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Smart Hospitals: Challenges and Opportunities

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Abstract

Smart healthcare technologies are widely in use for the prevention and early diagnosis of diseases and are instrumental in transforming conventional medical care to patient-centric care. However, the traditional hospitals cannot entirely be replaced by home health systems, rather forcing them to become smart. The future smart hospitals are expected to have artificial intelligence (AI) tools for performing the patient diagnosis and robots for performing surgeries. The physicians will have the managing role, which could be performed through a touchscreen. This paper explores the challenges and opportunities associated with smart hospitals, and how they contribute to the objective of quality healthcare for everyone. The methodology used for the research is literature review. Machines do not have the common sense and blindly do what human beings instruct them to do. Thus, in spite of the digitalization and technology transformation of the healthcare processes, we cannot have hospitals without the human element.

Keywords: AI, EHR, IoT, machine learning, smart heathcare, smart hospital, wearables.

1. INTRODUCTION

Smart hospitals are aimed at improving existing patient care procedures and introducing new capabilities at low cost using optimized and automated processes, built on an ICT environment [1]. The healthcare costs are steadily rising [2] with a projected global health spending rise from \$7.1 trillion in 2015 to \$8.7 trillion by 2020. This could be unsustainable for many countries mostly because of the "graying of the globe" [3], with a projected population of adults over 65 years of age to reach 761 million by 2025. The graying of the population is a major impetus for change in healthcare in the US [4] and according to the Medicare Payment Advisory Commission

(MedPAC), the Medicare enrollment is projected to increase by more than 50% over the next 15 years from 54 million beneficiaries in 2015 to more than 80 million in 2030.

To keep healthcare remain affordable and widely available for the common person, it requires automation and efficient management. Healthcare automation is considered to be one of the most difficult tasks while building the smart ICT infrastructures. These critical, smart infrastructures of smart hospitals need to be built using emerging technologies like internet of things (IoT), big data analytics, cloud computing, machine learning (ML) and AI. These technologies are destined to redefine the healthcare industry of the future by providing actionable insights from operational intelligence, at a relatively low cost. For example, in radiology, experts believe that more than 80% of the diagnosis could be done by ML algorithms, so also could be in oncology and dermatology. AI powered tools can perform disease diagnosis and assist doctors in conducting surgeries. Smart healthcare technologies promise better diagnostic tools, better quality treatment for patients, and services, thereby improving the quality of life for everyone at a lower cost. The smart hospital market is expected [5] to cross \$63 Billion by 2024 at a CAGR of 23.5%. The 2017 OECD ministerial statement on the next generation Health Reforms' was focused on adapting to new technologies and innovation for promoting health for all with lower overall healthcare costs [6].

Healthcare systems have undergone many transitions, which include migration from institutionalized settings to the home and everyday life, conventional medical care getting replaced with self-care, and trained nurses getting replaced with untrained patients and caregivers [7]. However, traditional hospitals cannot be totally replaced by home health provisioning systems (HHPS). With HHPS systems, doctors provide routine, emergent, and enhanced healthcare services at the patient's home for a premium [8]. The specialized services in HHPS include many services, which are non-available in the traditional healthcare practice such as specialist visits, 24-hour physician access, private waiting rooms, same day appointments, etc. [9]. The main goal of the home healthcare is to treat old age patients or those who cannot consult healthcare givers at regular working hours to get better from routine illnesses and to become as self-sufficient as possible. Moreover, many of the chronic and acute diseases cannot be treated from home without critical equipment and support mechanisms. Studies have shown that the HHPS may end up in reduced in-person communication with increased social exclusion for older people [10]. The technology readiness for smart homes of today is much below the expectations, even in the developed countries. Thus, HHPS can only complement the hospitals but not to replace them.

In conventional hospitals, delays are happening in collecting and processing patient data which could be detrimental for critical patients. Smart hospitals avoid these issues [11] through efficient and intelligent interconnection of physicians, patients, machines and equipment. The efficiency and speed with which we generate, access, communicate, analyze, and use health information very much depends on the underlying infrastructure and technologies. New technologies like IoT are becoming indivisible components of smart hospital technologies. IoT include electronic devices or machines embedded with sensors, which could be deployed to collect, store and analyze data. The IoT sensors can upload/ download data and be controlled remotely over the Internet. IoT wearable devices are available for wearing on body parts such as fingers, hands, legs, wrist, waist, neck, head, eyes, ears, etc. IoT applications include monitoring and emergency notification systems such as blood pressure, sugar and ECG/EEG/EMG monitoring, body temperature monitoring, and oxygen saturation monitoring. Chronic patients may need daily care and follow-up so that occasional visits to hospitals may not be enough for them.

2. LITERATURE REVIEW

Electronic health records (EHR) are cornerstones of smart hospitals. The EHR data could include diagnostic findings, allergic details, prescription data, laboratory data, x-rays, electrocardiograms, and medications, which can be stored on-premise or on the cloud. Regulatory restrictions can be there for storing healthcare data on the cloud, which varies from country to country. The Health Insurance Portability and Accountability Act (HIPPA) has been regulating the healthcare data processing in the US since 1996. A smart hospital will intelligently connect all departments and entities. When the digital processes and smart hospital technologies are taking care of patient care, the staff could be deployed for non-specialist activities [11]. The process automation will help bringing down the staff requirements. In addition, specialist doctors' expertise could be made available to a greater number of patients. These can bring down the operational expenditure, which in turn lower the treatment cost for patients. The potential technologies for smart hospitals include IoT, ML, AI, 3D printing, etc. These tools can be connected to a nationwide EHR cloud which in turn can bring down healthcare errors, inefficiencies, data redundancies and can allow better quality of care [12]. Authorized access to these data could be provided to patients and doctors over varieties of devices such as smartphones [13]. IoT on the Wireless Body Area Network (WBAN) for healthcare applications is gaining much attention in the recent years [14].

The improvement of the performance of predictive models with big data and ML will help in personalizing radiation treatments with safety and efficiency [15]. The deep learning-based multimodel ensemble method [16] reduces the error and obtains more information by using the firststage predictions as features than it is trained in isolation. Precision medicine [17] is an emerging technology for disease diagnosis, treatment and prevention. This combines developments in enhanced EHR systems, genomics medicine, IoT wearables, mobile device applications, etc. The Internet of Hospital Things (IoHT) includes [18] devices, equipment, appliances, applications and buildings, which has the capability and intelligence to connect, communicate and interoperate with other smart things within the healthcare ecosystem. IoHT is more oriented towards smart hospitals by enhancing the hospitals' ability to deliver care more efficiently and cost-effectively with better asset utilization.

The National Heart, Lung, and Blood Institute workinggroup regularlyreviews and examines the barriers and opportunities for integrating point-of-care technologies (POCT) with existing clinical systems to improve cardiovascular care [19]. Based on the studies [20] from India and China, the health-related mobile phone use was delaying the access to the physicians and hospitals. It was also found [21] that the mobile phone usage, despite providing a security blanket effect, can frame an emotional avoidance strategy leading to mental health issues.

3. CHALLENGES

The major challenges in the transformation into smart hospitals are the following:

3.1. Patient monitoring

Continuous monitoring, delivering high quality care, patient safety, and regulatory compliance with reduced healthcare staff, meeting customer satisfaction could be a major challenge. This requires round the clock health monitoring by doctors and alert generation, supported by fast decision-making and prompt responses. Lack of ability in deploying IoT and other technology solutions for patient monitoring are also causes for concern.

3.2. Data Accuracy

If a machine learning program is fed with wrong information, it learns wrong patterns and likely to give wrong insights, leading to erroneous treatment for patients. Thus, there is a need to ensure that only accurate data is fed to the EHR system. Data fed from IoT sensors might not cause problems as long as the sensors are working properly. However, when human beings feed data, there could be more chances of error.

3.3. Security and privacy

Maintaining confidentiality, integrity and availability of the healthcare data is a challenge. Storing health data in untrusted servers in hospitals is a concern for patients as there are chances for abuse and tampering of the data [22]. Compromising the privacy healthcare data can have many implications in real life. According to the Cost of Cyber Crime Study 2017 by Accenture, the annualized cost of cybercrime [24] for the healthcare industry is \$12.47 million. Cloud storage of healthcare data is also causing both security and compliance concerns. According to the 2018 survey by the Symantec Corporation, poorly secured cloud databases continued to be a weak point for many organizations [28].

3.4. Cost effectiveness

The increasing healthcare cost is a big challenge for patients. Performance and compliance requirements are also contributing to the hospital costs. There is a trade-off between user convenience and cost [29]. Cloud computing is a way to reduce the start-up expenses of implementing EHRs. Some of the hospitals have not implemented EHR due to the associated privacy and security issues. A hospital cannot become smart without EHR.

3.5. Intelligent data processing and data validation

With the increased heterogeneity of devices and equipment, the heterogeneity and diversity of healthcare data also increases. As it contains personal lifestyle data and diverse other health data, validating and extracting useful knowledge from it becomes very challenging. This could be done only with intelligent algorithms.

3.6. Interoperability and Standardization

The operating rooms (OR) of hospitals are generally crowded with many freestanding devices and supporting systems, with their own interfaces to display data [25]. The smart hospital expectation is that once the physician enters the OR, all screens must be ready with information such as patient data, diagnostic imaging, and pre-operative plan, etc. projected onto the preferred screens [11]. This could be challenging as many hospitals use different archives and systems for storing the patient's information and it may be possible that many of these programs and devices do not communicate with each other. Thus, there is a need to integrate all information systems and applications in smart hospitals to allow for the patient's relevant data display. Another challenge is with respect to IoT sensor interoperability, which refers to the ability to accept and adapt data from different types of IoT sensor devices [22].

4. OPPORTUNITIES

The smart hospital market value was \$13.52 billion in 2016 and is estimated [25] to reach \$63.49 billion by 2023, at a CAGR of 24.00% from 2017 to 2023. This market is segmented based on the wireless connectivity, application type, service rendered, service component, type of technology, and geographic region [25]. Smart hospitals need to equip themselves with smart hardware, smart software, and the related smart technologies. The smart technology systems include smart mobility systems and smart systems for patients, staff and equipment. The technologies that are likely to drive smart hospitals [1] include blockchain technology, bio-telemetry, drug development and precision medicine based on genomics and big data, virtual rehabilitation in orthopedics, etc. The smart hardware includes WiFi, active RFID, IoT sensors, wearables, dashboards, etc. Some of the driving factors of the smart hospital market [25] include demand for modernization of healthcare infrastructure, demand for efficient solutions in hospitals, developments in IoT Technologies in healthcare, increased rate of chronic diseases, increasing penetration of connected devices and instruments in hospitals, etc. The IoHT, with its intelligent devices, equipment, appliances, applications and buildings, is promising significantly towards smart hospitals and enhances the hospitals' ability to deliver healthcare more efficiently and cost-effectively with better asset utilization

The current use of information technology in healthcare can be enhanced with blockchain technologies. Blockchains add value to smart hospitals with its distributed ledger technology, interoperability and increased security and immutability. Blockchains offer secure and highly efficient transaction processing between patients, hospitals, insurance agencies and other stakeholders in a more efficient and seamless way. The smart hospitals will behave like a smart machine in the long run as the quantity and quality of operational intelligence available to it increases [26]. Smart machines will be using tools such as AI, advanced analytics and ML to derive actionable insights from operational intelligence. To sustain as smart hospitals, they must continuously learn, improve and demonstrate autonomous behavior appropriately.

5. DISCUSSION

The hospitals of the future can be of two types: (i) hospitals treating for acute care patients (ii) hospitals focusing on disease prevention, providing primary care services, and treating patients with chronic illnesses. The first type of hospitals will be likely to locate in urban areas with academic and research facilities. The second type could be located in suburban or rural areas, and performing routine procedures. The acute care hospitals will have more potential to become smart hospitals. Chronic illness needs continuous hospital treatment. As state-owned healthcare systems started paying for patients, hospitals need to focus on reducing costs, improving quality and customer experience. Medical buildings of the future will be designed like star hotels, to enhance the experience of patients and their families.

If a car can become a smart machine with wheels, then a smart hospital can be considered as a smart machine with beds. Smart machines must be capable to adapt their behavior based on experience, must not entirely dependent on directions from users, and must be able to produce unanticipated insights [26]. Smart solutions have already been implemented in many of the hospitals. Surgical robots can make the surgeon's job easier, with more precision and fewer complications. Brainlab's surgical navigation platform and software [27] enables access to efficient, less invasive and less expensive treatments for patients undergoing cranial, spinal, trauma, orthopedic, ENT and CMF surgery. Brainlab's Smart Anatomy Viewer permits online use to physicians in the OR, anywhere in the hospital or at home. It can automatically extract important information from a patient's CT scan or MRI image. In the events such as the resection of a liver tumour, the Viewer assists the physician in performing the tumour resection without causing damage to the vessels and other critical structures, which is difficult otherwise from a CT scan [11]. Brainlab's 3D Dicom Viewer Stereo allows visualization for the surgeon and can educate the patient.

The da Vinci surgical system, available worldwide, has a magnified 3D high-definition vision system and tiny wristed instruments that bends and rotates much better than the human hand so that a surgeon can perform surgeries with enhanced vision, precision and control [23]. The 3D mapping facilitating customized cardiac mapping of a patient's heart allows physicians gain new insights into the heart of an individual patient [11]. The chief of surgery in the Thun Hospital of Switzerland can check on the monitor in the entrance area whether all operating rooms are occupied and whether all surgeries are progressing as planned [11].

Hospitals wishing to become smart are expected to channelize their investments and resources toward building RTHS (Real-Time Health Systems), which represent the future state of the healthcare delivery organizations [26]. The RTHS allows healthcare providers with administrative, patient management and care delivery support systems to transform patients' data into actionable operational intelligence. The RTHS is likely to have better awareness of the physical world and the patient context with developments in sensor technologies and IoT. The RTHS can work more autonomously to meet its quality, cost and patient satisfaction requirements with developments in AI and ML techniques.

Despite the advancements in technology, it is impossible to imagine a hospital without the human element. Machines do not have the common sense and will blindly do what human beings tell them to do. If a ML program is fed with the wrong information, it subsequently learns wrong patterns. Only when human beings feed it with accurate data, AI systems can make correct diagnosis. A surgical robot cannot operate fully on its own and it requires supervisory control by the surgeons.

6. CONCLUSIONS

Healthcare systems have undergone many transitions that include migration from institutionalized settings to the home and everyday life. Smart healthcare is getting wider acceptance as an important development for the society for round-the-clock healthcare for aged patients, rural population, the working population, etc. However, smart home healthcare cannot replace the hospitals altogether. The steady increase in healthcare costs demand for smart hospitals, which are expected to be more efficient, patient friendly and less expensive. Emerging technologies such as AI, ML, IoHT and big data analytic methods will expedite the smart hospital transformations.

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