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Review and Analysis on Healthcare Analytics Transforming Patient Care with Data Insights

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ABSTRACT

The introduction of Big Data Analytics (BDA) in healthcare will allow to use new technologies both in treatment of patients and health management. The paper aims at analyzing the possibilities of using Big Data Analytics in healthcare. The research is based on a critical analysis of the literature, as well as the presentation of selected results of direct research on the use of Big Data Analytics in medical facilities. The direct research was carried out based on research questionnaire and conducted on a sample of 217 medical facilities in Poland. Literature studies have shown that the use of Big Data Analytics can bring many benefits to medical facilities, while direct research has shown that medical facilities in Poland are moving towards data-based healthcare because they use structured and unstructured data, reach for analytics in the administrative, business and clinical area. The research positively confirmed that medical facilities are working on both structural data and unstructured data. The following kinds and sources of data can be distinguished: from databases, transaction data, unstructured content of emails and documents, data from devices and sensors. However, the use of data from social media is lower as in their activity they reach for analytics, not only in the administrative and business but also in the clinical area. It clearly shows that the decisions made in medical facilities are highly data-driven. The results of the study confirm what has been analyzed in the literature that medical facilities are moving towards data-based healthcare, together with its benefits.

Keywords: Big Data Analytics (BDA), Medical facilities, Data Analytics, Healthcare.

INTRODUCTION

The main contribution of this paper is to present an analytical overview of using structured and unstructured data (Big Data) analytics in medical facilities in Poland. Medical facilities use both structured and unstructured data in their practice. Structured data has a predetermined schema, it is extensive, freeform, and comes in variety of forms [1]. In contrast, unstructured data, referred to as Big Data (BD), does not fit into the typical data processing format. Big Data is a massive amount of data sets that cannot be stored, processed, or analyzed using traditional tools. It remains stored but not analyzed. Due to the lack of a well-defined schema, it is difficult to search and analyze such data and, therefore, it requires a specific technology and method to transform it into value [2]. Integrating data stored in both structured and unstructured formats can add significant value to an organization [3]. Organizations must approach unstructured data in a different way. Therefore, the potential is seen in Big Data Analytics (BDA). Big Data Analytics are techniques and tools used to analyze and extract information from Big Data. The results of Big Data analysis can be used to predict the future. They also help in creating trends about the past. When it comes to healthcare, it allows to analyze large datasets from thousands of patients, identifying clusters and correlation between datasets, as well as developing predictive models using data mining techniques.

The first part consists of a brief literature review of studies on Big Data (BD) and Big Data Analytics (BDA), while the second part presents results of direct research aimed at diagnosing the use of big data analyses in medical facilities in Poland.

Healthcare is a complex system with varied stakeholders: patients, doctors, hospitals, pharmaceutical companies and healthcare decision-makers. This sector is also limited by strict rules and regulations. However, worldwide one may observe a departure from the traditional doctor-patient approach. The doctor becomes a partner and the patient is involved in the therapeutic process. Healthcare is no longer focused solely on the treatment of patients. The priority for decision-makers should be to promote proper health attitudes and prevent diseases that can be avoided. This became visible and important especially during the Covid-19 pandemic [4].

The next challenges that healthcare will have to face is the growing number of elderly people and a decline in fertility. Fertility rates in the country are found below the reproductive minimum necessary to keep the population stable. The reflection of both effects, namely the increase in age and lower fertility rates, are demographic load

indicators, which is constantly growing. Forecasts show that providing healthcare in the form it is provided today will become impossible in the next 20 years. It is especially visible now during the Covid-19 pandemic when healthcare faced quite a challenge related to the analysis of huge data amounts and the need to identify trends and predict the spread of the coronavirus. The pandemic showed it even more that patients should have access to information about their health condition, the possibility of digital analysis of this data and access to reliable medical support online. Health monitoring and cooperation with doctors in order to prevent diseases can actually revolutionize the healthcare system. One of the most important aspects of the change necessary in healthcare is putting the patient in the center of the system.

LITERATURE SURVEY

Technology is not enough to achieve these goals. Therefore, changes should be made not only at the technological level but also in the management and design of complete healthcare processes and what is more, they should affect the business models of service providers. The use of Big Data Analytics is becoming more and more common in enterprises [5]. However, medical enterprises still cannot keep up with the information needs of patients, clinicians, administrators and the creator's policy. The adoption of a Big Data approach would allow the implementation of personalized and precise medicine based on personalized information, delivered in real time and tailored to individual patients.

To achieve this goal, it is necessary to implement systems that will be able to learn quickly about the data generated by people within clinical care and everyday life. This will enable data-driven decision making, receiving better personalized predictions about prognosis and responses to treatments; a deeper understanding of the complex factors and their interactions that influence health at the patient level, the health system and society, enhanced approaches to detecting safety problems with drugs and devices, as well as more effective methods of comparing prevention, diagnostic, and treatment options [6].

In the literature, there is a lot of research showing what opportunities can be offered to companies by big data analysis and what data can be analyzed. However, there are few studies showing how data analysis in the area of healthcare is performed, what data is used by medical facilities and what analyses and in which areas they carry out. This paper aims to fill this gap by presenting the results of research carried out in medical facilities in Poland. The goal is to analyze the possibilities of using Big Data Analytics in healthcare, especially in Polish conditions. In particular, the paper is aimed at determining what data is processed by medical facilities in Poland, what analyses they perform and in what areas, and how they assess their analytical maturity. In order to achieve this goal, a critical analysis of the literature was performed, and the direct research was based on a research questionnaire conducted on a sample of 217 medical facilities in Poland. It was hypothesized that medical facilities in Poland are working on both structured and unstructured data and moving towards data-based healthcare and its benefits. Examining the maturity of healthcare facilities in the use of Big Data and Big Data Analytics is crucial in determining the potential future benefits that the healthcare sector can gain from Big Data Analytics. There is also a pressing need to predicate whether, in the coming years, healthcare will be able to cope with the threats and challenges it faces.

This paper is divided into eight parts. The first is the introduction which provides background and the general problem statement of this research. In the second part, this paper discusses considerations on use of Big Data and Big Data Analytics in Healthcare, and then, in the third part, it moves on to challenges and potential benefits of using Big Data Analytics in healthcare. The next part involves the explanation of the proposed method. The result of direct research and discussion are presented in the fifth part, while the following part of the paper is the conclusion. The seventh part of the paper presents practical implications. The final section of the paper provides limitations and directions for future research.

CONSIDERATIONS ON USE BIG DATA AND BIG DATA ANALYTICS IN THE HEALTHCARE

In recent years one can observe a constantly increasing demand for solutions offering effective analytical tools. This trend is also noticeable in the analysis of large volumes of data (Big Data, BD). Organizations are looking for ways to use the power of Big Data to improve their decision making, competitive advantage or business performance [7]. Big Data is considered to offer potential solutions to public and private organizations, however, still not much is known about the outcome of the practical use of Big Data in different types of organizations.

As already mentioned, in recent years, healthcare management worldwide has been changed from a disease-centered model to a patient-centered model, even in value-based healthcare delivery model. In order to meet the requirements of this model and provide effective patient-centered care, it is necessary to manage and analyze healthcare Big Data.

The issue often raised when it comes to the use of data in healthcare is the appropriate use of Big Data. Healthcare has always generated huge amounts of data and nowadays, the introduction of electronic medical records, as well as the huge amount of data sent by various types of sensors or generated by patients in social media causes data streams to constantly grow. Also, the medical industry generates significant amounts of data, including clinical records, medical images, genomic data and health behaviors. Proper use of the data will allow healthcare organizations to support clinical decision-making, disease surveillance, and public health management. The challenge posed by clinical data processing involves not only the quantity of data but also the difficulty in processing it.

In the literature one can find many different definitions of Big Data. This concept has evolved in recent years; however, it is still not clearly understood. Nevertheless, despite the range and differences in definitions, Big Data can be treated as a: large amount of digital data, large data sets, tool, technology or phenomenon (cultural or technological.

Big Data can be considered as massive and continually generated digital datasets that are produced via interactions with online technologies [8]. Big Data can be defined as datasets that are of such large sizes that they pose challenges in traditional storage and analysis techniques. A similar opinion about Big Data was presented by Ohlhorst who sees Big Data as extremely large data sets, possible neither to manage nor to analyze with traditional data processing tools. In his opinion, the bigger the data set, the more difficult it is to gain any value from it.

In turn, Knapp perceived Big Data as tools, processes and procedures that allow an organization to create, manipulate and manage very large data sets and storage facilities [9]. From this point of view, Big Data is identified as a tool to gather information from different databases and processes, allowing users to manage large amounts of data.

Similar perception of the term 'Big Data' is shown by Carter. According to him, Big Data technologies refer to a new generation of technologies and architectures, designed to economically extract value from very large volumes of a wide variety of data by enabling high velocity capture, discovery and/or analysis.

Jordan combines these two approaches by identifying Big Data as a complex system, as it needs data bases for data to be stored in, programs and tools to be managed, as well as expertise and personnel able to retrieve useful information and visualization to be understood.

Following the definition of Laney for Big Data, it can be state that: it is large amount of data generated in very fast motion and it contains a lot of content [10]. Such data comes from unstructured sources, such as stream of clicks on the web, social networks (Twitter, blogs, Facebook), video recordings from the shops, recording of calls in a call center, real time information from various kinds of sensors, RFID, GPS devices, mobile phones and other devices that identify and monitor something. Big Data is a powerful digital data silo, raw, collected with all sorts of sources, unstructured and difficult, or even impossible, to analyze using conventional techniques used so far to relational databases.

Therefore, the potential is seen in Big Data analyses, especially in the aspect of improving the quality of medical care, saving lives or reducing costs. Extracting from this tangle of given association rules, patterns and trends will allow health service providers and other stakeholders in the healthcare sector to offer more accurate and more insightful diagnoses of patients, personalized treatment, monitoring of the patients, preventive medicine, support of medical research and health population, as well as better quality of medical services and patient care while, at the same time, the ability to reduce costs

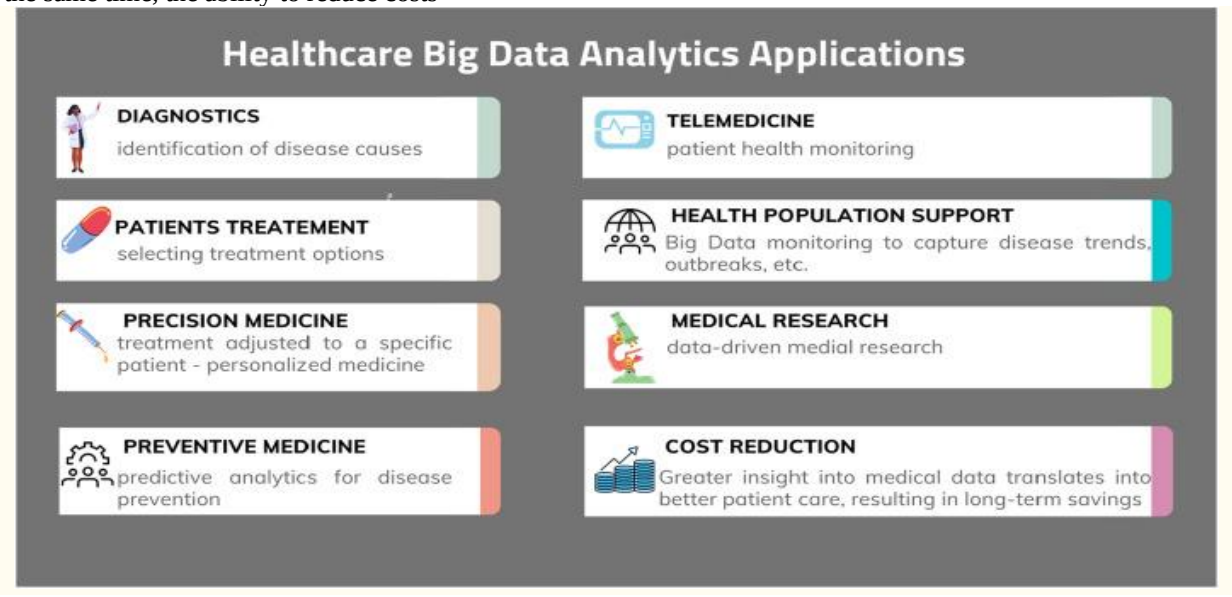

Figure 1: Healthcare Big Data Analytics applications

The main challenge with Big Data is how to handle such a large amount of information and use it to make data-driven decisions in plenty of areas [11]. In the context of healthcare data, another major challenge is to adjust big data storage, analysis, presentation of analysis results and inference basing on them in a clinical setting. Data analytics systems implemented in healthcare are designed to describe, integrate and present complex data in an appropriate way so that it can be understood better (Fig. 2). This would improve the efficiency of acquiring, storing, analyzing and visualizing big data from healthcare.

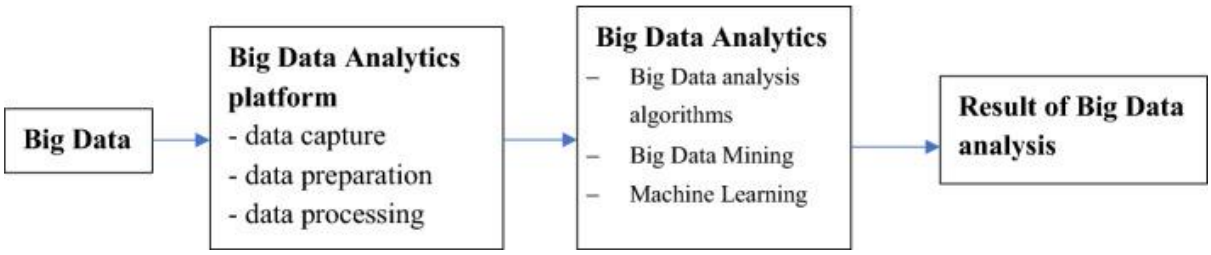

Figure 2: Process of Big Data Analytics

The result of data processing with the use of Big Data Analytics is appropriate data storytelling which may contribute to making decisions with both lower risk and data support. This, in turn, can benefit healthcare stakeholders. To take advantage of the potential massive amounts of data in healthcare and to ensure that the right intervention to the right patient is properly timed, personalized, and potentially beneficial to all components of the healthcare system such as the payer, patient, and management, analytics of large datasets must connect communities involved in data analytics and healthcare informatics. Big Data Analytics can provide insight into clinical data and thus facilitate informed decision-making about the diagnosis and treatment of patients, prevention of diseases or others. Big Data Analytics can also improve the efficiency of healthcare organizations by realizing the data potential [12].

Big Data Analytics in medicine and healthcare refers to the integration and analysis of a large amount of complex heterogeneous data, such as various omics (genomics, epigenomics, transcriptomics, proteomics, metabolomics, interactomics, pharmacogenetics, deasomics), biomedical data, talemedicine data (sensors, medical equipment data) and electronic health records data [13].

When analyzing the phenomenon of Big Data in the healthcare sector, it should be noted that it can be considered from the point of view of three areas: epidemiological, clinical and business.

From a clinical point of view, the Big Data analysis aims to improve the health and condition of patients, enable long-term predictions about their health status and implementation of appropriate therapeutic procedures. Ultimately, the use of data analysis in medicine is to allow the adaptation of therapy to a specific patient, that is personalized medicine (precision, personalized medicine). From an epidemiological point of view, it is desirable to obtain an accurate prognosis of morbidity in order to implement preventive programs in advance.

In the business context, Big Data analysis may enable offering personalized packages of commercial services or determining the probability of individual disease and infection occurrence. It is worth noting that Big Data means not only the collection and processing of data but, most of all, the inference and visualization of data necessary to obtain specific business benefits.

In order to introduce new management methods and new solutions in terms of effectiveness and transparency, it becomes necessary to make data more accessible, digital, searchable, as well as analyzed and visualized.

Erickson and Rothberg state that the information and data do not reveal their full value until insights are drawn from them. Data becomes useful when it enhances decision making and decision making is enhanced only when analytical techniques are used and an element of human interaction is applied [14].

Thus, healthcare has experienced much progress in usage and analysis of data. A large-scale digitalization and transparency in this sector is a key statement of almost all countries governments policies. For centuries, the treatment of patients was based on the judgment of doctors who made treatment decisions. In recent years, however, Evidence-Based Medicine has become more and more important as a result of it being related to the systematic analysis of clinical data and decision-making treatment based on the best available information. In the healthcare sector, Big Data Analytics is expected to improve the quality of life and reduce operational costs. Big Data Analytics enables organizations to improve and increase their understanding of the information contained in data. It also helps identify data that provides insightful insights for current as well as future decisions [15].

Big Data Analytics refers to technologies that are grounded mostly in data mining: text mining, web mining, process mining, audio and video analytics, statistical analysis, network analytics, social media analytics and web analytics. Different data mining techniques can be applied on heterogeneous healthcare data sets, such as: anomaly

detection, clustering, classification, association rules as well as summarization and visualization of those Big Data sets [16]. Modern data analytics techniques explore and leverage unique data characteristics even from high-speed data streams and sensor data. Big Data can be used, for example, for better diagnosis in the context of comprehensive patient data, disease prevention and telemedicine (in particular when using real-time alerts for immediate care), monitoring patients at home, preventing unnecessary hospital visits, integrating medical imaging for a wider diagnosis, creating predictive analytics, reducing fraud and improving data security, better strategic planning and increasing patients' involvement in their own health.

Big Data Analytics in healthcare can be divided into:

[1]. Descriptive analytics in healthcare is used to understand past and current healthcare decisions, converting data into useful information for understanding and analysing healthcare decisions, outcomes and quality, as well as making informed decisions. It can be used to create reports (i.e. about patients' hospitalizations, physicians' performance, utilization management), visualization, customized reports, drill down tables, or running queries on the basis of historical data.

[2]. Predictive analytics operates on past performance in an effort to predict the future by examining historical or summarized health data, detecting patterns of relationships in these data, and then extrapolating these relationships to forecast. It can be used to i.e. predict the response of different patient groups to different drugs (dosages) or reactions (clinical trials), anticipate risk and find relationships in health data and detect hidden patterns. In this way, it is possible to predict the epidemic spread, anticipate service contracts and plan healthcare resources. Predictive analytics is used in proper diagnosis and for appropriate treatments to be given to patients suffering from certain diseases [17].

[3]. Prescriptive analytics—occurs when health problems involve too many choices or alternatives. It uses health and medical knowledge in addition to data or information. Prescriptive analytics is used in many areas of healthcare, including drug prescriptions and treatment alternatives. Personalized medicine and evidence-based medicine are both supported by prescriptive analytics.

[4]. Discovery analytics—utilizes knowledge about knowledge to discover new "inventions" like drugs (drug discovery), previously unknown diseases and medical conditions, alternative treatments, etc.

Advanced analytical techniques can be used for a large amount of existing (but not yet analytical) data on patient health and related medical data to achieve a better understanding of the information and results obtained, as well as to design optimal clinical pathways. Big Data Analytics in healthcare integrates analysis of several scientific areas such as bioinformatics, medical imaging, sensor informatics, medical informatics and health informatics. Big Data Analytics in healthcare allows to analyze large datasets from thousands of patients, identifying clusters and correlation between datasets, as well as developing predictive models using data mining techniques. Discussing all the techniques used for Big Data Analytics goes beyond the scope of a single article.

The success of Big Data analysis and its accuracy depend heavily on the tools and techniques used to analyze the ability to provide reliable, up-to-date and meaningful information to various stakeholders [18]. It is believed that the implementation of big data analytics by healthcare organizations could bring many benefits in the upcoming years, including lowering health care costs, better diagnosis and prediction of diseases and their spread, improving patient care and developing protocols to prevent re-hospitalization, optimizing staff, optimizing equipment, forecasting the need for hospital beds, operating rooms, treatments, and improving the drug supply chain.

Healthcare organizations see the opportunity to grow through investments in Big Data Analytics. In recent years, by collecting medical data of patients, converting them into Big Data and applying appropriate algorithms, reliable information has been generated that helps patients, physicians and stakeholders in the health sector to identify values and opportunities. It is worth noting that there are many changes and challenges in the structure of the healthcare sector. Digitization and effective use of Big Data in healthcare can bring benefits to every stakeholder in this sector. A single doctor would benefit the same as the entire healthcare system. Potential opportunities to achieve benefits and effects from Big Data in healthcare can be divided into four groups:

[1]. Improving the quality of healthcare services:

A. assessment of diagnoses made by doctors and the manner of treatment of diseases indicated by them based on the decision support system working on Big Data collections,

B. detection of more effective, from a medical point of view, and more cost-effective ways to diagnose and treat patients,

C. analysis of large volumes of data to reach practical information useful for identifying needs, introducing new health services, preventing and overcoming crises,

D. prediction of the incidence of diseases,

E. detecting trends that lead to an improvement in health and lifestyle of the society,
F. analysis of the human genome for the introduction of personalized treatment.

[2.] Supporting the work of medical personnel

A. doctors' comparison of current medical cases to cases from the past for better diagnosis and treatment adjustment,
B. detection of diseases at earlier stages when they can be more easily and quickly cured,
C. detecting epidemiological risks and improving control of pathogenic spots and reaction rates,
D. identification of patients who are predicted to have the highest risk of specific, life-threatening diseases by collating data on the history of the most common diseases, in healing people with reports entering insurance companies,
E. health management of each patient individually (personalized medicine) and health management of the whole society,
F. capturing and analyzing large amounts of data from hospitals and homes in real time, life monitoring devices to monitor safety and predict adverse events,
G. analysis of patient profiles to identify people for whom prevention should be applied, lifestyle change or preventive care approach,
H. the ability to predict the occurrence of specific diseases or worsening of patients' results,
I. predicting disease progression and its determinants, estimating the risk of complications,
J. detecting drug interactions and their side effects.

[3]. Supporting scientific and research activity

A. supporting work on new drugs and clinical trials thanks to the possibility of analyzing "all data" instead of selecting a test sample,
B. the ability to identify patients with specific, biological features that will take part in specialized clinical trials,
C. selecting a group of patients for which the tested drug is likely to have the desired effect and no side effects,
D. using modeling and predictive analysis to design better drugs and devices.

[4]. Business and management

A. reduction of costs and counteracting abuse and counseling practices,
B. faster and more effective identification of incorrect or unauthorized financial operations in order to prevent abuse and eliminate errors,
C. increase in profitability by detecting patients generating high costs or identifying doctors whose work, procedures and treatment methods cost the most and offering them solutions that reduce the amount of money spent,
D. identification of unnecessary medical activities and procedures, e.g. duplicate tests.

According to research conducted by Wang, Kung and Byrd, Big Data Analytics benefits can be classified into five categories: IT infrastructure benefits (reducing system redundancy, avoiding unnecessary IT costs, transferring data quickly among healthcare IT systems, better use of healthcare systems, processing standardization among various healthcare IT systems, reducing IT maintenance costs regarding data storage), operational benefits (improving the quality and accuracy of clinical decisions, processing a large number of health records in seconds, reducing the time of patient travel, immediate access to clinical data to analyze, shortening the time of diagnostic test, reductions in surgery-related hospitalizations, exploring inconceivable new research avenues), organizational benefits (detecting interoperability problems much more quickly than traditional manual methods, improving cross-functional communication and collaboration among administrative staffs, researchers, clinicians and IT staffs, enabling data sharing with other institutions and adding new services, content sources and research partners), managerial benefits (gaining quick insights about changing healthcare trends in the market, providing members of the board and heads of department with sound decision-support information on the daily clinical setting, optimizing business growth-related decisions) and strategic benefits (providing a big picture view of treatment delivery for meeting future need, creating high competitive healthcare services).

The above specification does not constitute a full list of potential areas of use of Big Data Analysis in healthcare because the possibilities of using analysis are practically unlimited. In addition, advanced analytical tools allow to analyze data from all possible sources and conduct cross-analyses to provide better data insights. For example, a cross-analysis can refer to a combination of patient characteristics, as well as costs and care results that can help identify the best, in medical terms, and the most cost-effective treatment or treatments and this may allow a better adjustment of the service provider's offer.

In turn, the analysis of patient profiles (e.g. segmentation and predictive modeling) allows identification of people who should be subject to prophylaxis, prevention or should change their lifestyle. Shortened list of benefits for Big Data Analytics in healthcare is presented in paper and consists of: better performance, day-to-day guides, detection of diseases in early stages, making predictive analytics, cost effectiveness, Evidence Based Medicine and effectiveness in patient treatment.

Summarizing, healthcare big data represents a huge potential for the transformation of healthcare: improvement of patients' results, prediction of outbreaks of epidemics, valuable insights, avoidance of preventable diseases, reduction of the cost of healthcare delivery and improvement of the quality of life in general. Big Data also generates many challenges such as difficulties in data capture, data storage, data analysis and data visualization [19]. The main challenges are connected with the issues of: data structure (Big Data should be user-friendly, transparent, and menu-driven but it is fragmented, dispersed, rarely standardized and difficult to aggregate and analyze), security (data security, privacy and sensitivity of healthcare data, there are significant concerns related to confidentiality), data standardization (data is stored in formats that are not compatible with all applications and technologies), storage and transfers (especially costs associated with securing, storing, and transferring unstructured data), managerial skills, such as data governance, lack of appropriate analytical skills and problems with Real-Time Analytics (health care is to be able to utilize Big Data in real time) [20].

CONCLUSION

The quantitative analysis of the research carried out and presented in this article made it possible to determine whether medical facilities in Poland use Big Data Analytics and if so, in which areas. Thanks to the results obtained it was possible to formulate the following conclusions. Medical facilities are working on both structured and unstructured data, which comes from databases, transactions, unstructured content of emails and documents, devices and sensors. According to analytics, they reach for analytics in the administrative and business, as well as in the clinical area. It clearly showed that the decisions made are largely data-driven. The results of the study confirm what has been analyzed in the literature. Medical facilities are moving towards data-based healthcare and its benefits.

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