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Big Data Applications in Healthcare Administration

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ABSTRACT

The healthcare industry has a growing record of using big data-related technologies such as data analytics, internet of things, and machine learning, especially in the clinical areas. However, healthcare institutions must also perform all of the administrative processes just as any other organization. Thus, like many other industries, healthcare has begun to apply these same technologies to improve their understanding of these internal operations and use them to make better decisions and run a more effective operation. This study takes a structured literature review approach to describe the current state of this literature and identify the major themes and priorities of both the research community and the healthcare industry as a whole. The contribution made by this study is to provide a comprehensive analysis of the state of the literature to use as a foundation for the future research opportunities noted in the paper.

KEYWORDS

Administration, Big Data, Healthcare, Structured Literature Review

INTRODUCTION

As the concept of big data and the tools that surround it have matured, the world of business has witnessed an inexorable migration of these tools from the financial sector to other areas of commerce such as transportation and insurance. Shortly into this transition, these tools made their way to the healthcare industry. Some of the first areas within healthcare that big data techniques first appeared were in the clinical areas such as oncology, radiology, and genetics (Chang & Choi, 2016). However, healthcare organizations are also businesses with the same internal and external processes as any other business. These include the hiring of staff, the procuring of supplies, and the running of sometimes vast physical plant installations. So, it is not surprising that the healthcare industry has begun using big data techniques to improve their ability to perform these important, yet often out of the spotlight, activities.

There is a large and enthusiastic literature surrounding the clinical uses of big data in healthcare and there have been a number of reviews in these various areas (Pashazadeh & Navimpour, 2018; Otokiti, 2019). However, there is a much smaller, but still important, literature that describes the uses of big data in the administration of healthcare and hospital activities. The purpose of this paper is to review the literature regarding the uses of big data and its ancillary tools and processes in the

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improvement of healthcare processes. The term improvement can, of course, encompass many different aspects of healthcare and hospital administration. Improvement can involve the reduction of costs, the improvement of patient care and experience, the prediction of patient admission or readmission, and the allocation and management of hospital resources. In these and many other cases the use of big data techniques and tools has provided many options and opportunities for hospitals, healthcare systems, and other parts of the overall healthcare industry to create more effective and efficient methods for providing quality healthcare to their community and the nation.

BACKGROUND

When most people encounter the healthcare industry, they see mostly the clinical side of the process (except when it comes time to pay the bill). Many do not consider that healthcare is an industry and even if the facility they are using for provision of healthcare services is a non-profit organization, the business side of the healthcare equation is a crucial part of the overall system. Hospitals depend on well-trained and experienced personnel to perform their essential services, thus human resources is a critical activity. Even if they do not have shareholders to answer to, though many healthcare systems in the US are publicly traded companies, they still must monitor costs and revenues just as any other organization and therefore the financial processes of the organization is just as important as for any Fortune 500 firm. Issues of workflow streamlining, document management, and technology selection and implementation have very important roles in healthcare just as they do in any other organization.

Healthcare as a Business

Healthcare organizations face many of the same challenges as other firms. Cost reduction is a constant process. Large healthcare bureaucracies are inherently expensive to run, and with the high level of expertise in the clinical side of the organization and very expensive equipment to purchase and operate, cost reduction processes often take center stage. This is vitally important not just for the success of the enterprise, but for the healthcare system writ large. Workflow analysis allows the reduction of delays for patients to receive care and also reduce the overall complexity of the organization (Wolf, Herrmann & Rothermel, 2013). Increasing accuracy is a fundamental objective of healthcare administration as it is closely related to not just patient outcomes, but also the areas of cost reduction, asset utilization, and continuous process improvement (Cutler, Wikler & Basch, 2012).

Big Data Related Technologies

When organizations say they are using "big data," it also means they are using some other tools to utilize that large collection of data. The simple collection of data, even in large amounts, is of little value unless actionable information can be extracted from them. Therefore, when reviewing the literature on the use of big data in the administration arm of healthcare, these ancillary but closely related technologies and tools must be included in the analysis. In the current study, the search for literature of big data in healthcare administration was combined with the following technologies to provide a more robust view of the literature:

- **Internet of Things (IoT):** The proliferation of sensors attached to machines, monitoring a process, and even measuring a patient's vital signs, is the basis of much of the huge datasets that organizations are using to create new understandings of their processes. Therefore, even if big data is not explicitly mentioned, they are implicitly creating a big data environment;
- **Deep Learning:** A branch of machine learning that leads to tools such as Artificial Neural Networks (ANN) that can be trained to make decisions such as classifications or speech recognition. Related to big data because the datasets required to train and verify the algorithms are typically very large and commonly fall into the general definition of big data;

- **Machine Learning:** A broader category of algorithms that use training data to create the ability to make decisions. Included in this are many different types of training methods and architectures, which are out of the scope of this paper but can be reviewed in (ref);
- **Data Analytics:** A broad term covering all of the statistical and mathematical tools and techniques commonly used to analyze and draw meaningful information from big data repositories.

There are, of course, many other terms that can be associated with big data – based technologies, but these terms are some of the more commonly used and therefore make a good starting point for the literature examination process. In the rest of the paper, this grouping of technologies and tools will be referred to as Big Data technologies.

METHODOLOGY

As this study is a structured review of the literature, it is important that the methodology used is both transparent and easily replicated. Briner & Denyer (2012) provide an easily implemented and repeatable approach to the completion of a systematic literature review:

- Identify the research question(s);
- Locate and select relevant studies;
- Critically appraise the studies;
- Analyze and synthesize the findings;
- Disseminate the findings.

There are two research questions driving this study:

- For which healthcare administrative processes are big data technologies (as defined in this study) being used to improve or analyze?
- For how long have big data technologies been used to improve or analyze healthcare administrative processes?

In order to perform a structured literature review properly, a set of ground rules must be established to ensure consistency and validity of the study protocol. This study limits the review to peer reviewed academic journals, conference proceedings, dissertations, and edited book chapters. This removes the professional journals, unpublished papers, white papers, and other sources of information from the study. This is not to say that they are not sources of valid information, only that the study is centered on the research efforts that have resulted in either specific tools to be used in healthcare administration tasks or big data tools that are being used to research these activities. Future research will be necessary to unearth whether the directions of researchers are aligned with the concerns and ideas of the practitioner literature.

Searches were carried out in many of the major electronic databases that provide coverage for the vast majority of scholarly journals in the field. The databases analyzed were ABI/Informs, Emerald, IEEE Explore, JSTOR, Science Direct, Scopus, Springer, Taylor & Francis, Web of Science, Google Scholar, PubMed, CINAHL, and ACM. The searches were conducted by searching the metadata (title, abstract, keywords) using the following search terms in all combinations: big data, Internet of Things (IoT), deep learning, machine learning, and analytics along with healthcare and hospital. To center on the administrative aspects of the industry, administration and management were also included. This study does not claim to be exhaustive, but the wide selection of databases combined with the increased rate of result duplication as the study progressed, provides evidence that a reasonable

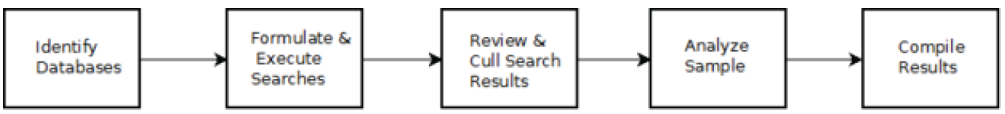
coverage of the topic has been achieved. There was no temporal restriction placed upon the searches so that the full scope of relevant research might be discovered.

This search protocol retrieved thousands of initial results, but the vast majority of them were focused on the clinical side of the healthcare industry. This is partially because of the use of the search term management (i.e. "*disease* management"), partially because of the automatic use of synonyms in many search protocols, and probably because the exclusion of purely clinical systems is very difficult to do in many situations. In the case of many of these returned articles, the title was sufficient to classify them as clinical in nature. However, that still left a list of over a thousand articles to deal with. After reading the abstract of these articles to gain more insight into their core topic, the final list of 227 articles remained to begin the actual analysis.

For those papers accepted into the study, the next step was to use the abstract, introduction, and conclusion sections to gain a more complete understanding of the topic being addressed by the author(s). Using a technique known as open coding, which is a qualitative research method of identifying the set of concepts within a document, the papers were sorted into sets of major themes that represent the focus of the author(s). As these themes were defined and refined, it became apparent that the complexity of the topics being studied required a more subtle approach. Therefore, a set of sub-themes were developed under the major topic headings to provide a better understanding of the scope of the research being undertaken. As these themes and sub-themes took shape, the last task was to categorize each paper into the theme and sub-theme that fit them most accurately. It should be noted that a significant number of studies could have been slotted into multiple categories. These papers required a deeper analysis to discern their main contribution. This involved a close reading of the entire paper, not just the introductory and concluding sections, to make that determination based on the author's stated goals, outcomes, and methodologies. The interdisciplinarity inherent in the healthcare and many other industries makes this overlap unavoidable.

To complete the structured review protocol, the findings of the literature analysis are presented and discussed in the following section. The complete literature review process followed in this project is depicted in Figure 1.

Figure 1. Literature review process



RESULTS

The findings section is divided into two sections. The first contains an overview of the descriptive statistics of the sample. The second section describes the various research themes and sub-themes contained in the sample.

Descriptive Statistics

The documents included in this study come from only three sources: journals, conference proceedings, and book chapters. The searches did not uncover any theses, dissertations, or books on the topics listed in the methodology section. The breakdown among these three forms is shown in Table 1.

The proportions of each format given above held relatively constant for each of the themes discussed below except for the technology theme, which had almost twice as many conference proceedings as journal articles. Most of these articles discussed a framework or architecture for

Table 1. Types and quantity of article types uncovered in the literature review

Article Type	Quantity Found
Journal Articles	121
Conference Proceedings	94
Book Chapters	12

a proposed system or tool, which is a common topic at many technology-related conferences and workshops.

There were no time boundaries placed upon the searches so that the full range of activity in the field could be captured. The searches were all completed by May 1, 2020 and the temporal results of those searches are shown in Figure 2. The search results show that there were very few articles published on Big Data – type processes or tools in healthcare administration prior to 2014, with the earliest occurring in 2007. However, in 2014 the level of activity began to increase significantly with an exponential growth displayed through 2019. Since the data for 2020 represents only a third of the year, it appears that the trajectory points to at least as many publications in the field for the current year.

Research Themes

There are four research themes identified in the literature: resource management, technology, hospital management, and patient outcomes. These themes are expanded on in the following paragraphs. However, within each theme there are sub-themes that serve to better focus the analysis of the papers within each theme. To assist in understanding how these various sub-themes organize to support the major themes, Figure 3 provides a graphical representation of these themes and sub-themes.

Figure 2. Number of publications in Big Data / Healthcare administration by year (as of 1 May, 2020)

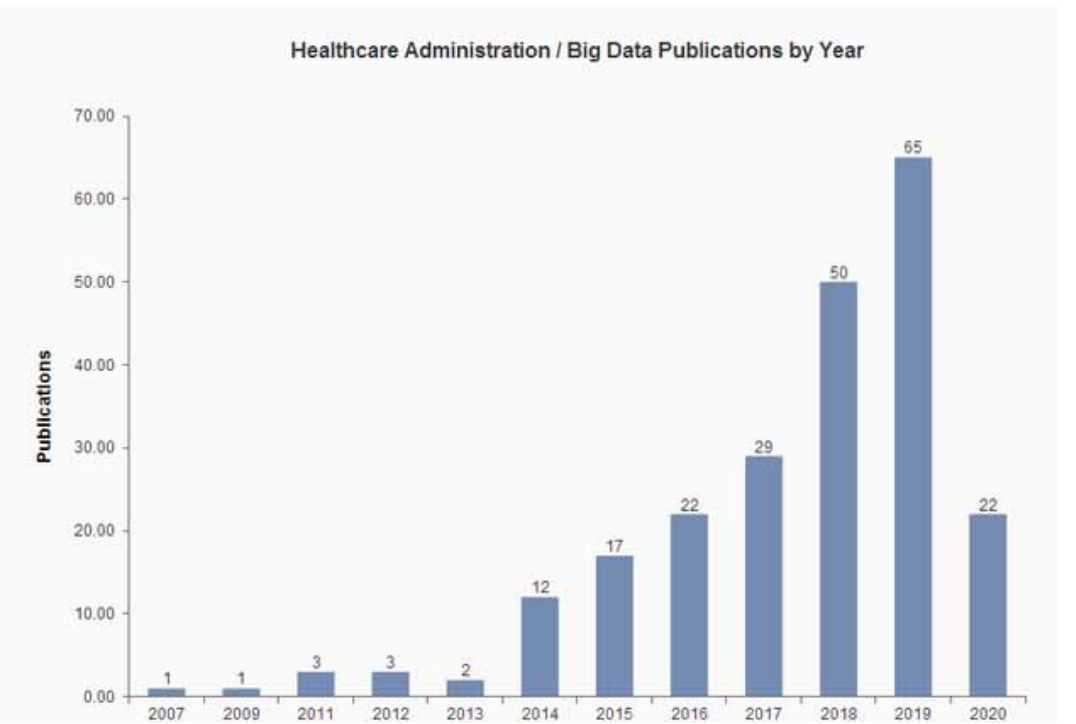
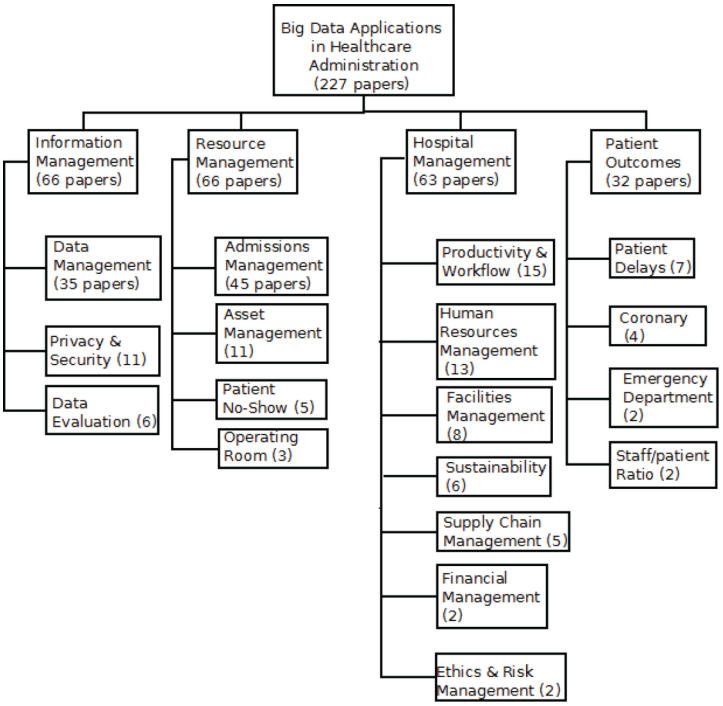


Figure 3. Breakdown of themes and sub-themes within the Big Data/Healthcare Administration Literature



Three of the four themes identified in this analysis are of very similar size, which suggests an even spread of importance for these various topics. The Information Management theme will be discussed first. The papers that fall into this theme are centered on the use of Big Data technologies to assist in the handling and application of organizational data and information to improve, or in some cases enable, certain functions. As will be true of most of these research themes, a number of authors provide very important overview papers that help to orient those readers who are relatively new to the topic. Such overviews can be found in Robinson, Presskila & Lawrence (2020) who discuss the Internet of Things, Alsinglawi & Mubin (2019) who explore predictive analytics and deep learning, and Menasalvas, Rodriguez-González & Gonzalo (2018) who look into the mining of electronic health records.

Of the three sub-themes in this grouping, by far the largest is that of data management (35 papers). These authors develop mechanisms and tools that use Big Data technologies to improve the movement and analysis of healthcare information. Some examples of these efforts include the team of Redfield et al (2020) who develop a machine learning record linkage mechanism to improve information flow between emergency services and the emergency department and Mehmood, Mehmood & Song (2019) who look at the use of IoT mechanisms to improve e-prescription processes. Perdana et al (2019) link Big Data with knowledge management tools to increase the efficiency of hospital inpatient services and Silvestri et al. (2019) describe a Big Data architecture that improves the extraction of actionable information from Electronic Health Records (EHR).

The privacy and security of patient and hospital data is of prime importance and eleven author teams addressed this imperative. Some excellent examples of these efforts include Xu et al's (2019) design of a blockchain-based privacy preserving mechanism for large health data depositories, Martinez's (2018) approach to securing IoT-based medical device systems, and Yoon-Su and Seung-Soo (2019) who consider virtual reality to help professionals secure multimedia healthcare information.

The last sub-theme (6 papers) includes those papers using Big Data technologies to assist in the evaluation of some aspect of healthcare data. Some examples include the use of data analytics to assess the level of medication requirements using EHR data (Xu et al, 2019), the use of data analytics to detect anomalies in many areas such as cardiac monitoring (Ukil et al, 2016), and the evaluation and monitoring of data quality in multisite EHR systems (Nobles et al, (2015). Table 2 lists the works in the Information Management theme.

Table 2. Papers focused on the use of big data technologies to promote information management

Sub-Theme	Author(s)
Overview	Alsinglawi & Mubin (2019); Chauhan et al (2019); Ghosh & Scott (2011); Halder & Pan (2018); Liu & Park (2014); Mathew & Pillai (2015); Menasalvas, Rodriguez-González & Gonzalo (2018); Mohamed et al (2020); Nithya & Ilango (2017); Patel & Gandhi (2018); Robinson, Presskila & Lawrence (2020);Thangaraj, Ponmalar & Anuradha (2015); Woodside (2014); Zhu & Hou (2018)
Data Management	Azaria et al (2016); Celesti et al (2016); Chennamsetty, Chalasani & Riley (2015); Cronin et al (2017); Hong, Morris & Seo (2017); Ivan et al (2016); Khazaei et al (2014); Khennou, Khamlichi & Chaoui (2016); Lauría & March (2011); Liu et al (2019); Liu, Zhang & Xing (2017); Lu & Feng (2018); Ma et al (2018); Mamoon et al (2018); Maria, Sever & Carlos (2018); Mehmood, Mehmood & Song (2019); Mian et al (2014); Nammour, Danas & Mansour (2016); Nicolau, Alexandru & Ianculescu (2019); Nouraei et al (2015a,b); Noussa-Yao, Heudes & Degoulet (2018); Perdana et al (2019); Pir, Akram & Khan (2015a,b); Rathee et al (2019); Redfield et al (2020); Silvestri et al (2019); Stadler et al (2016); Sudarto et al (2018); Wilder et al (2020); Weng et al (2017); Ye et al (2018); Zhang et al (2018); Zhang et al (2017)
Privacy/Security	He & Zeadally (2015); Elhoseny et al (2018); Maheswari & Vasanthanayaki (2020); Martinez (2018); Mavroeidakos, Tsolis & Vergados (2016); Nortey et al (2019); Patil & Seshadri (2014); Shi et al (2019); Tang et al (2019); Xu et al (2019); Yoon-Su & Seung-Soo (2019)
Data Evaluation	Carvalho et al (2019); Nobles et al (2015); Solangi, Aziz & Asadullah (2015); Ukil et al (2016); Woodbridge et al (2015); Xu et al (2019)

The second, and equally large, theme has to do with the use of Big Data technologies to manage hospital resources. The literature reviewed uncovered four classes of asset management tasks addressed by these researchers and they form the four sub-themes. Two of these deal with the utilization of general resources in terms of admisssions and, in the converse, no-shows. More specific asset management activities center on the operating room and the medical equipment used throughout the organization, which will be grouped under the sub-theme of asset management. A good overview of the science of medical asset management can be found in Cui et al (2018) and Pollom, Balvach & Jones (2007).

The ability to understand and predict the rate of admissions to a specific practice, department, or the hospital in general is the key to being able to predict and control asset allocation, and thus costs. The largest sub-theme in this grouping (45 papers) centers on the use of Big Data technologies to enable healthcare organizations to regulate and predict the flow of patients into the various areas of treatment within the healthcare system. Some examples of these efforts include the use of semi-supervised machine learning models to predict the length of stay of hospitalized patients (Livieris et al, (2018), the readmission of diabetic patients using neural networks (Chopra et al, 2017), and the use of machine learning models for the prediction of peak emergency department visit times (Peng et al, 2020). The literature suggests that machine learning has applicability in many areas of patient activity prediction such as predicting the admission of patients with Chronic Obstructive Pulmonary Disease (Orchard et al, 2018), asthma (Luo et al, 2020), and elective spine surgery (Stopa et al, 2019).

This is but a sample of how machine learning tools (and others) can be used to help level the demand profile and reduce the level of uncertainty for hospital planners.

The management of medical assets such as IV machines and ventilators has long been an area of concern due to the high cost of these items and their importance in the healing of patients. The eleven articles in this sub-theme look specifically at the use of Big Data technologies to improve the availablility and utilization of these important assets. Some studies provide approaches to IoT-based systems that help to locate and manage the usage of wheelchairs (Kurita, Matsuo & Barolli, 2019), incubators (Kovačević et al, 2019), and rehabilitation equipment (Meng, Zhang & Yu, 2018). Others apply these tools to the need for predicting maintenance (Shamayleh, Awad & Farhat, 2020) or monitoring performance (Gurbeta, Badnjević & Kurta, 2020) of medical equipment.

Certain areas of the hospital have much more specific needs in terms of asset management, such as operating rooms (OR). These are often in short supply and therefore highly sought after, so their proper management is literally a life or death challenge. Three papers examine this problem specifically. Bellini et al (2020) review the use of artificial intelligence and machine learning in OR organization including the prediction of care of perioperative patients with impacts on OR scheduling. Schneider & Brandeau (2017) use machine learning to improve surgical case length estimation and Fairley, Scheinker & Brandeau (2019) use machine learning tools to estimate post-anesthesia care of surgical patients to remove patient-flow bottlenecks.

Last, the bane of effective hospital administration is patients that do not show up for scheduled meetings or procedures. This phenomenon is studied by five research teams. Luo et al (2018) use machine learning to identify surgeries with a high risk of cancellation, while no-shows at a community health center are modeled by Mohammadi et al (2018). Levy (2013) uses a predictive tool to understand nonattendance at a specialty clinic. Table 3 displays the papers in this study that focus on resource management.

Table 3. Papers focused on the use of big data technologies to promote resource management

Sub-Theme	Author(s)
Overview	Cui et al (2018); Pollom, Balbach & Jones (2007)
Admissions	Allam et al (2019); Alloghani et al (2019); Artetxe et al (2017); Baechle et al (2020); Barnes et al (2016); Belderrar & Hazzab (2017); Benbelkacem et al (2019); Berger et al (2020); Cho et al (2019); Chopra et al (2017); Daghistani et al (2019); Grana et al (2019);Golas et al (2018); Gowsalya, Krushitha & Valliyammai (2014); Helm et al (2016); Hendri & Sulaiman (2018); Inibhunu et al (2017); Jeong, Kim & Shin (2019); Kadri, Baraoui & Nouaouri (2019); Karhade et al (2018); Kong et al (2020); Li et al (2014); Lin et al (2019); Livieris et al (2018a,b); Luo et al (2020); McCoy & Das (2017); Moyo et al (2018); Mtonga et al (2019); Nas & Koyuncu (2019); Nelson et al (2019); Orchard et al (2018); Peng et al (2020); Roy & Chin (2014); Shams, Ajorlou & Yang (2015); Silva et al (2018); Tesfaye et al (2019); Tideman et al (2019); Turgeman, May & Aciulli (2017); Raluy-Callado et al (2018); Stopa et al (2019); Vargheese & Viniotis (2014); Wojtusiak, Elashkar & Nia (2018); Zhang (2019); Zhu, Akkati & Hongwattanakul (2016)
Asset Management	Çoban et al (2018); Chai et al (2018); Gurbeta, Badnjeić & Kurta (2020); Karthikeyan, Devi & Valarmathi (2015); Kovačević et al (2019); Kurita, Matsuo & Barolli (2019); Meng, Zhang & Yu (2018); Nutdanai, Pornthip & Sanpanich (2016); Patil et al (2016); Ranjbar et al (2019); Shamayleh, Awad & Farhat (2020)
Operating Room Mgmt.	Bellini et al (2020); Fairley, Scheinker & Brandeau (2019); Scheinker & Brandeau (2017)
No Show Mgmt	Harris, May & Vargas (2016); Levy (2013); Luo et al (2018); Mohammadi et al (2018); Simsek, Tiahrt & Dag (2020)

The third theme is only slightly smaller (63 papers) and consists of those papers highlighting Big Data technologies in the management of the hospital or healthcare facility. Once the healing processes are stripped away, the hospital is much like any other business and the same opportunities for improvements in the organizational processes exist. A number of authors have provided useful overviews of the application of Big Data technologies in this realm, including Juswishin (2019), Kane et al (2019), and Kumar & Suresh (2019). The sub-themes that support a more specific application of these technologies are detailed in the following paragraphs.

As with any other organization, productivity and efficiency are of vital importance. The papers in the largest sub-theme are all related in that they discuss some way in which these technologies might either improve or analyze a hospital's productivity. Fizgerald & Dadich (2009) use visual analytics to improve hospital scheduling. Xu et al (2017) use machine learning to predict the length of patient stay and time to transition for a specific care unit in a hospital. Gattner, Ekinci & Schneider (2016) point out the clinical, operational, and financial improvements brought about by the implementation of workflow analytics in healthcare.

Human resources are a critical component of any knowledge-based operation and healthcare is at the top of any list of knowledge-intensive industries. Ouyang, Shan & Bui (2016) design a RF-based sensor network that provides for the tracking of essential personnel within the hospital for ease of contact. Mesabbah, Abo-Hamad & McKeever (2019) discuss a hybrid process mining framework that will support complex decision-making during hospital staff planning, and Fischer et al (2020) use IoT and data analytics to support the flexible management of human resources in a smart hospital.

Facilities management processes are often overlooked and more complex than first understood, and they represent a fertile opportunity for these technologies to improve. Ramanathan et al (2020) use IoT to control access to the hospital through its various apertures. Facility layout planning is improved through the use of clinical pathway mining by Arnolds & Gartner (2018), and Guo et al (2016) use IoT technologies to monitor temperature and humidity in the key areas of a hospital.

When discussing hospital facilities, the conversation often turns to sustainability. This turns out to be another sub-theme of hospital management addressed by researchers. For example, Sahni, Arora & Dubey (2017) and Golbaz, Nabizadeh & Sajadi (2019) both take on the management of medical waste, Bacon (2014) addresses the low-carbon hospital design problem using what he calls "occupancy analytics," and Ruiz, Pacheco-Torres & Casillas (2017) use machine learning to model energy consumption by a hospital.

A few very small sub-themes emerged, as well. Supply chain management using datamining (Hussein et al, 2018) and IoT (Kakkar & Farshori, 2019) are two examples. A data-driven marketing analysis tool is proposed by Lee et al (2019) to improve pricing and resource allocation. Lastly, two single paper sub-themes on vitally important topics are Mittlestadt's (2017) review of the ethical dimensions of IoT devices and Peng et al's (2017) discussion of an IoT-based risk management system. Table 4 displays the papers that address various hospital management issues using Big Data technologies.

The last theme (32 papers) evident in the literature centers on the impact that Big Data technologies have on patient outcomes. This encompasses the disposition of a patient's medical problem but also the factors that affect these outcomes. There are a number of papers that provide a comprehensive discussion of how Big Data and patient outcomes are related such as Tan et al (2016), Lee et al (2011), and Kachroo, Melek & Kurian (2013). However, the improvement of patient outcomes has been applied to more specific medical conditions as well as specific areas within the hospital. These applications form the basis of the following sub-themes.

The largest of the sub-themes in this category focuses on patient delay. In this paper, the term patient delay is taken in its broadest sense, encompassing any delay in the movement, treatment, or discharge of a patient from a medical department or facility. It is a clear case of research topics taking root in multiple themes, since this could also be examined through an organizational process lens. In these papers, the thrust was more technical, rather than organizational, hence a different theme. While

Table 4. Papers focused on the use of big data technologies to improve hospital management

Sub-Theme	Author(s)
Overview	Couturier et al (2012); Dhanvijay & Patil (2019); Erickson & Rothberg (2017); Guha & Kumar (2017); Habibzadeh et al (2020); Juswishin (2019); Kane et al (2019); Kumar & Suresh (2019); Rathore, Panwar & Soral (2014); Ratia, Myllärniemi & Helander (2019); Stephens (2018); Wills (2014)
Productivity/Workflow	Agnihothri, Banderjee & Thalacker (2015); Ali, Salehnejad & Mansur (2018); Almeida (2016); Biehl, Girgensohn & Patel (2019); Gattner, Ekinci & Schneider (2016); Hall & Partyka (2012); Firzgerald & Dadich (2009); Katrakazas et al (2018); Koufi et al (2017); Lee & Lee (2020); Nukavarapu & Durbha (2017); Safdar, Khan & Shaukat (2019); Sousa et al (2019); Xu et al (2017); Yip et al (2016)
Human Resources	Bala & Venkatesh (2017); Berkowitz (2017); Cheng & Kuo (2016); Fischer et al (2020); Foster et al (2017); Kushniruk & Borycki (2019); Mesabbah, Abo-Hamad & McKeever (2019); Meskó, Hetényi & Győrffy (2018); Ouyang, Shan & Bui (2016); Packianather et al (2019); Rashwan, Fowler & Arisha (2018); Verma, Xavier & Agrawal (2016); Ye et al (2019)
Facilities Management	Arnolds & Gartner (2018); Fatema, Malik & Iqbal (2020); Gartner & Padman (2017); Guo et al (2016); Iqbal, Dar & Bukhari (2018); Marques, Ferreira & Pitarma (2019); Ramanathan et al (2020); Yang et al (2019)
Sustainability	Bacon (2014); Baghapour et al (2018); Godpole & Lamb (2015); Golbaz, Nabizadeh & Sajadi (2019); uiz, Pacheco-Torres & Casillas (2017); Sahni, Arora & Dubey (2018)
Supply Chain Management	Alotaibi, Mehmood & Katib (2020); Feng et al (2018); Hussein et al (2019); Jordan, Dossou & Chang Jr. (2019); Kakkar & Farshori (2019)
Financial Management	Lee et al (2019); Rivera & DeLaney (2015)
Ethics & Risk Mgmt	Mittelstadt (2017); Peng et al (2017)

not a patient outcome per se, it does impact the swiftness of the application of medical activities to the patient and is a strong influencer of patient satisfaction (Price & Lauffer, 2014). A study using datamining methods to create simulations of coronary patient flows provides a framework within which to improve decision making and training methods (Kovalchuk et al, 2018). Perimal-Lewis and King (2018) describe the process of making data ready for a simulation study of the movement of patients from the ED to the various wards in the hospital. Jiang, Abouee-Mehrizi & Diao (2020) explore the use of data analytics to support scheduling of patients with complicated conditions based on their clinical priorities.

Because coronary disease is such a large contributor to the total patient load, there have been a number of studies directed at the management of these patients and because it appears as more of a focus than other maladies, it is provided its own sub-theme. For example, Delen, Oztekin, and Tomak (2012) use a data analytic approach to study and predict the complex medical interventions necessary for a successful outcome. A number of supervised machine learning models that help predict the risk of heart disease are compared and verified by Krishnani et al (2019) and Jain and Kaur (2018).

A few minor sub-themes also emerged from the overall category of patient outcomes. The emergency department is the focus of one of them. Raita et al (2019) uses machine learning to predict clinical outcomes and Hu et al (2017) use it to select patients for more intense case management. Another sub-theme centers on the relationship between staffing and patient outcomes. Leary et al (2016) use datamining to unearth the nonlinear relationship between nurse staffing levels and outcomes while Intensive Care Unit (ICU) staffing is examined to understand how specific staffing characteristics help predict certain patient results.

A significant number of papers addressed very compelling issues having to do with patient outcomes, but there were not enough of them on any particular topic to create even a very small sub-theme. Hopefully, these topics will be expanded upon. Some examples of the "miscellaneous" papers in this theme include the use of machine learning to reduce the number of false alarms in the ICU (Hever et al, 2020), the creation of an in-hospital IoT-based infection management system (Yamashita et al, 2019), and the prediction of hospital-acquired pneumonia (Kuo et al, 2019). Table 5 displays the papers that center on the relationship between Big Data technologies and patient outcomes.

Table 5. Papers focused on the use of big data technologies to promote patient outcomes

Sub-Theme	Author(s)
Overview	AbdulGhaffer et al (2020), Atoum & Al-Jarallah (2019); Krishnan & Kamath (2019); Kachroo, Melek & Kurian (2013); Lee et al (2011); Phillips-Wren & McKniff (2019); Sahoo, Mohapatra & Wu (2017); Seng et al (2016)
General Patient Delays	Cáceres, Rosário & Amaya (2019); Jiang, Abouee-Mehrizi & Diao (2020); Kolesnichenko et al (2017); Kovalchuk et al (2018); Niu et al (2019); primal-Lewis & King (2018); Sumarsono, Anshari & Almunawar (2019)
Coronary Patient Outcomes	Delen, Oztekin & Tomak (2012); Jain & Kaur (2018); Krishnani et al (2019); Rajiwall, Chetty & Davey (2017)
Emergency Department	Hu et al (2017); Raito et al (2019)
Staffing Levels/Patient Outcomes	Leary et al (2016); Zampieri et al (2019)
Miscellaneous	Chu et al (2018); Chung & Jung (2019); Hever et al (2020); Kuo et al (2019); Khaldi et al (2017); Martinez-Millana et al (2019); Parisi, RaviChandran & Manaog (2018); Yamashita et al (2019); Zachariadis et al (2018)

DISCUSSION

A number of interesting insights can be drawn from the documents analyzed for this project. The first is driven by the types of studies published. Overall, 77 papers in the sample were strickly theoretical or prescriptive in nature, in that the purpose of the study is to either describe an opportunity, describe a need, or to provide an overall description of some aspect of the topic at hand. This means that the remaining papers fell into one of three categories (again, with some overlap):

- Papers that provide a design, framework, or model for a proposed system or tool (62 papers);
- Papers that describe the implementation of a system or tool, either at a prototype or production level of development (27 papers);
- Papers that perform some form of empirical analysis (61 papers).

The high number of design-based papers displays the level of energy being applied to creating systems and tools to improve the administration of healthcare organizations. More importantly, 27 papers discuss the actual implementation of some of these designs so that they can be evaluated for effectivenenss and demonstrated to the key stakeholders in the medical fields. There are a number of implemented systems that provide key capabilities. These include a tool to increase accuracy and efficiency of medical coding using MongoDB (Noussa-Yao et al, 2018), a cloud-based medical equipment management tool that has been implemented in a number of Greek hospitals (Katrakazas et al, 2018), and Rivera and Delaney's (2015) description of a performance management tool at an Orlando hospital. Each of these implementation descriptions provide valuable insight into what has already been done in this field and provide a guide as to what can be done with future research.

The amount of empirical papers included in the study largely consists of analyses of various aspects of healthcare management (e.g. patient stay prediction) that have been completed using some form of machine learning. In many cases, these studies center on the comparison of multiple machine learning models to see which one created a more accurate prediction. In very view of these papers do the authors apply empirical methods to study the actual usage of Big Data tools in the healthcare administration.

There was an almost even split between papers that centered on technology solutions, resource management, and hospital management. Those efforts regarding patient outcomes showed a relatively distant fourth. This might be due to a lack of interest in the topic, but more likely it has other roots. First, many systems that seek to improve patient outcomes would have been excluded from the study because they would have been primarily clinical in nature, which was one of the gates used to define this particular study. The papers included in the study were focused on management processes that influence patient outcomes, but it is possible that the clinically-focused papers would also have some management themes within them. Also, since the overall reason for the application of Big Data technologies is to improve the services provided to patients, it is entirely reasonable that the papers ending up in the other three categories could also be considered to be "patient outcomes" papers, as well.

The last point to be considered in this body of literature is that while the technological and analytical aspects of healthcare administration have been well covered, there has been relatively little discussion of any changes in organizational processes to adapt to these new tools or to take advantage of them. Many authors discussed the organizational issues at hand when providing justification of their new systems or analyses, but the repercussions for the organization were seldom fully considered. Thus, there appears to be much opportunity for fruitful research to consider how these, and other, data-centric tools might be reflected in the personnel and procedures in the organization.

CONCLUSION

This analysis provides a detailed overview of the literature surrounding the application of Big Data Technologies, as defined in the beginning of the paper, to the administrative functions of the healthcare industry. By completing this review, the paper makes two contributions to the literature. First, it should serve as a starting point for future researchers to select the organizational area to address as well as lending assistance in the selection of methodology and approach. As noted above, there is a need for a deeper look into the inner workings of the organization as these tools are implemented, including an analysis of implementation techniques to understand the level of involvement of the clinical and administration staff, as well as developing a deeper understanding of the changes in information flow, usage, and control as this new paradigm continues to mature. Moreover, because of the scale of the present study, there was not sufficient space to provide any significant level of detail regarding the strengths and contributions of each paper or a more indepth analysis of those papers that could have been categorized into multiple themes. These, and other research questions such as the contributions of Big Data technologies to the improvement of healthcare performance or the reduction of healthcare costs are fruitful areas for future research that the present paper forms a foundation for.

The second contribution of this study is to inform practitioners and administrators in the healthcare industry of the areas of emphasis that are consuming research resources. In some cases, we see significant involvement by clinical and administrative staff in these papers as coauthors and sources of information, but there is always room for more interdisciplinary research and hopefully studies such as this will provide a strong foundation for those efforts.

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