

An IoT aided model to remotely monitor post-surgery recovery of Orthopaedic patients

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Abstract— Population of Indian cities in general and particularly Pune has seen an exponential growth in the last 20 years. Unfortunately, our healthcare services have not been able to keep up with the growing demand for quality hospitals and doctors. Being a practice leader in Digital domain for the past 20 years and after having implemented multiple mobility and Internet of Things based solutions in the healthcare industry, it has become imperative for the researcher on a personal front to work on a technology-based solution for the problem closer to home.

In conversation with leading doctors and hospital administrators, it was realized the biggest challenge that hospitals face is to do with providing care to patients when they are discharged after a major Orthopaedic surgery. Most of the human resource and infrastructure at a hospital is spent for the recovery of the in-patients after surgeries and other major procedures. Patients also must bear the cost and inconvenience of the patients and their relatives when a patient is admitted to the hospital. Hospitals are always struggling to reduce the “Length of Stay” of patients.

It was also observed that Orthopaedic patients typically have the least life threatening risk once a procedure or surgery is successful, but these patients must remain admitted in order to complete their physiotherapy sessions, gain strength and their health vitals like BP, Heart rate etc. needs to be monitored.

The idea of implementing IoT to track the health vitals and exercises and progress in gaining strength through pressure sensors from a remote location i.e. the patient’s home, was very well received by the doctors and hospital administrations.

This research is to identify the benefits that Hospitals, Doctors and Patients would get from an IoT Devices and sensors based remote monitoring system. The research will investigate as to how this system will reduce the length of stay at hospital of Orthopaedic patients.

Keywords— IoT in Healthcare industry, Internet of Things, Patient Remote Monitoring, Health Data Analytics

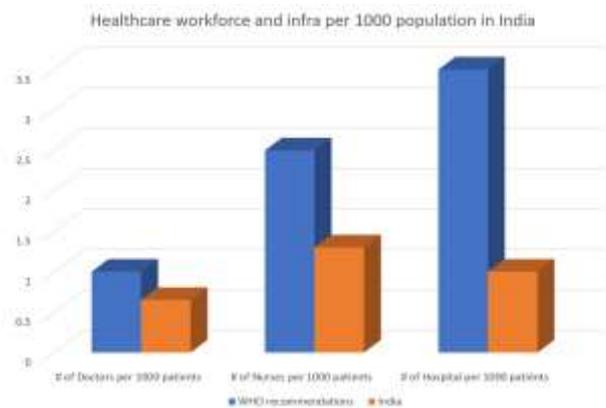
I. INTRODUCTION

Internet of things enables advancement in surgery, treatment, monitoring of patients and education of patients in the healthcare industry.

The number of connected things in use will go up to 25 billion by 2021, from 14.2 billion in 2019, according to a Gartner (top analyst firm) forecast "The IoT will continue to deliver new opportunities for digital business innovation for the next decade, many of which will be enabled by new or improved technologies," said Nick Jones, Research Vice President at Gartner.

II. NEED FOR INTERNET OF THINGS AS A TECHNOLOGY ENABLER FOR INDIAN HEALTHCARE

The Indian Healthcare sector still has a lot of ground to cover, thanks to the huge gap between the number of healthcare practitioners, facilities and the patients. For instance, India still has only one doctor for every 1,674 patients, which is well below the 1:1000 ratio recommended by WHO. Likewise, the number of hospital beds stands at 1.3:1000, whereas WHO recommends that it should be at least 3.5:1000.



Source: PwC analysis

Figure 1: Comparison of minimum WHO standards and Indian healthcare workforce per 1000 population

Poor quality of healthcare services, an overburdened healthcare staff, and an inadequate healthcare infrastructure are some other bottlenecks in the sector. These call for an urgent action plan to improve the healthcare scenario in the country.

Internet of Things can be the technology enabler for the healthcare professionals and hospitals. This research is an

Endeavor to explore the opportunities in using technology to enhance the capabilities of healthcare professionals and hospitals in Pune to provide care effectively to an increased number of patients.

III. RESEARCH OBJECTIVES

1. To Identify the various components and sub-components required for the optimal implementation of IoT into healthcare specifically for Orthopaedics in Pune city
2. To Design a new model for optimal implementation of IoT for Monitoring of Orthopaedic patients in Pune city Region.
- 3.

IV. IMPORTANCE AND BENEFITS OF STUDY

The study will provide inputs for IoT usage for making healthcare affordable for Orthopaedic patients during the recovery stage. It will enhance the Care giving capability and cost-effectiveness of hospital for its in-patient spending by providing higher efficiency and effectiveness in healthcare services.

Specifically, below stakeholders can benefit from IoT in the following ways:

A. Potential Benefits to Patients

- Quality healthcare services at affordable costs with IoT applications and sensors, physical interaction between a doctor and a patient could be minimized, leading to reduced hospital bills for patients. There will be significant benefits to the costs involved with recovery.
- Patients and their caretakers/relatives will have more comfort as the length of stay of patients will be reduced and patients can be provided better care

B. Potential Benefits to Doctors

- Doctors capability to provide service to increased number of patients with the same time and efforts will be greatly increased
- Remote monitoring of patients can be done by junior doctors who can alert their seniors if some patients health metrics deteriorate. This will lead to better utilization of the limited number of experienced doctors.
- With the help of wearables and sensors, several basic but important parameters like blood pressure, ECG, etc., can be shared with doctors any time over the internet.

C. Potential Benefits to the Hospitals

- Hospitals capability to serve patients will be extended beyond their “number of beds” limitations, since remote monitoring will lead to reduced length of stay (LoS) of patients. A typical reason for high LoS in hospitals is that patients need to be monitored for some time before being discharged, typically after a surgery. Even though many surgical procedures have now been reduced to just a few hours,

hospitals are forced to hold patients back primarily to monitor their condition. With the help of IoT sensors, hospitals can send patients home and monitor their vital statistics remotely.

- Hospitals can cope up with the patients’ inflow without compromising on quality.
- Hospital revenues would eventually increase as they will be able to service more patients and get benefits of better scale of operations. The hospitals would charge a nominal fee for providing remote care.

V. USE CASES OF IOT IMPLEMENTATIONS IN ORTHOPAEDICS

IoT enables better communication between monitoring of patient’s health after major Orthopaedics procedure like knee replacement or arthroscopy, this means that there are better chances of recovery of the patient. Sensors can collect the data of exercise and daily routine of the patient and alert the doctors to follow up on the recovery after surgery.

TABLE I
TYPICAL USE CASES FOR UTILIZING IOT IN ORTHOPAEDICS

Applications	Description
fractured bone & deformations	IoT sensors can send information regarding bone fractures Different parameters like bone pain, blood pressure and frequency of physiotherapy exercises can be monitored
Knee replacement	Sensors can monitor a patient’s daily activity and leg movement Information related to physiotherapy exercises and if they are being completed on schedule can be captured and shared
Hip-Ball replacement	Information regarding improvement in movement and pressure applied on ground by leg post-surgery can be shared Information related to physiotherapy exercises and if they are being completed on schedule can be captured and shared

VI. IMPLEMENTING IOT FOR REMOTE MONITORING OF ORTHOPAEDIC PATIENTS

IoT systems are made up of four main components which are detailed below:

A. Sensors and Devices

Data is collected remotely using a combination of devices and sensors which can capture and transmit data over the internet into the IoT Cloud for it to be processed further.
e.g. Smartwatches capture hear rates, footsteps and blood pressure information of the person wearing the smartwatch

B. Connectivity

The Devices and sensors need a medium to transmit the collected data into the cloud which is where they need “connectivity”.

Most smart sensors can connect to the internet using WIFI and Bluetooth to connect to a device which can transmit the

information over internet connections in the cloud using APIs and web services.

C. Data Processing and Storage

Once the data reaches the cloud it can be further processed to extract information, process and transform the data to be stored in data storages.

The data transmitted is mostly in text formats like JSON, XML etc. These need to be extracted and algorithms need to be applied to convert them into intelligent data. Validations and Rules are applied to the data, e.g. is your heart rate within the normal range etc.

This data is then stored in traditional RDBMS servers like SQL server or in NoSQL storages like MongoDB and Azure Data Lakes.

D. User Interface

The stored data is then exposed to users in intuitive dashboards and reports by using BI tools like Power BI.

A set of API interfaces allow for external systems like mobile and web applications to access and present data to users.

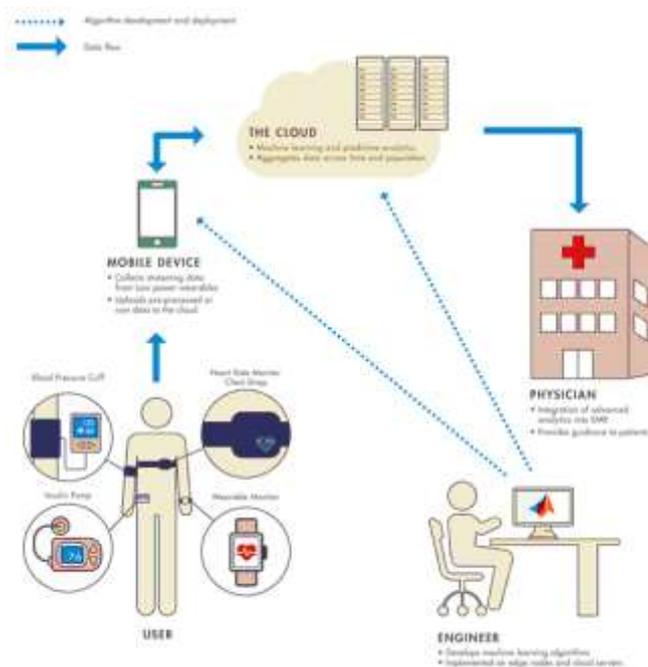


Figure 2: Graphical presentation of the Remote Monitoring system enabled with IoT devices, Sensors and Cloud.

VII. LITERATURE REVIEW

There is limited research done in Internet of Things implementation for healthcare particularly for Orthopaedic patients. However, some interesting articles have been written and published in journals which is being reviewed in below paragraphs.

The information on the factors leading to the rapid development of Internet of Things as a technology in the article -

Jagadeeswari et al. Health Inf Sci Syst (2018) 6:14 <https://doi.org/10.1007/s13755-018-0049-x>,

, Health Information Science and Systems, A study on medical Internet of Things and Big Data in personalized healthcare system.

The article says, “With the rapid development of the new telecommunication services, wearable IoT sensors, cloud computing, fog computing, and mobile computing provide real-time monitoring of users, diagnosis, communication with doctors and prescribe medicines and deliver at doorsteps are applicable in the better way.”

An article on “IoT and Big Data Healthcare” helped understand the conceptual architecture of an IoT solution particularly on mechanism to capture data using sensors and pushing it into the cloud.

Dimitrov, Dimiter. (2016). Medical Internet of Things and Big Data in Healthcare. Healthcare Informatics Research. 22. 156. 10.4258/hir.2016.22.3.156. The article provides good information on some of the devices used in the healthcare environment like “Zip Patch” for heart rate and electrocardiogram, “Myo” used by Orthopaedic patients to capture data of exercises done by patient post a treatment for bone fractures.

It provides valuable information on data processing of sensor data using big data architecture.

As part of the literature review an interesting article - Haleem A, Javaid M, Khan IH, Internet of things (IoT) applications in orthopaedics, Journal of Clinical Orthopaedics and Trauma (2019), doi: <https://doi.org/10.1016/j.jcot.2019.07.003>. - provides details on how IoT can be implemented for Orthopaedic patients during the recovery phase at home post-surgery.

It states “Orthopaedics surgery requires a lot of exercises and physical therapy at home. This technology monitors the patient without any requirement of health professionals. Surgeon and patient care team send message to remind and guides them step by step for better exercise to improve patient outcome. Patient and their family can quickly check recovery progress without any appointment of doctors.”

The article however does not provide in-depth view into how the IoT solutions can be designed and implemented in the real-world. It also focusses on the recovery of the patient post-hospitalization and does not delve into how IoT systems can benefit Hospitals, Doctors and Patients by reducing the patients “Length of Stay” at the hospital.

The researcher found the below gaps in research done for the topic of this paper.

1. Limited research done to understand feasibility of utilizing IoT for enabling remote care of Orthopaedic patients in Pune

2. Most IoT researches have not focused on specific medicine streams like Orthopaedics, Paediatrics, Neurology etc. Post-surgery recovery for Orthopaedic patients is not critical. In conversation with renowned Orthopaedic doctors in Pune like Dr. Shivanand Chikale of Jehangir hospital, we have understood that recovery from procedures like surgery for compound fractures, hip-ball replacement, knee-replacement etc. is seldom fatal and most patients do not require hospitalization for recovery if the vital health parameters like heart beats, blood pressure etc. can be captured and monitored remotely.

3. Visibility of data for the recovery phase of orthopaedic patients can be done with sensors currently available in India. Most of the literature has information of sensors not readily available in India.

4. Most researches have been done from a patient's perspective, but we did not find enough information on how IoT would benefit for in-patients.

VIII. CONCLUSIONS

As detailed in this paper there is a dire need to help our healthcare industry to overcome the current limitations in providing care to patients. The research will open doors to knowledge which will help in the rational implementation of technology to help decrease the length of stay in a hospital and consequently the cost of Orthopaedic patients after their surgery. This will have a dominoes effect in increasing the capacity to oversee patients of healthcare professional, revenue of hospitals, decrease cost for the patients and add to the comfort of the patients and their relatives.

The proofing of the IoT based solution will help the hospital management to gain confidence and have a positive outlook towards allowing admitted patients to be sent back home earlier and provided care remotely.

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