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Role of Big Data in Healthcare with Non-Invasive and Minimal Invasive Medical Imaging Modality

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ABSTRACT: The stacks of global healthcare data are increasing exponentially. To supply high value healthcare at lower cost there is a need felt in the direction of implementing successful big data analytics practice to find insight from very large data sets and improving coordination, care quality and outcomes through improved analytics of healthcare big data. The medical records such as nursing observation, reading of patient tests, Doctor's prescription and images are very functional in discovering important patterns relating to diagnoses and disease treatments. Big data in healthcare has big potential; however there remain some challenges to overcome. Healthcare data analytics is continuously improving but there is a need of more efforts because advanced data integration and data analytics techniques are only theoretically exist. This paper defines big data characteristics, advantages of big data, tools and technologies, life cycle phases to big data, challenges of big data in healthcare. The paper also provides a brief description on non-invasive and minimal- invasive medical imaging modalities such as MRI, CT scan, X ray imaging, ultrasonography and PET scan.

KEYWORDS: Big data, Healthcare, Analytics tools Non-invasive, Minimal- invasive.

I. INTRODUCTION

Big Data referred to as massive amount of high velocity, complex and variable data that exceed the abilities of traditional data processing systems to acquire, store, analyze and process it and require advance analysis technologies to manage these challenges [8]. Big data is an important concept used to define a tremendous volume of both unstructured and structured data [11]. Big data is different from traditional data in many ways: volume (size of data), velocity (speed of data creation) and variety (diversity in data types). To improve the decision making process we need right technologies to collect, manage and store the large variety of data sets from different sources and find out hidden patterns and unknown correlations [1, 11].

Healthcare (very responsive industry since information related to health is very critical) is the most promising area where big data can be applied to make a change in human life. Healthcare industry usually has generating large amounts of data. As we all know historically the data stored in hard copies but nowadays there is a rapid digitization of this massive amount of stored data [16]. This big data analysis holds a broad collection of medical and healthcare applications for example- public health management, clinical assessment, and disease scrutiny.It is known as healthcare big data analytics. Analytics of healthcare data has the power to decrease the costs of treatment, improve care, save lives and also improve the quality of life.

Today we are floating in "Data Ocean". In other words data is being collected at unexpected scale. Data comes from many sources: web and social media data, human generated data, machine generates data (sensors, RFID, devices), scientific data (astronomy, physics, genomes), spatial data (long/lat coordinates, GPS output) and medical data and biometric data etc. Big data in healthcare is very vast because of data volume and variety of data types [8]. U.S.

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government report say that the healthcare system in U.S. alone reached, in 2011, 150 Exabyte's and also one day the data will reach the yottabyte (10^{24} gigabytes) [1, 19]. There is so large and complex electronic data sets in healthcare and these complex data sets are not possible to handle and analyze with traditional software and hardware technologies.

In 2010 there were 5 billion smart phones in use, in each month 30 billion pieces of contents shared on facebook. At the global level the available digital data exceeds from 150 Exabyte's in 2005 to 1200 Exabyte's in 2010. This growth of digital data means that the available data will increase 44 times between 2007 and 2020 means doubling-up every 20 months

II. SEVEN STACKS OF BIG DATA

More and more data format is multimedia. Semi structured, structured and unstructured data are the dimensions that makes the healthcare data more challenging [7]. Size of the big data is primary attribute to define but big data isn't just about data volume. Big data can be defined by following characteristics (7Vs):-

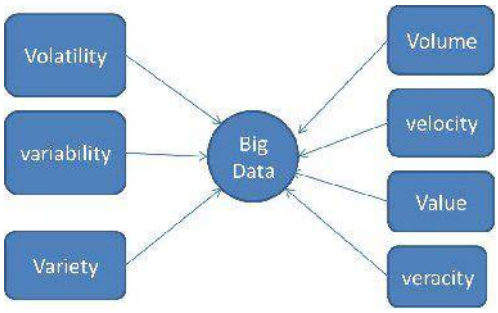

Fig 1: Big Data Characteristics

Volume: - (Quantity of data, terabytes to zettabyte) [12, 14] Health related data produced and accumulated continuously and create unthinkable amount of data. New form of data for e.g., biometric sensor readings, 3D imaging and genomics etc are growing rapidly.

Velocity: - (Pace of data generation) [9] Real time data growing at very high rate. Traditionally healthcare is static [14]. Constant rate of new data creation presents new challenges [7] in data collection, data storage, analysis, modeling and data delivery.

Value: - It refers to the process of finding hidden values from huge amount of data sets [1]. ***Veracity***: - (meaningfulness) it refers to the 'data assurance' and 'data trust' [14]. Veracity is the goal of data analytics. Because healthcare is data highly unstructured and has the total concern with life and death, so data quality and correctness is the main issue.

Variety: - (Multiplicity in data formats) [9] refers to the complexity and heterogeneity of healthcare data. Healthcare data increases due to the digitization of existing data and from new generated data [14].

Variability: - means complexity and the data whose meaning is constantly changing and variation in data flow rates.

Volatility: - It refers to the data validity and longitivity means how long data will be useful for us and it is also important to know when the data is no longer appropriate for processing and analysis [18].

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III. LIFECYCLE OF BIG DATA

Data capture/collection-It includes data gathering from various data sources. Data collection involves data analysis and understanding of healthcare data needed for improving public health and evaluating public health prevention programs [12].

Data cleaning- To differentiate between anomaly and insight, data must be cleaned. The junk data must be removed [12].

Data classification- To perform meaningful analysis data must be classified into images, structured and unstructured. For example healthcare data consist of lots of unstructured data [12]. ***Data modeling***- In this phase analysis is done on classified data. For example government may need the record of swine flu caught people in Jaipur. Firstly the data has to classify based on the location and these data will be processed [12].

Data delivery-It includes report creation based on data modeling done. It will produce a report based on swine flu caught people in Jaipur. This report will help the government to take required action to improve the public health [12]. At every big data lifecycle stages there must be a need of access control, data integrity and data storage.

IV. BIG DATA SAVE BIG DOLLAR IN HEALTHCARE

Possible benefits of big data analytics in healthcare include disease treatment more easily and effectively at earlier stages, reducing healthcare fraud and managing individual and public health [7].

According to McKinsey analytics of big data offers extra $300 billion money per year in U.S. healthcare, and reduces approximately 8% in national expenditure. McKinsey believes that big data analytics will reduce inefficiency mainly in three areas- Clinical operations, research and development and public health [7]. Healthcare system considered as a patient centric or holistic framework consisting 5 key pathways to value

The new value pathways:-

***Right Care*:** Through this pathway of healthcare we ensure that patients get the most suitable treatment in right time with safety. Additionally it is also called evidence based care which requires coordinated approach that provides required outcomes for each patient [10].

***Right Living*:** Right living pathway is all about consumer or patients own interest in self care or treatment by being actively engaged, including disease prevention, which helps them to remain healthy and fit [10].

***Right value*:** Payers and providers will endlessly augment healthcare worth to accomplish the purpose of this pathway along with improvement and preservation of quality. For ensuring cost effectiveness of care, right value analysis includes several measures [10].

***Right providers*:** This pathway involves ensuring that patients should always be medicated or treated by the experts (i.e. professionals) that are perfect in their work and provide better outcomes. Right providers (e.g. Nurse, physician, assistants) with their expert skills are the finest match to deliver approved medical impacts [10].

***Right innovation*:** to deliver the care across all aspects of healthcare system, the right innovation pathway identifies some new approaches and therapies by advancing medication and boosting R&D efficiency in development, discovery and safety [10].

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V. HEALTHCARE DATA ANALYTICS

Healthcare data is devastating not because of its vast quantity but also because of multiplicity in data types and pace of data generation. The big data analytics framework in healthcare is same as the traditional health analytics. The difference is only how its processing is executed. The distributed processing concept has been used for decades.

Hadoop/MapReduce is open source platform used in healthcare big data analytics. The methods, models and algorithms are similar, but the user interface is different from traditional analytics process [7]. Traditional health data analytics tools were very user friendly and clear. The tools and platforms for health data analytics are mostly open source and there is limitations of support and user friendliness, also require complex, programming intensive and different types of skills [7]. The diagram shows the complexity of data itself:-

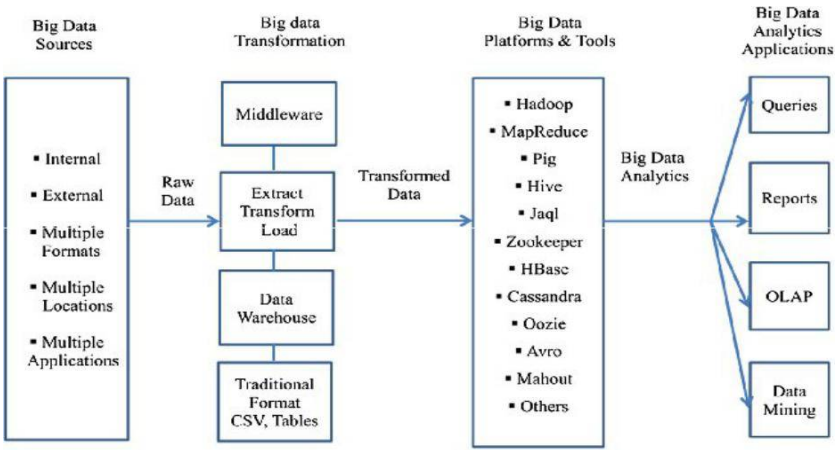

Fig 2_Raghupathi: Healthcare data analytics architecture [7]

Healthcare big data can be collected from internal (e.g., HER report, doctor prescription etc) and external sources (e.g., laboratories, government departments etc) and has different-different data formats (e.g., text, video, audio, images, flat files, relational tables etc) and also reside at multiple places because there is many healthcare providers [7].

At the second level data is in 'raw' form and necessary to perform analysis on raw data, at this point many options (middleware, ETL, data warehouse etc) are available. Data in this step various data sources are integrated and made prepared for analysis. With the help of ETL steps data from different sources is cleansed depending on data types [7].

Next component is data analysis framework; based on the input data, tools and analytics models, many decisions are made and finally four classic big data analytics applications o are retrieved-queries ,OLAP, reports, and data mining [7]. The popular and effective podium for analytics of big data in healthcare is distributed open source data processing framework "Hadoop", it belongs to the "NoSql" technologies.

Hadoop is a feasible platform to process on tremendously quantity of data by allowing partition of data sets on number of nodes, each node process on distinct parts of bigger problem and then aggregate them to produce result [11]. It offers industries to harness of the data that has been, until now, impossible to process and manage.

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Platform/Tool	Description
HDFS (Hadoop distributed file system)	Hadoop is distributed file system that enables the storage of giant file in the form of Hadoop cluster. It scattered the data into smaller chunks and distributes it among different nodes/servers.
HBase	The column based distributed database management system relies as top layer of HDFS responsible for providing quick random access to huge quantity of structured data.
MapReduce	It is distributed programming software which enables the distribution of subtasks and collection of final results after process where each server node is tracked by MapReduce.
Hive	To process the structured data in Hadoop with SQL, Hive comes into picture as a runtime Architecture. It is not a relational database; it is intended for online transaction processing (OLTP).
PIG and PIG Latin	To incorporate all types of data (both unstructured and structured), PIG is configured as programming language. Generally it is comprised of two modules, first is the language itself known as PIG Latin and second one is the runtime environment in which the code (written in PIG Latin) is run or executed.
Zookeeper	Zookeeper is used to coordinating and managing various services involving synchronization across a huddle of several nodes, which is a big issue in big data analytics. These services are helpful in big data analysis for coordinate parallel processing across big data clusters.
Jaql	It is functional, declarative query programming language for JavaScript Object Notation (JSON) designed to process huge datasets.
Cassandra	It is a distributed database system based on NoSQL, designed to manage or handle big data distribution across a number of nodes/servers. Cassandra provides reliability as well as it is fault tolerant (with no particular point of failure while provides reliable services).
Lucene	The purpose of Lucene project is to use it for text analytics and searches. To use full text indexing and library search in java based application has been included in its scope. This project has been integrated into numerous open source projects.
Oozie	Oozie project is responsible for coordinating the tasks and Streamlines the flow of work. It is also an open source project.
Avro	Avro facilitates several features: version control, versioning and Serialization services are some of them.
Mahout	The goal of this apache project is to create scalable machine Learning algorithm and distributed free applications supported by big data analytics.

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VI. CHALLENGES

The key requirement in healthcare is the big data analytics in real time. In the awash of data in healthcare, it is necessary to analyze or manage the processed data in a proper manner so that only meaningful or useful data and patterns can be kept [17]. Generally in the process of data analytics, only the analysis phase is to be focused, while different phases like acquisition, cleaning, integration etc. involves some challenges and issues with them [17]. There are some great dealing challenges regarding healthcare: Integrating multi source data, data cleaning, non uniformity, multiple instances for unique patients.

Big data challenges can be divided into three categories:-

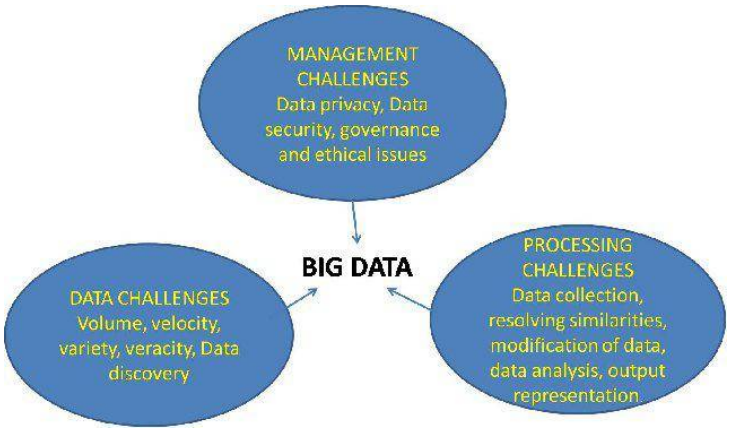

Fig 3_Chinchmalatpure: Big Data Challenges [13]

VII.NON-INVASIVE AND MINIMAL INVASIVE MEDICAL IMAGING MODALITY

A. *Magnetic Resonance Imaging (MRI):*

To record the internal structure and some portion of function in the body, a non-invasive imaging modality, MRI is significantly used. MRI is a spectroscopic imaging technique based on nuclear magnetic resonance principle, uses non-ionizing electromagnetic radiation [3].

There are a huge number of hydrogen atoms in our body because the main ingredient in the body is water or lipid [2]. The nucleus of a hydrogen atom is composed with positively charged protons. The protons produce MRI signals in the body. Patient's body is plant within a strong magnet field with a small gradient. There is a static magnetic field normally greater than 10^4 times powerful than that of earth's magnetic field [2]. Every atom has precession frequency along with their magnetic fields which is directly proportional to the magnetic field strength. Radiofrequency (RF) pulse is applied to match the precession frequency; some atoms soak up energy and change their direction [3]. After that these atoms re-emit the energy while transition to their original orientation (relaxation). MRI makes use of radio frequency and strong magnetic field to construct high quality cross-sectional, anatomical and functional body images in any plane [3].

The main advantage of MRI in medical is that it is mainly used to provide in depth analytic imaging of soft tissues in the body such as soft organs and cartilage tissues like brain and the heart [2]. MRI is normally painless and not uses radiations so MRI scans generally considered safe in pregnancy and for children. It allows defined and immediate finding of functional,

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Molecular and anatomical data. MRI shows some unique information those other techniques not capable to show and has the great impact for cell tracking and breast tissue regeneration [2].

On the other hand MRI does have many drawbacks such as it has very tight space and too much noisy. For some people it may be claustrophobic and quite expensive. MRI is not for intra-luminal abnormalities [4] and there is need of sedation to little children because they can't remain still [3].

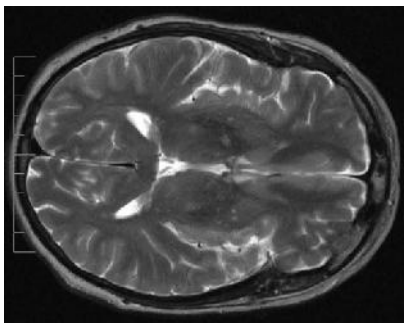

Fig 4: Brain Structure [33]

B.Ultrasonography:

Ultrasound imaging is very efficient medical imaging technique to ensure the blood circulation in heart and in blood vessels and to check the development of baby inside a mother's uterus [2]. Ultrasound medical imaging uses high frequency sound pulses in the range of megahertz and their echoes to generate medical images [4]. Transducer probe is use to pass the high frequency sound pulses into the patient's body [2]. After passing through the body, sound pulses hits a wall between soft tissues (e.g. between soft tissue and small structure). Many sound pulses find a wall and get reflected and other pulses wait until meets another edge then reflected. Scattered sound pulses relayed to the ultrasound machine and machine calculates the space from probe to the tissue (5,005 ft/s or1,540 m/s) and time of the echo's return (in terms of millionths of a second). Now the ultrasound machine demonstrates the space and echoes intensities on screen and display a ultrasound image in 2D, 3D and 4D. Many other ultrasounds are also in use such as: 3D ultrasound imaging and Doppler ultrasound [31]. Now a day ultrasound technology is readily present, inexpensive for the treatment of endometriomas, bladder lesions, rectovaginal septum and ovarian endomeriosis.[5] Ultrasound has the three major area of application **Obstetrics and Gynecology, Cardiology, Urology**: - as used to detect intra and extra luminal abnormalities, observing fetal health, checking the sex of the baby, view inside the heart to recognize the abnormal patterns, measuring the blood circulation in major blood vessels or heart, finding kidney stones and cancer respectively [16].

As we all know that ultrasound is energy so it can cause two major problems; first is: it enables increase of temperature and second is: ultrasound release gases which dissolved in the blood or tissues and it forms bubbles when gases go out [31].

Fig 5: Detection of Fetus [32]

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C. X ray Imaging:

X Rays are a type of high energy electromagnetic waves which can penetrate many body parts at varying levels such as fat, bones, tumors and other body parts can absorb x rays at different levels which will reflected in the x ray image [4]. For the creation of medical x ray imaging ionizing electromagnetic radiation travel through the body, absorbed by the body parts at different levels depending on the atomic number and density of the tissues, it creates a profile [4]. X ray attenuation is work more efficiently in bones rather than soft tissues. The produced image is simply a two-dimensional projection between the source of x ray and film [2].

X rays consist of many medical applications such as chiropractic and dental. Radiographs are used to view the movement of body parts and useful for blood vessels of heart and brain, enables to take the internal structure of stomach, intestines and lungs, detect fracture in bones etc [4]. Mammography is used to detect the breast cancer and Hysterosalpingogram is used for uterus and Fallopian tubes [4].

Due to the use of relatively high level of radiations people suffer from many problems such as skin reddening, hair loss, tissue effects such as cataracts and also increase chances to have cancer later in life [6].

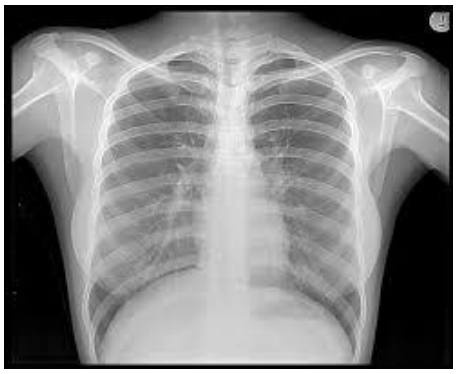

Fig 6: Chest Internal Structure [30]

D. Computed Tomography (CT scan):

CT scan is a diagnostic technology consists of a rotating frame which has two parts; one is a x ray tube at one side and a detector at opposite side of the frame. An image is acquired each time when the x ray tube and detector completes one round the patient body and many images will be collected from many angles. Every profile of x ray beam is reconstructed by the computer to produce 2D image and then scanned. 3D CT can also acquire with the help of spiral CT which is helpful in visualization of tumor in three dimensions. Recently 4D CT scan introduced to overcome with the problem of respiratory movements. 4D CT produces temporal and spatial information about the organs [4].
It is painless and non invasive method to diagnose the medical problems. It captures the picture of bones, soft tissues and blood vessels in our body. CT scan also provide detailed information about very minute abnormalities even the body don't have the symptoms of it. CT scan provides detailed spatial information and a good picture of veins [4, 6].

CT scan releases relatively high radiations which has the risk of lung and breast cancer and mainly not recommended for pregnant women and has health issue for unborn babies and fetuses. It is not useful for intra-luminal abnormalities [6].

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Fig 7: Showing Internal Body Structures [29]

E. Positron Emission Tomography (PET):

It is a radionuclide and very sensitive molecular technique, make use of short life isotopes, they have half-lives from 2 to 20 minutes for e.g. ^{15}O, ^{13}N and ^{11}C [3]. Short life isotopes release gamma rays and when gamma rays come in contact with a human body causes positron to be emitted. Positron is a particle having opposite charge and same mass as electron. The positron undergoes an annihilation reaction by producing two photons to travel in opposite direction to each other. PET is based on detection of coincidence of two 511keV photons which emitted in opposite direction after annihilation of a positron. Scintillation crystals are used to capture signals and photomultipliers for the amplification. The PET images are generated by computer analysis [3, 4].

As compared to other technologies PET can tell how the human body is functioning rather than how it looks, it is finding very useful from medical point of view. PET scan is generally used to detect brain disorders, cancer, central nervous, heart problems and body system abnormalities and view the abnormalities at the cellular level. PET shows the doctors how the cancer is metabolizes, whether it is spreading to new areas and shows how the tumor is responding to chemotherapy. PET has minimal health risks as compared to the beneficial results in diagnosing serious problems. However radiations are not considered to be useful in fetus development and not for pregnant ladies [3, 4].

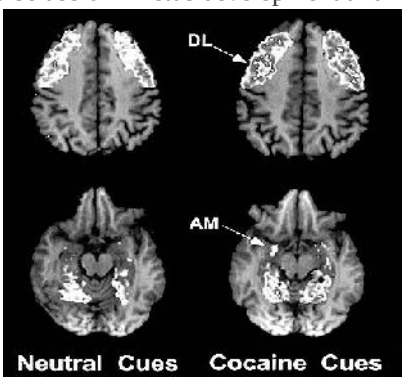

Fig 8: PET scan of brain [34]

VIII. CONCLUSION

The availability of data and their analytics are disconnected. The big data period is about the creation of potential information through the use of efficient analytic techniques rather than not to just collecting and storing the data. We conclude this paper by providing a brief overview on how the big data analytics has a great impact on healthcare industry. Big data contains a sheer volume of data and it is a complex ecosystem that carries data of various characteristics (7 pillars of big data) as variability, velocity, variety, volatility, volume, veracity and value. Big data analytics has exposed outstanding outcomes in various application domains such as business, healthcare, IT industries

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etc. Healthcare industry is one of the most popular industries which have big implication of big data and its analysis. In future there will be more advancement in big data analytic technologies and processes, we dream the healthcare cost will reduce considerably and will see much healthier public as compared to now. The future healthcare will be like god gifted.

The paper mainly focuses on importance of healthcare big data analytics, big data life cycle phases, methodology (Hadoop MapReduce), challenges and medical imaging modalities.

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