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ABSTRACT

Big Data has been considered as an effective tool to reduce healthcare costs by eliminating adverse events and reducing readmissions in hospitals. The purpose of this study was to examine the emergence of Big Data in the United Sates healthcare industry, to evaluate hospital's ability to effectively make use of complex information, and to predict the potential benefits hospitals might realize if they are successful. The findings of the research suggest that there were a number of benefits expected by hospitals when using Big Data analytics, including cost savings and business intelligence. In addition, hospitals have recognized that there have been challenges including lack of experience and cost of developing the analytics. Many hospitals will need to invest the expense of acquiring adequate personnel with experience in Big Data analytics and data integration. The findings of this study suggest that the adoption, implementation, and utilization of Big Data technology will have a profound positive impact among healthcare providers.

Key Words: Analytics, Big Data, Business Intelligence, Costs, Data Warehouse, Health Information Management

INTRODUCTION

The widespread adoption of Electronic Health Records (EHRs) has emerged, in large part, as a result of the Healthcare Information Technology for Economic and Clinical Health (HITECH) Act, which was enacted in 2009 and gave incentives to hospital and physician providers who adopted the new technology (HealthIT.gov, 2014). In just a few years, these EHRs have collected large amounts of patients' personal health information, and simultaneously, many hospitals have either already begun, or have goals, to connect with outside health-information exchanges giving them access to receive and transmit unprecedented amounts of healthcare data (Groves, Kayyali, Knott, & Van Kuiken, 2013). Some hospitals and many industry analysts have concluded that if all of the healthcare data being collected could be manipulated and studied, there could be many benefits to be gained, for example cost containment might be possible by evaluating high-risk patients' behavior and providing some early interventions that might curtail the worsening of their condition (Brigham and Woman's Hospital, 2014). The activity that involves amassing and rapidly analyzing large amounts of different kinds of data is known as working with Big Data (Cognizant, 2012).

Working with Big Data has not been without many obstacles, and the early adopters in the healthcare sector have learned that working with Big Data is very difficult (Frost & Sullivan, 2012). The authors reported that sheer size of the data sets overwhelms most standard computer and software programs. With the advent of applications for smart phones and other hand-held medical devices that patients can use to check their medical condition and then transmit results to their hospital, the data storage requirements will need to be measured by petabytes (Halamka, 2014). A petabyte is 1,000 terabytes (one trillion bytes) of data, which is more than four times all the information contained in the United States (US) Library of Congress (McKenna, 2013). Another factor that makes working with Big Data an arduous task has been the lack of data standards (Cognizant, 2012). Despite the fact that most hospitals have been working in the electronic realm in billing services for an even longer time than they have with EHRs, the billing data has lacked consistency across different payers, and therefore has not been very useful (Frost & Sullivan, 2012). Beyond the physical space needed to store Big Data, there have been difficulties in allocating the appropriate levels of capital and human resources needed to transform so much raw data into meaningful information (Halamka, 2014).

And finally, an important real barrier to Big Data analytic adoption has been legal, which include laws that were designed to protect a patient's privacy (Roski, Bo-Linn, & Andrews, 2014).

Because the U.S. spends far more on healthcare than the rest of the world for similar, or some cases poorer outcomes, and most notably in 2009, the healthcare costs represented almost 18% of the gross domestic product, the ability to lower healthcare costs has been a major incentive for hospitals to invest in Big Data (Groves et al., 2013). These scholars also reported with new payment systems being introduced into the healthcare market, such as population health management and patient centered medical homes, both of which, put the hospitals at risk for not only lowering costs, but improving outcomes, Big Data healthcare analytics have been looked to as necessary information in order for hospitals to be successful. Using Big Data, hospitals hope to be able to predict the patients' outcomes and can tailor the care that certain patients receive if it is believed that they will do poorly without additional intervention, and in doing so, the hospital could prevent unnecessary readmissions, adverse events, or other delays in getting well (Brigham and Women's Hospital, 2014).

The purpose of this research project was to examine the emergence of Big Data in the U.S. healthcare industry, to evaluate hospitals' ability to effectively make use of complex information, and to predict the potential benefits hospitals might realize if they are successful.

METHODOLGY

The methodology for this research was a literature review with a semi-structured interview with an expert in Healthcare Information Technology (HIT).

The hypothesis of this study was that hospitals utilizing Big Data will have an increase in efficiency, efficacy and increased cost savings. The research approach followed the steps and research framework utilized by Yao, Chu, & Li. (2010) (Figure 1). This framework has been effectively applied in preceding studies, increasing its internal validity (Coustasse, Tomblin and Slack, 2013; Porterfield, Engelbert and Coustasse, 2014).

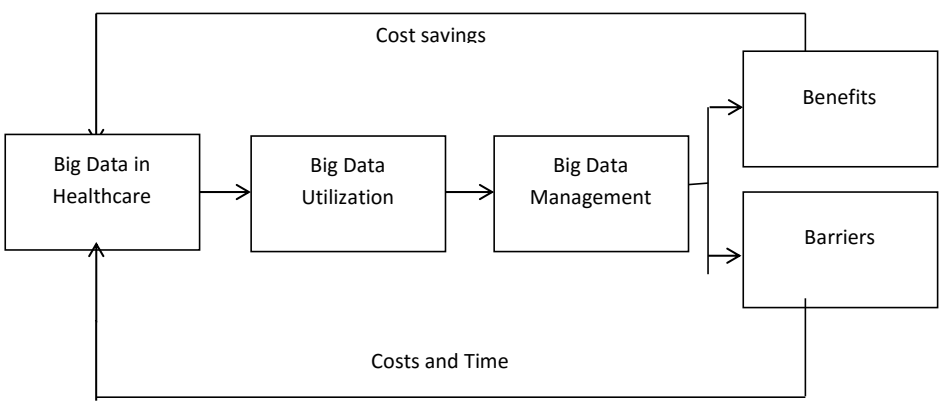

Figure 1: Research Framework (Yao, Chu & Li, 2010)

Figure 1 shows the major steps of Big Data utilization and cost savings in a healthcare institution and the barriers to impeding its implementation. The application of this conceptual framework with this study was considered suitable. For example, it starts with identifying the major benefit of harnessing Big Data, which is cost savings, and then the framework highlights the barriers of cost and time needed to work with Big Data (Figure 1).

The key phrases "Big Data" OR "Business Intelligence" OR "Data Warehouses" AND "Healthcare Information Management" OR " Data Mining" OR "Health Information Exchange" AND "analytics" OR "analysis" OR "healthcare" OR "health" OR "clinical" OR "review" OR "benefits" OR "barriers" OR "costs" OR "outcomes" as inclusion criteria to explore scholarly databases for articles. The following databases were used for this research: PubMed, ProQuest, Medline, EBSCO host, Academic Search Premier, Science Direct, SpringerLink, Google Scholar and Google. Information from various websites was included, such as, National Institute of Health, Centers for Medicare and Medicaid, Center for Diseases Control and Prevention, HealthIT.gov, Intel Corporation, Robert Wood Johnson Foundation, McKinsey Global Institute, Brigham and Woman's Hospital.

Literature was selected for review on the basis of relevance to the study, governmental regulations, and barriers and benefits to using Big Data. In an attempt to stay current, references utilized were limited to those written in English and published between 2009 and 2014. Only primary and secondary data collected from reports, articles, research studies and reviews were included in this research. References were analyzed and established to have satisfied the inclusion criteria if the material yielded accurate knowledge regarding Big Data, with special consideration on its management, benefits and barriers. A total of 68 sources were reviewed. Only 25 references to date were utilized in this literature review. The literature search was conducted by CS, AH, LB, and validated by AC who acted as a second reader and also confirmed if references met the research study inclusion criteria.

The semi-structured interview of D.L., Cabell Huntington Hospital's Chief Informational Officer, with a long experience in healthcare informatics, was used to learn about the process of developing data warehouses, the potential barriers in working with Big Data and the expected benefits (Appendix A). This interview was digitally recorded, and only relevant and pertinent answers were used to support the information found in the literature review to provide a contextualized and more comprehensive overview of this emerging technology and its utilization by U.S. hospitals.

RESULTS

The Emergence of Big Data

Many authors have identified three attributes of Big Data: volume, variety, and velocity (Jee & Kim, 2013; Moore, Eyestone, and Coddington, 2013; Raghupathi & Raghupathi, 2014). The first, attribute, volume, was characterized as the sheer size of the data sets, and would be measured in terabytes or petabytes (Sarasohn-Khan, 2014). The existence of Big Data in healthcare has emerged as a by-product of providing services to patients and includes documentation in physician and nursing notes, diagnostic imaging studies, laboratory test results, treatment documentation, pharmacy records, and billing information (Raghupathi & Raghupathi, 2014). The sources and formats of data continue to grow in variety and complexity. Manyika et al. (2011) reported that beyond the physician and hospital collected data, additional information has come from the internet; social media; mobile devices; government records and databases; and traditional offline documents scanned by optical character recognition into electronic form. The introduction of hand-held devices with sensors has expanded the capacity to collect data from individuals in their own homes (Manyika et al., 2011). The second attribute, variety, refers to the wide range of types of data that are captured, for example, much of the data is structured in a manner that would allow it to be queried by data identifiers; where as much of the data is free-text contained in notes that would require manipulation before it could be co-mingled with the structured and semi-structured data sets (see Table 1 Jee & Kim, 2013). The third attribute, velocity, refers not only to the rate at which the data is being collected and stored; but also velocity also refers to the necessary speed of the data analytics to be effective, which has been said to be as close to real-time as possible (Moore et al., 2013; Nash, 2013; Wills, 2014).

Barriers to Hospital's Use of Big Data

A review of the literature found a number of barriers that might prevent or slow hospitals in the development of Big Data and the related analytics. Many researchers have found that the time and costs associated with the integration of the data from various information systems has been a major challenge in developing a Big Data warehouse (Jee & Kim, 2013; Shapiro, Mostashari, Hripcsak, Soulakis, and Kuperman, 2011; Northover, 2014; Raghupathi, & Raghupathi, 2014; Wills, 2014; Chute et al., 2013). Another concern has been the issues surrounding security of the data, compliance, and patient privacy issues, and many researchers have thought that regulatory and policy changes will need to be addressed to promote adoption (Bates, Saria, Ohno-Machado, Shah, and Escobar 2014; Jee & Kim, 2013; Northover, 2014; Raghupathi & Raghupathi, 2014). Many of the researchers have cited lack of

expertise in Big Data analytics as a hurdle to hospitals, which will be important since having all of the data gathered in a warehouse without the ability to analyze it properly would not accomplish any benefit (Table 1). A complete list of challenges associated with Big Data identified by the researchers were compiled and included in Table 1.

Table 1: Challenges for Hospitals in Using Big Data Analytics

Challenges	Details (Citation)
Cost and difficulty of connecting disparate systems to data warehouse	• Lack of standardization of data sets is costly (Raghupathi, & Raghupathi, 2014). • Sheer volume of data and lack of connectivity of systems makes it costly (Wills, 2014). • Complexity of extracting data from a large variety of sources in different formats (Chute, 2013). • Integration costs (Jee and Kim, 2013). • Cost of developing interfaces (Shapiro, 2011). • Data standardization and interoperability between numerous IT systems (Northover, 2014).
Lack of information systems and analytical professionals with experience	• New leadership is needed, Chief Analytical Officer (CAO) (Nash, 2014). • Lack of information technology big data talent in healthcare (Northover, 2014). • Ability to find big data analytic talent (Jee and Kim, 2013). • Lack of competency of healthcare staff in using analytics (Skiba, 2014).
Concerns over data quality and quality assurance practices	• Data quality will be important to be validated before predictive analytics are applied (Northover, 2014). • Quality assurance will be a difficulty ongoing task (Raghupathi, & Raghupathi, 2014). • Predictive modeling might have harmful effects if patients are treated differently based on a flawed data model (Wills, 2014). • Data must be extremely current or not going to be helpful in analytics (Moore, 2013).
Security and privacy	• Security and privacy concerns (Northover, 2014; Raghupathi & Raghupathi, 2014). • HIPAA and other regulatory restrictions need to be modified with new policies (Bates, 2014). • Data security and compliance programs (Jee and Kim, 2013).
Financial motivations	• Current payer systems still mostly fee for service will need to continue to shift to motivate hospitals (Bates, 2014).

Potential Benefits to Hospital Using Big Data Analytics

Based on the review of the literature, there were some common benefits cited for hospitals if they are successfully able to use Big Data analytics. The most common benefit found was the reduction of healthcare costs, which might be achieved in many different ways, including: reducing readmissions, eliminating unnecessary tests, diagnosing patients earlier when interventions are more successful, and effectively managing patients who are at high risk for complications or those who utilize services frequently; these strategies are often associated with population health (see Table 2). Other benefits included improving health care outcomes and using Big Data for business intelligence leading to better operational decisions (see Table 2).

Table 2: Benefits of Using Big Data Analytics

Benefits	Details (Citation)

Reduce costs of healthcare delivery	• Tracking high-cost patients, lower readmissions, reduce adverse events, treatment optimization (Bates, 2014). • $200,000 USD in monthly savings experienced by University of Michigan Health System in providing blood transfusions using big data analytics (Raghupathi, & Raghupathi, 2014). • Reduction of healthcare costs by predictive modeling (Wills, 2014). • Reduce healthcare spending (Jee and Kim, 2013). • Lower readmissions (Stempniak, 2014). • Lower costs through better patient interventions (Northover, 2014). • $7 billion USD in total estimated savings by 2,700 Premier member hospitals after using Big Data analytics to analyze supply chain costs (IBM, 2013).
Reduce costs of research and development	• Analytical tools could lessen time for research study by predicting which patients that would most likely comply with studies (Jee and Kim, 2013). • Reduce development costs for pharmaceutical companies (Chute, 2014).
Improve health care outcomes	• Better detection and earlier detection of medical conditions (Jee and Kim, 2013). • Being able to use analytics to intervene with patients that will benefit most (Skiba, 2014). • Anticipate patient needs and provide tools for population health (Moore, 2013). • Analytics to support population health strategies (Shapiro, 2011). • Increase quality of care (Nash, 2014).
Business Intelligence	• Using data to make better operational decisions at hospitals (Stempniak, 2014). • Improve hospital's collections (Moore, 2013). • Provide for automated means for better quality reporting (Shapiro, 2011). • Improve patient engagement with predictive analytics (Nash, 2014).
Expand patients access to care	• E-health, mobile health tools that transmit data to hospitals from patients' home (Nash, 2014).

Hospital Case Study: Cabell Huntington Hospital's Experience with Big Data Warehousing and Analytics

Cabell Huntington Hospital (CHH) is a 313-bed acute care hospital serving patients in West Virginia, eastern Kentucky, and southern Ohio. CHH has had a close working relationship with the School of Medicine at Marshall University (Marshall). About a year ago, CHH's CEO and the Dean of the medical school determined that developing a data warehouse with analytic tools would be made a priority. For one payer, CHH and Marshall had been responsible for managing the costs of providing all health care to a certain group of patients. The insurance company had been requesting proof of lowered costs as well as other quality outcome measures. Without the data analytics, Marshall and CHH had not been able to appropriately respond to the insurance company (D.L, 2014).

According to D.L., the first step in the process of developing a Big Data solution was forming an Informatics Technology Governance Committee made up of CHH's CIO, Marshall's CIO, and the Chief Medical Information Officer, a physician who is involved with this project, and some key financial executives in the hospital. After doing some research, the group concluded that there were basically two approaches that could be undertaken: the first, would involve building a data warehouse from scratch with all of the analytics to be added using some commercial software; the second, would involve buying a pre-packaged data warehouse and analytic solution all in one. CHH and Marshall decided to choose the first option. The main reason was the perceived cost of building versus buying. In 2014, an estimate of the cost for the pre-packaged solution was projected to be $1 million (D.L., 2014).

One of CHH/Marshall's biggest challenges has been that they do not have any organizational knowledge of working with Big Data analytics. D.L. admitted that they do not have the skill set, expertise, and other experience, because they have never worked in this new sector before; so they are on a learning curve. The first thing that the team had to do was to hire a data architect who would have the responsibility to build the data warehouse. CHH also hired two data analysts to work on the day-to-day duties. So far, the staff members have been in the process of evaluating all of the different data sources, building the data dictionaries, doing some normalization of data, so that they can start pulling data into one place and do some analytical reporting.

As far as the potential benefits to be realized by developing the Big Data analytics, the CIO, envisioned two focus areas. The first area would be internally-focused benefits, such as improving internal operations, efficiencies, working denials, and improving quality and safety issues; the second area would be externally-focused benefits, such as population health, understanding where the patients go throughout the entire healthcare spectrum – not just the hospital or physician's office. Performing the analytics, could result in preventing readmissions, excessive or unneeded care, or more drugs (D.L, 2014).

DISCUSSION

The purpose of this research project was to examine the emergence of Big Data in the U.S. healthcare industry; to evaluate hospitals' ability to effectively make use of complex information, and to predict the potential benefits hospitals might realize if they are successful.

The findings of this study suggest that the adoption, implementation, and utilization of Big Data technology may have a profound positive impact among healthcare providers. Cost containment, cost savings, and better patient outcomes through more successful disease management are among the principal benefits to be expected. Kaiser Permanente Health Connect® is an EHR that has improved the management of disease among cardiovascular disease patients, as well as yielding Kaiser Permanente an approximate savings of $1 billion (Groves, et al., 2013). Utilizing demographic characteristics, previous diagnoses, and various information collected from EHRs, enables healthcare organizations to predict costs for individual patients, which may be used by insurers and providers (Loginov, Marlow, & Potruch, 2012).

The results suggests that adoption and utilization of Big Data technology have increased in recent years, making a significant impact in reducing costs in the delivery of care at the patient level. For instance, Raghupathi & Raghupathi (2014) found that blood transfusion costs were reduced by $200,000 USD per month just at one health system by the use of Big Data analytics. Brought about, in part, by the HITECH bill encouraging providers to adopt EHRs, the gathering, synthesizing, and practical use of Big Data is expected to continue. However, the results also suggested that adoption of Big Data analytics has been implemented relatively slowly due to numerous barriers, such as security and privacy concerns, lack of connectivity between disparate HIT systems, and a shortage of experienced health care informatics personnel. Therefore, it can be surmised that many health care organizations will be working to overcome many of these barriers in order to survive in a new era of health care which is focused on health care value and the efficient delivery services. Overall the results suggest that hospitals utilizing Big Data technology have had an increase in efficiency, efficacy, and increased cost savings.

Many hospitals and health systems will need to invest the expense of acquiring adequate hardware and software with the capability to accommodate the volume of data for their expected future HIT needs. Because the integration of linking data from numerous systems can be challenging, many providers will need to factor in a considerable amount of planning in order to appropriately estimate the amount of capital and staff required to implement a sufficient strategy to harness Big Data technology. Providers have to put forth the cost of ensuring that relevant members of their workforce are adequately trained in HIT, in order to effectively use of the new HIT systems. Hospital planners will need to develop pro forma statements that strive to predict the costs savings that might be realized by preventing unnecessary readmissions, and eliminating unneeded tests.

Healthcare providers also have a duty to design their organizations' HIT systems to assure that patient privacy is safe guarded, and must take action to meet the legal obligation to conform to any privacy laws. It is incumbent upon the leadership of a healthcare organization to pave the way toward implementing a system to accommodate its Big Data technology needs in order to affect the desired increase in efficiency, efficacy, and cost savings.

STUDY LIMITATION

The literature review may be limited by: the quality and number of databases accessed, and the search strategy utilized. Also, the consideration of developing technology for the purpose of harnessing Big Data is a relatively new concept; therefore, there was a limited amount of quality research available on the quantitative benefits of Big Data, which restricted the researchers' ability to conduct a thorough analysis. Researcher publication bias cannot be ruled out due to research evaluation to determine articles study relevancy.

CONCLUSION

Harnessing Big Data technology is an effective solution for reducing healthcare costs, reducing adverse events and readmissions. Until recently, it has been found that the Big Data technology has been too expensive, and it has been very time consuming to implement. However, as the cost savings are realized, hospitals will invest more into developing Big Data analytics.

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APPENDIX A

Questions Asked in Semi-Structured Interview of Mr. Dennis Lee, Chief Information Officer at Cabell Huntington Hospital in Huntington, West Virginia on September 19, 2014.

1. As a Chief Information Officer, what has been your experience working with Big Data generated in the hospital environment?
2. What efforts have been undertaken to develop data warehouses at Cabell Huntington Hospital and/or Marshall Health? Why?
3. How would you develop a realistic estimate of the resources (personnel, hardware, storage, software, time, etc.) required to capture and analyze Big Data generated by a 313-bed academic medical center's operations, such as Cabell?
4. In your experience, what have been the main challenges with working with Big Data? Why?
5. What do you believe are the likely benefits that might be realized if the data could be effectively managed and mined?

6. Do you believe that the pay-off of successfully obtaining Big Data analytics will be worth the investments? Why or Why not?
7. What do you believe is going to be the first area(s) that the healthcare market will see Big Data applications being employed? Why?
8. How far in the future do you predict these applications will occur?
9. What advice would you give hospitals that are in early planning stages of developing a data warehouse and tools for Big Data analytics? Why?