, & Goldfeder, 2016).

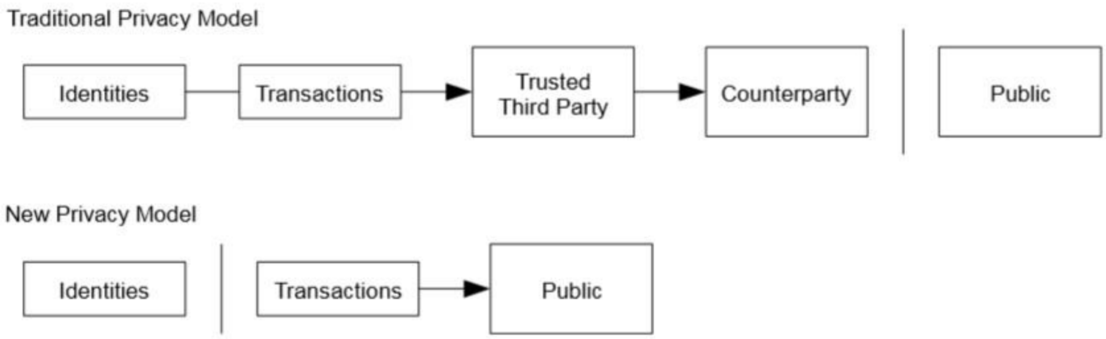

Figure 8. Blockchain Anonymity

This allows a patient to 'own' their data by being the only one to have an encrypted key to access the content and permissions of their chain. Although the blockchain is public, only the metadata is available to all parties, but this does not mean the data is readable to them. "Sensitive health information would be encrypted and stored in the blockchain and could only be decrypted by parties that have the patient's private key" (Ivan, 2016). By separating a patient's identity from their information, this devalues the black market opportunity of health information and allows for health data to be shared amongst the public for research, coordination, and care delivery. Blockchain technology, "would eliminate delays and impediments to health record access and use, as only the patient's authentication would be required for retrieval, rather than navigating the complexity of the existing bureaucracy" (Pauwels & Nathaniel, 2017).

Scalability

Scalability has historically been a concern of blockchain. To create immutability and public consensus, the blockchain must communicate with all computers on the network and use massive amounts of computing power to complete the verification algorithm. The Bitcoin network is capable of processing a maximum of seven transactions per second (TPS) — for the millions of users worldwide (Malanov, 2017). As more users join Bitcoin platforms such as CoinBase, this transaction rate slows as the verification algorithms become more complex. The interoperability of blockchain will allow for unprecedented amounts of data ownership, longitudinal health, and research, but how effective can this be if data is only communicated between small networks? Although one of blockchain's first application was Bitcoin, it is not limited to the capabilities of Bitcoin. Bitcoin operates on a public blockchain, but there are several other types as described in Table 3 below. (Khatwani, 2018)

Type	Description
Public	Anyone can participate in reading, writing, and auditing the blockchain
Private	Access for reading, writing, and auditing is governed by a central authority
Federated/Consortium	A group of companies or representative individuals' majority vote audits the blockchain

Table 3. Types of Blockchains

The verification algorithms used for public blockchains must require high computing power to ensure security and trust in an anonymous and public system. The computing power necessary to write to a public blockchain is costly, which has slowed the adoption of blockchain to other industries. However, the issues of cost and time can be solved by using private blockchains where appropriate. Due to the security and sensitivity of health information, a private blockchain is a logical solution. Research conducted by Change Healthcare found, "in healthcare, a standard requirement for a network solution at scale would be around thirty million transactions per day" (Bresnick, 2018). By shifting their efforts toward a private blockchain, Change Healthcare, which currently processes millions of transactions daily, was able to create their own Hyperledger framework and obtain the capability to process fifty million transactions daily. Change Healthcare's solution obtains a 600 TPS rate. Not only does this exceed the requirements of the healthcare industry, but also it revolutionizes the scalability capabilities of blockchain outside of healthcare.

Policy Compliance

Policy compliance will refer to two types of policies. The first one addressed will refer to the contracts and rules between providers and payers in a VBC system. The second will be laws the national government has instilled to protect patient information.

Creation of payment models under VBC requires regulation. A payer will pre-determine metrics of quality upon which a provider will be paid, but how will this information be tracked and completed? The immutability of blockchain allows for the contract or policy between payer and provider to be posted and thus held as the single source of truth for each party to see. These contracts posted to the block chain are known as "smart contracts." A smart contract is an agreement, "between parties that is posted to the blockchain. These agreements can be between peer-to-peer (P2P), person-to-organization (P2O), and person-to-machine (P2M)" (Adams, 2014). The financial ability of blockchain allows for smart contracts to be automatically executed (payment transferred) once conditions of the contract are met. The high functioning interoperability of blockchain will allow the necessary information to be shared not only with payers, providers, and patients, but also with the smart contract. This will allow the contract to operate autonomously once initialized and mitigate the high administration costs for payment. An immutable contract will hold all parties accountable within a VBC system.

Healthcare policy is a complex system which often causes political complexity. With the recent movement towards EHRs, policymakers have gained exposure to creating laws that continue to protect patient information while still enabling the free flow of information. However, because it is essential that the identity of a patient remains secure throughout data transfer, EHRs have face policy compliance issues. As noted in the introduction to interoperability, health payers and providers are hesitant to participate in data transfer because of the possibility of breaking federal privacy laws. The overarching law guiding all privacy concerns is the Health Insurance Portability and Accountability Act (HIPPA). HIPPA only allows for distribution of protected health information (PHI) with consent of the patient (Electronic Frontier Foundation, 2018). PHI is any demographic information that can be used to identify a healthcare patient. As discussed, blockchain creates patient information, which is separated from identifying information, allowing patient information to be policy compliant on the blockchain. A unique encrypted key will be given to patients to route patient information back to the correct individual. This allows patients to own their data. Overall, the features of immutability and pseudo-anonymity of the blockchain allow it to automatically execute contracts between payers and providers as well as remain compliant with national privacy policy.

Chapter 7

Conclusion

The United States healthcare system is shifting from the current FFS payment model towards a VBC payment model. Whereas FFS rewards volume of care, VBC rewards value of care. The U.S. currently spends the highest percentage of its GDP on healthcare when compared to all OECD countries, but fails to provide the highest level of health care. The creation of the VBC model has served to address the categories of waste in FFS: care coordination failure, care delivery failure, overtreatment, pricing failures, fraud and abuse, and administrative complexity. To successfully create a reimbursement system based on value, payers and providers must be able to determine the proper value proposition, prospective performance and cost objectives to provide the optimal health outcomes. To fully understand expected health outcomes and metrics of patients, the payer and provider must have accurate and accessible data. Given the complexity of the healthcare system and the sensitivity of healthcare data, the current EHR digital systems are incapable of enabling VBC. The technology system must be interoperable, scalable, and policy compliant. The immutability, pseudo-anonymity, decentralized, private blockchain adheres and supports all requirements of VBC. Payers expect forty-two percent of members to be operating under VBC by 2019, but only sixteen percent of healthcare companies intend to have blockchain in place by the end of 2018 (Hogan, Fraser, Korsten, Pureswaran, & Gopinath, 2016). VBC has gained attention and optimism, but due to the data required for execution, a feasible technology solution must be in place to operate VBC at scale. The emergence and popularity of blockchain has allowed the healthcare industry the opportunity to capitalize on the creativity and effectiveness of VBC.

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