Computer Science Review
Volume 45, August 2022, 100599

Utilization of IOT for cardiac surgery patients

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***Abstract*— The Internet of Things (IoT) has an extensive range of applications, namely in the healthcare field. Its renovation is reforming the existing healthcare, with stimulating economic, technological, and social consequences.**

The augmentation of the cardiac patients' numbers with restricted totals of caregivers, which is a challenge as each caregiver ought to be careful of several patients, thereby representing a stress for caregivers and undergoing for the patients. Therefore, this study examines the state-of-the-art (network architectures/platforms, functions, and industry movements) in IoT-based healthcare fixes, and the developments in IoT-based healthcare knowledge, especially related to the cardiac surgery (CS). Additionally, we analyzed how IoT-based up-to-date advances could influence on the surgery patients in general and particularly CS-patients. Further, this paper examines how various advances, such as robotic surgery, ambient intelligence, and wearables, for CS-patients, and benefit from this demonstration to improve a function/architecture, which can monitor the condition of open-heart CS.

Keywords*— *Internet of things; Cardiac surgery; Healthcare; Applications; Platforms; Services.

I. Introduction

With recent developments in the information communication technology (ICT) and the growth of distinctive device recognition legislation, the Internet of Things (IoT) movement is achieving attraction in many areas, in which all are in one's environment is linked to the internet [1]. IoT is a notion that encompasses everyone, everything, at any time, in any location, with any assistance, on any system.

The IoT is quickly becoming a critical topic in the realm of information technology (IT). Real-world objects will be transformed into virtual objects. Its goal related to give the world, not only control over things, but also the ability to learn about them. There are many various fields that use IoT, such as education, industry, agriculture, healthcare, and so on. The healthcare industry is one of the key area that has seen a rise in the use of computer technology in its domain. The medical field, thus, is one of the most important aspects of life that demands extensive research by computer scientists.

As a result, researchers are focusing their efforts on the healthcare sector. For example, [2] presented an intelligent advising system for decision-making based on the artificial intelligence (AI) approaches to diagnose and treat patients, hence utilizing the X-ray pictures and/or hand-written text reports *via* the AI methods. Furthermore, AI has found its way into the IoT and cloud environments, due to its an important topic for prediction and machine learning, which is one of its subsets. This was demonstrated by the authors of [3], who used the machine learning techniques to predict the user charging behavior in the cloud based on their charging history logs.

The IoT is allegedly making its way into the medical industry, most importantly it is being utilized in the medical equipment. For example, the "smart bed system TM" may centrally manage different biometric data *via* ICT [4]. Furthermore, in the realm of surgery, attempts have been made to handle the medical items, such as the steel tools automatically and centrally [5], and to automatically check the govern of medical equipment during the heart surgery [6].

However, the above-mentioned medical uses are only “experimental” in nature. The application is not up to par when compared to the IoT movement generally society that is nearing the point of the societal deployment.

Meanwhile, several forceps and throwaway surgical apparatus utilized for the start surgery are marked with bar computer code and/or radio occurrence identifiers. The IoT fashion has not yet begun in the major of CS, and the probability of whether the “visualization” of surgical practices can essentially be placed into way *via* the IoT tendency has not yet been determined.

While several forceps and throwaway surgical apparatus utilized for the launch of surgery are marked with bar codes and/or radio frequency identifiers (RFID). Such codes are mainly used for the logistical functions, and they could not be utilized to track the movement and traffic of the forceps throughout surgery or detect if the energy apparatus is turned on or off. [7].

The rest of this report is structured as subsequent In Section A, the paper will discuss IoT application in the healthcare services in general and particularly in CS-patients then is Section B, this paper will discuss the IoT and surgical performance, the conclusion and future work is explained In Section C.

A . IoT Usage In Healthcare Services IN General And In CS In Particular

IoT-depenidinghealthcare practices could be utilized in a variety of majors, namely pediatric and geriatric patient care, chronic illness checking, exclusive health, and fitness management, etc.

IoT uses Bluetooth, Wi-Fi, RFID, and/or machine-to-machine (M2M) wireless technologies to connect smart sensors, tools, and software to computer interacting techniques. The goal of this inter functionality is to provide cost-efficient, information-determined, and effective patient care.

The healthcare workers are starting to use IoT in conjunction along with robots, artificial intelligence, and big data applications and technologies as part of the industrial-based IoT phenomena.

The IoT is now pervasive, altering the healthcare understanding for both patients and providers in a variety of aspects:

1. Telehealth

Telehealth is a wide name that involves different services. It contains a broad variety of technology and systems for identifying and controlling patients, as well as tutoring and additional attributes of healthcare.

Telehealth was firstly delimited to the remote diagnosis and medication of persons alive in rural areas without entrance to specialist medical personnel. Patients, smart medical devices, pills, phones, and wireless sensors are all linked to healthcare employees currently. Herein, some practical Telehealth purposes are portrayed: [8]

- **Live streaming (synchronous)**: It could be utilized to substitute an in-person doctor’s appointment.
- **Asynchronous imagery (store-and-progress)**: Implies to the communication of pre-filmed tapes, x-rays, and images of a patient’s therapeutic history. Doctors may utilize such devices to assess the conditions and extend care without getting to connect with patients in the real period.
- **RPM stands for remote patient checking** and means to individual health and medical data gathered *via* linked sensors and abiliment devices, namely blood sugar examining apparatus, electronic blood pressure cuffs, and insulin pumps. The data is wirelessly transmitted to the patient's Electronic Health Record (EHR) or to apps that healthcare practitioners may view instantly. In essence, the linked monitoring gadgets allow doctors to acquire and evaluate information about their patients' health without having to meet them personally. As a result, doctors have constant insight into how their patients are doing and may detect early warning signals of issues and take preventative measures.
- **Remote diagnostics:** Data transfer *via* EHR allows for faster and more precise diagnosis and treating of a wide range of diseases.
- **Mobile health (mHealth)**: The IoT uses permit for the compilation of society and medical health data; the providing of healthcare data to physicians, scientists, and patients, the checking of patient crucial symptoms, and the requirement of real-time treating *via* a mobile instrument.

Tele health and cardiac surgery

A study made about use of Telehealth by Surgical Specialties in 2021 showed that in response to the COVID-19 epidemic, Telehealth utilization was increased throughout all the surgical experties including CS in Michigan, according to the findings of this study. While telemedicine usage has decreased as in-person care has returned. The Telehealth utilization leftovers much greater than it was prior to the pandemic in all surgical specialties [9].

2. Telesurgery

Doctors may conduct operations on patients even if they are not in the same place, owing to remote surgery (Telesurgery) technology. A system depended on robots, extreme-speed data links, and organization evidence networks, thereby reducing the distance barrier between surgeons and patients.

The main advantage is that patients no extended must go outside of their regional hospital to get the knowledge of qualified surgeons from across the world.

The da Vinci Si surgical robot, for example, gives surgeons unrivalled accuracy and control, allowing for a less aggressive attempt to complicate the surgical operations. The surgeon's hand measures are translated into lesser, more accurate measures of microscopic tools within the patient's body by the robot [10].

On of such little device is the laparoscope. The laparoscope's small camera delivers pictures to a television monitor in the operating room, which surgeons may use to assist them during the surgery. The robot provides superior surgical dexterity and precision to the human hand, with improved 3D, high-definition visualization of the operating major, optical simplicity of tissue and anatomy, and operating ingenuity and accuracy [10].

3.Treatment adherence

Only half of people with chronic diseases, including heart failure, diabetes, cancer, or HIV in developed countries stick to their long-term medical therapy. Medication non-adherence is the primary reason of unnecessary costs in the US, with patients who do not follow prescriptions incurring yearly costs of $105 billion [11].

People with medication-dependent illnesses can use IoT solutions like the smart pill bottle to stay on track with their therapy. This web-connected gadget functions as an electronic nudge. The pot can store a charge for a long time and may notify patients when it's time to take their prescription by calling, texting, and/or blinking.

The smart pill is the most recent of the IoT option for treatment adherence. The first medication with a digital intake tracing system was permitted by the US Food and Drug Administration in 2017. The bilify MyCite pill has an ingestible sensor that reports when the medicine is shown and delivers a note to a wearable patch, which then directs the data to a mobile app. The patient may use their smartphone to track their prescription intake and provide their careers access to the information *via* a web-based interface [12].

Treatment adherence and CS

IoT services and applications had made it possible to ensure medication adherence prior to the surgery and after it.

4. Equipment monitoring

Hospitals lose or misplace equipment that accounts for 20% of their annual expenditure.

The University Medical Center (UMC) in New Orleans lost $15 M rate of apparatus, according to a 2015 investigation. Because the resources were never identified or recognized by the personnel. Connected gadgets let the medical personnel to maintain path of supplies and control them more efficiently [13].

The increased emergency department wait times are caused, among other things, by a lack of insight into the hospital capacity. And this is a problem that IoT can readily address. In a New York hospital, for example, GE installed a bed tracking system that shows whenever and wherever beds are available. The bed sensors allow medical workers to cut wait times in the emergency room by up to 4 h.

5. Surgery room hygiene

Patient healing is heavily influenced by sanitary conditions. Especially because one in every 25 hospital patients is infected with a healthcare-associated illness every day. However, it is difficult to keep track of sanitary circumstances in large hospitals and ensure that everything is as sanitary as possible [14].

The infection governs directors and hospital workers can help from interlinked examining equipment to promote culture of the security and accountability. IoT gadgets for hand cleanliness.

It could establish and identify a level of hygiene among medical and healthcare employees. For instance, the hand hygiene device that displays dispenser utilize and routinely accounts on cutting in real-time, following, and informing on accordance. Other IoT hand hygiene devices can send out a real-time warning anytime medical workers consider a patient bed without cleaning their hands [14].

IoT creates a paradigm change by merging networks of linked devices: healthcare is no longer restricted to hospital or hospice sides; it is now accessible where the person is extremely relaxed - at home.

B. IoT improves surgical performance

Thousands of people are affected by cardiac arrhythmias, which manifest as a fluttering in the heartbeat that is very disruptive and could lead to possibly deadly strokes and heart assaults.

A few medical medicines help improve the symptoms, but they don't address the dead tissue injuries in the heart that create the fundamental condition, known as atrial 3abulation, or Afib for short.

Ablation, a new IoT technique that removes injuries by quietly tearing them away with a laser, is addressing this challenge [15].

This procedure entails putting a catheter into the heart and attempting ablation to eliminate the AFib-triggering lesions. Each gadget is hard-connected to a monitor, which displays live data from the catheter's tip as a view of the heart's inside. However, unlike many technologies, the data procedure entails putting a catheter into the heart and attempting ablation to eliminate the AFib-causing lesions. Each gadget is hard equipped to a monitor, which displays live data from the catheter's tip as a view of the heart's inside. However, unlike many technologies, the data between the heart and monitors does not end there.

Figure 1. The difference between normal and atrial fibrillation heart.

This IoT service is a Silicon Valley startup that collaborates with couple of actual IoT powerhouses, PTC ThingWorx [16] and Glassbeam [17], to create something far more powerful. ThingWorx simulates the catheter's functioning, so that secure data may be sent to the cloud and evaluated by Glassbeam.

Glassbeam converts free data into organized data in the form of understandable statements, which the device firm may utilize to help surgeons conduct better surgeries. This type of data can also help high-value asset manufacturers improve the uptime of their catheter apparatus.

Others can utilize IoT Analytics to improve CAT-Scan and MRI uptime since the data could reveal when even the tiniest part is exhibiting indications of vulnerability or failure, allowing for a fix that protects the apparatus running [18].

Imagine this IoT optical catheter, small enough to pass through a vein easily, entering a heart and mapping it out to locate the lesions causing AFib.

The surgeon will then use CaridoThings' monitors to draw the borders of the lesions to identify which ones are dying and need to be burnt away. The lesions are subsequently cut away by the laser beam from the sensor-embedded catheter, and the patient is cured.

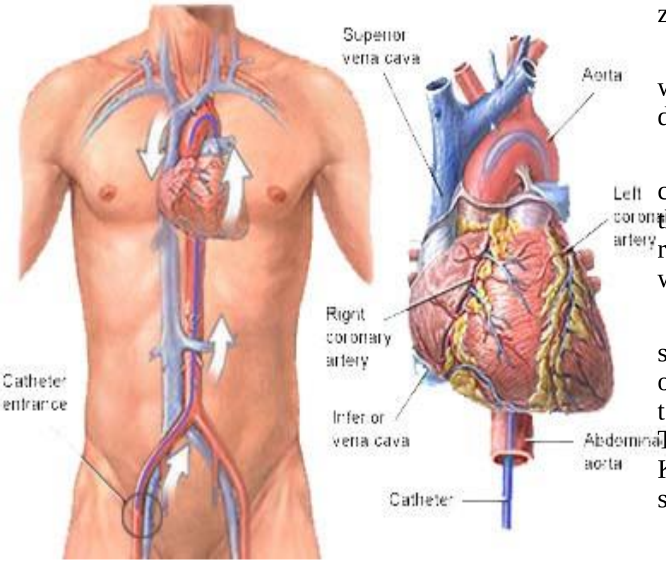

Figure 2. Catheter’s journey inside abdominal aorta to reach bad sites causing AFib.

MRIs and CAT scans are expensive devices that cost a lot of money. Interruption for them is not only expensive for the hospital since they are not charging patients, but it also prevents patients from receiving the greatest treatment available.

ThingWorx allows medical apparatus to connect with other Things in the cloud (Things, sensors represented by ThingWorx to convey as if they were the device).

Once the unstructured data is in place, Glassbeam's analytics engine can mix and recombine it to look for anomalies. Preventing tiny difficulties from developing major ones that crash pricey, heavily-utilized apparatus is the greatest benefit of analytical maintenance for MRIs, CAT scans, and other devices.

It allows data from EKG devices, MRI devices, pharmaceutical research, personal medical record-preserving procedures, blood screens, and hundreds of other healthcare procedures to be integrated and recombined with cardiac data from the same operation. This is how IoT is causing a healthcare upheaval.

IoT will play a huge part in hospitals' cost-cutting and profit-boosting efforts. Patients benefit because their physicians will have a better understanding of how to manage them following any treatment, whether it's a heart bypass, cancer surgery, a heart transplantation, or a simple blood analysis.

IoT, 5G and Remote cardiac Surgeries

Although 5G communication technology has been used in telemedicine in a variety of fields, its efficacy, safety, and constancy in remote laparoscopic Telesurgery have yet to be determined [20].

Telesurgery has become a possibility thanks to the integration of robotic and network connection technology [21]. On the one hand, Telesurgery can help to preserve and improve medical supplies by delivering high-quality medical care to underserved regions including rural districts, disaster zones, and battlegrounds [22].

Telesurgery, in contrast, can cut down on the time patients wait for treating, and therefore, avert illnesses from deteriorating.

Jacques Marescaux performed the first clinical tele-cholecystectomy in 2001 using the ZEUS robotic system and the transatlantic optical fiber network. This procedure, as well recognized as the Lindbergh process, is regarded as a watershed moment in the history of Telesurgery [23-24].

Then, with updated dexterous surgical robots and a shortened internet connection technology, Telesurgery was optimized. Surgical robot systems and network interaction technologies have made significant advances in recent years. The da Vinci robot in America, the REVO-I robot in South Korea, and the ALF-X robot in Italy all have more flexible and sophisticated operation systems [25-28].

A preliminary testing on the swine was done in June 2019 utilizing the “MicroHand” system robot *via* a 100 Mb/s Internet (at a distance of 300 km). The overall intraoperative delay was 170 milliseconds, which is acceptable for laparoscopic surgery [19].

First Remote CS

Apex Heart Institute cardiologists Tejas Patel and Sanjay Shah, together with Samir Pancholy, director of The Wright Center for Graduate Medical Education Cardiology Fellowship, stated that the surgeon operated a robotic arm from 20 miles away to do a heart surgery on 5 patients [29].

A 5 patient all had coronary artery syndrome, a situation in which blood arteries are compromised and the heart is deprived of sufficient oxygen and nutrients. According to the article, the doctor put a tiny device in each patient's blood artery to free it up and enable blood to flow across [29].

The authors said that the five patients reported no procedural problems and that the procedure was "successful in all respects."

Despite the fact that surgeons have been using robots in processes since 2001, the accomplishment of these procedures might be a significant step ahead in the treating of cardiac disorder. According to the WHO, cardiovascular illnesses are the primary reason of mortality worldwide [29].

Using telementoring with telestration in real-time, 5G technology allows safe and effective facility surgical operations with a high level of surgical team satisfaction. It allows for very high communication speeds, a steady signal, and, most importantly, almost eliminating delay that may be felt by the human brain. Teams, on the other hand, must be held to a set of criteria [30].

Because the strategy had to fulfil the criteria for outside broadcasting, latency in both operations was higher than was possible. In an ideal world, both ends of the circuit would have 5G internet, and picture processing would be accelerated by high-performance video capturers and software.

The latency limit for negative effects (anxiety, impaired working remembrance, dizziness, nausea) 5,6 as well as real influence on judgment-creating has been set at 300 milliseconds [31].

Though, the latencies obtained so far by optic fibre are sufficient for safe telementoring, the higher data transmission quality, the potential of multiconnectivity, and the expected cost savings (due to the lack of a robot) make 5G a more realistic substitute [32].

There are several limits to current 5G technology, such as the expense of particular hardware and buildings, and potential safety issues. Transmission through optical fibre is a viable method over small expanses with well-established structures; nevertheless, the major benefit of 5G is the ability to telementor across extremely large distances with few infrastructure (antennas and router). As a result, it would be an ideal resource for impoverished areas and/or locations where skilled surgeons are scarce [33].

C. Conclusion and Future work

The most common IoT service utilized nowadays is robotic cardiac surgery; Robotic CS is a kind of surgery in which the heart is controlled on through extremely small incisions in the chest. Specialists may do CS that is far fewer invasive than open-heart surgery because to the use of small devices and robot-operated tools. The method is usually described to as da Vinci surgery after the creator of the robot that is regularly used in this operation.

Valve surgery, coronary artery bypass, cardiac tissue ablation, heart defect repair, and tumor exclusion is the amongst operations that have been done with robotic surgery.

The major benefit of robotic CS over open-heart surgery is that it is fewer intrusive. Smaller scratches permit you to heal quicker and go back to your usual activities quicker.

If you require an arterial bypass treatment to increase blood flow to your heart, your healthcare practitioner may propose robotic CS.

It can also be utilized for the subsequent objectives:

- Heart valves that are rigid or leaky that need to be restored or changed.
- Correct atrial fibrillation, a familiar kind of arrhythmia.
- Remove a tumor in the heart.
- Fix congenital heart situations.

Robotic CS offers less hazards than open-heart surgery, which is one of its primary benefits. To open your chest, the surgeon does not require to slice through your breastbone. Many of the risks associated with open-heart surgery are eliminated.

Anesthesia is still required for robotic CS, and there are always dangers associated with any type of surgery, including:

- Heart attack
- Stroke
- Infection
- Death

The doctor may not be capable to end the procedure with the robot in some circumstances, which will result in open-heart surgery in this instance.

Other dangers may exist, depending on the patient’s medical condition.

The following is a basic timeline of what will probably happen during robotic heart surgery:

- The patient will be given a sedative to help you relax before the surgery.
- For the procedure, the patient will be put under general anesthesia and have a breathing tube.
- On the side of your chest, a surgeon will create a series of keyhole-sized incisions. The holes between the ribs will be aligned with these incisions.
- For the procedure, the patient may require to be put on a heart-lung machine.
- Numerous exactness-directed robotic arms will be introduced into these openings depending on the treatment being performed.
- These robotic arms hold and operate small devices that are used to perform tasks on the heart or nearby arteries.
- Another incision will be used to install a small video camera that will offer a magnified, three-dimensional picture of the surgical site.
- From a console in the operational room, the surgeon will control the robotic arms and camera.
- The surgeon will then eliminate the equipment and seal the incisions after they are finished.

When compared to conventional sternotomy, the use of robots in CS is associated with lower mortality and morbidity. As a result, the use of robotic technology in CS (CABG, MV replacement, tumor excision, and ASD repair) has increased in recent years.

The numerous well-documented benefits of a minimally invasive technique are expected to continue to boost robotic surgery usage in the future.

The researcher on the other hand will create an application/architecture, which can monitor the health of open-heart surgery patients. to progress the access to care, to increase the quality of care, and to reduce the cost of care. Monitor the health status of patient by a sensor, which generates information that goes through a network so that it can be conveyed or analyzed.

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