INTEGRATING BLOCKCHAIN FOR IMPROVING DATASHARINGIN IMPLANT SURGERY

[1]YM TANG, [2]GEORGE HO, [3]JACK WU

[1] Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hong Kong
[2,3]Department of Supply Chain and Information Management,Hang Seng Management College, Hong Kong
E-mail: [1]mfymtang@polyu.edu.hk, [2]georgeho@hsmc.edu.hk,[3]jackwu@hsmc.edu.hk

Abstract - Nowadays, Block chain technology is widely used in different industries for supply chain management, data privacy and smart contracts. Block chain is a new data infrastructure that supports seamless data interchange in a distributed ledger that allows a system with a data source to be decentralized, open, safe and trusted. Nevertheless, most of the existing healthcare applications either focus on data sharing or transactions between different parties. We propose to integrate the blockchain to improve data sharing among different parties in order to improve collaboration in implant surgery forfacilitating the operations processes. In this article, we have reviewed the current difficulty and existing situation of implant orthopaedic surgery in Hong Kong.We describe the general implant operations process and how the integration of blockchain technology can facilitate the implant operations process.On the other hand, we have proposedan implementation framework including data collection, data integrity and collaboration among different stakeholders. Successful implementation of this project cannot only reduce medical mistakes,but can also facilitate collaboration among different parties in implant surgery.

Keywords – Block chain, Healthcare, Implant, Orthopaedic, Total Hip Arthroplasty (THA), Total Knee Replacement (TKR)

I. INTRODUCTION

In recent years, the rise of wearable technology and the Internet-of-Things (IoT) has brought great opportunities and challenges to the healthcare domain.Recently, Joyia et. al. [1] conducted a study on the contribution of IoT in the healthcare domain and the application of IoT in terms of medical services in healthcareprogrammes. One of the applicationswas to monitor the patient health status,and IoT makes medical equipment more efficient by allowing real time monitoring of a patient's health and acquiring patient's data and reducing human errors [2].

With the development of mobile and cloud technologies,it is clear that the mobile applications and wearable healthcare devices can facilitate better personalized healthcare and disease management. Recent mobile applications and wearable devices are mostly supported by cloud technologies. Healthcare or medical service delivery is becoming more decentralized nowadays, where the patient can receive care in different institutions. Therefore, a central certifying authoritymay not fulfil the current change of patients' wider choice of healthcare institutions. Hussain et al. [3] have developed a digital orthopaedic rehabilitation platform that comprises a mobile phone app, wearable activity tracker, and clinical Web portal in order to engage patients with self-management tasks for surgical preparation and recovery. Despite mobile and website technologies being adopted in many healthcare domains, most focus on monitoring the patients' recovery process. Applications on the collaboration between different parties prior to the pre-surgical processes are still deficient. On the other hand, maintaining the privacy of the collected data and the sharing of the private patient information is still challenging.

Blockchain technology [4] is a new data infrastructure that supports seamless data interchange within the supply chain in different industries. It is a distributed ledger technology that allows a system with a data source to be decentralized, open, safe and trusted, which also refers to a continuously updated record of who holds what[5]. No one can tamper or cheat the system by editing records, because everyone using the system will be watching[6].

Current researchers state that the patients' information is collected in different ways usingmobile devices, patients' wearables, documents and EMRs. Making use of blockchain technology can make the medical or health care data structures become more flexible and extendable, which allows big data analytics to be easily applied. Furthermore, the blockchain technology can greatly improve the data security of the Internet of Medical Things (IoMT) where data security is of high concern in the healthcare industry. Blockchain technology can keep the patients' health data private because of the distributed ledger system, where the data can only be shared across trusted networks and nodes. Using this technology, a central certifying authority is not needed to confirm the patient information exchange with different stakeholders in implant surgery.
Despite the fact that the technology can be applied in many different application, mostare applied in smart contracts, etc. Work has seldom been donein applying blockchain technology to improve communication between different parties so as to minimize human mistakes. Conducting implant operations require a

series of processes and procedures that involves collaboration among different parties.Many medical errors have been reported in the complex implant operation processes [7]. In this article, we propose to make use of blockchain technology to improve the collaboration in implant surgery. By applying the blockchain technology, collaboration between the medical researchers, doctors and other relevant stakeholders in the implant surgery field can be initiated successfully. It is because blockchain technology can allow all the researchers access to the considerable level of the history of patients, design of implants and patients' records throughout the clinical and development process. In addition, using blockchain technology in the implant industry can improve medical data security, reliability, patients' privacy, so healthcare data becomes easily managed. Through blockchain technology, the process of billing and claims management can also be streamlined by better auditability and traceability so as to enhance the trust and reduce the fraud and errors along the supply chain. It is also an innovative approach in the field of insurance claims processing for preventing fraudulent claims.

II. IMPLANT SURGERY

2.1. Demand in orthopaedic surgery

Globally, there is a growing need for implants in orthopaedic surgery for bone fixation, and to replace damaged and defective joints. With the aging of the population and more people participating physically demanding sports and activities, the number of people that need bone fixation or joint replacement is expected to increase. Recent data from the National Joint Registry for England, Wales and Northern Ireland (NJR) [8] show that the number of primary total joint replacement operations in the United Kingdom (UK) is climbing to 75,366 hip and 76,497 knee procedures performed per year. According to Culliford et. al. [9], the projected figures will be increased to approximately 96,000 total hip arthroplasty (THA) and 119,000 total knee replacement (TKR) in the year 2035 in the UK.Accounting for the number of hip and knee procedures worldwide, it is projected that demand for TKR and THA would increase by 673% (to 3.4 million procedures) and 174% (to 572,000 procedures) respectively by 2030 [10].In Hong Kong,few projection figures have been reported. However, based on the figures from the public hospitals, there are more than 2000 TKR operations performed each year in Hong Kong and more than 10000 patients are on the waiting list.It is estimated the number of TKA is approximately half TKR operations [11].

Currently, almost all orthopaedicimplants used in Hong Kong are imported from overseas; these are either expensive, have a long delivery time and involved many different parties. The market share isfilled by several big companies, such as Stryker, Zimmer, Exactech, Link and Aesculap. The price of products from these companies is rather high, around HK$50,000. On the other hand, there is a great difficulty in collaboration between different partiesin ordering an implant and therefore it is easy to make mistakes [7]. There were 53% reported observed medical errors in the previous six months and kneeswere the most frequent anatomic locations, accounting for 35% of the total error.

2.2. Implant operations processes

Conducting implant operations involve a series of processes and procedures. It also involves collaboration among different parties. At the beginning, patients are required to conduct an orthopaedic evaluation. An Orthopedic surgeon will review the medical history of a patient to evaluate the general health and risk, and a physical examination will be conducted to assess joint motion, strength andstability. Advanced imaging, such as a magnetic resonance imaging (MRI) scan, may be needed to determine the condition of the bone and soft tissues of theskeleton. [12] MRI can be used to construct a 3D skeleton model with the aid of medical software such as Materialise Mimics [13], for segmentation. This modeling procedure is usually implemented by some experienced surgeons. Information, including patients' data and the implant requirements will be sent to the overseas implant provider. Figure 1 shows an overview of the procedures involved in the implant operation. The process involves a number of stakeholders including patients, surgeons, engineers, implant providers and logistics parties. Therefore, it increases the chance of mistakes.For instance, a recent serious mistake was reported in a total knee replacement surgeryoperation in Hong Kong. It was found that a wrong right knee implant was ordered and implanted to the patients' left knee. Surgeons found the mistakes after the surgery commenced [14]. The orthopaedic error not only increases the risk but also affects the life of the implant and the effect of the surgical outcomes.

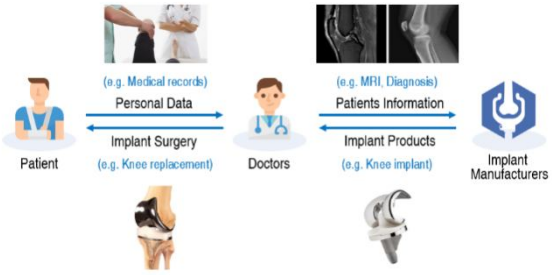

Fig.1. Overview of the procedures involved in the implant operation.

III. SYSTEM DESIGN

3.1. System Overview

In this article, we propose to integrate blockchain technology for improving collaboration in implant surgery. Figure 2shows a general scenario of the

implant operation and collaboration between the different parties: namely the patient, surgeon, implant manufacturer/ supplier, and insurance company (see Section 3.2).

All the data and information are stored onblocks which are encrypted and distributed over the peer-to-peer blockchain network. These data include participants who are involved in the implant surgery domain lifecycle, and the assets which store the medical record, product information (implant), transactions, etc. Details of the blocks data structure is described in Section 3.3.

3.2. Stakeholders

As mentioned, the implant operation involves several stakeholders namely:

Patients

The patient is the primary party that receives treatment,with personal useful data such as health information and medical records. The health data such as sleeping record, heart beat, etc. can be collected throughwearable devices. Other medical information such as treatment, medicine usage, etc. should be inputted by doctors. Patients own the data and authorize other parties to view and modify the information. For instance, if a patient suffers from severe damage by arthritis,he/ she will update the authority of the doctors/ surgeons to view his/ her medical record and update the diagnosis.

Surgeons

A Surgeon provides diagnosis, surgical preparation and operateson the patient. In the diagnosis phase, the surgeon evaluates the patients' condition and decides what kind of surgical operation is needed. In the surgical preparation phase, some advanced imaging such as an MRI scan may be needed to determine the condition of the patients. They also need to decide what kind of operation is needed and order a suitable implant. The information, including patients' personal data and implant specification, will be sent to the implant manufacturer/ supplier.

Implant manufacturer/ supplier

The Implant manufacturer/ supplier will receive the order from the surgeon. Depending on the diagnosis by the surgeons and situation, the implant can be tailor-made to fit the specific requirement of the patient or in using the standard implant. The surgeon will provide private data of the patients such as basic body information, size of the implant, etc. The implant provider will determine if there is any existing standard implant on stock or it needsto be tailor-made. The implant contains several specifications such as size, materials, position, etc.

Insurance company

Some patients may buy medical insurance from an insurance company. Blockchain technology is an excellent approach to formulate a smart contract [15] between different parties. This smart contract is a computer protocol intended to digitally facilitate, verify, or enforce negotiations or performance of a contractbetween patient, hospital, implant supplier and the insurance company. It also allows transactions between each party once the contract is activated.

3.3. Data Structure

The data structure of the blocks in the blockchain is defined by the two major attributes, namely participants and assets [16]. Figure 2 illustrates the general picture of the proposed block data structure. The participants include the patient surgeon, implant supplier and insurance company. An ID is used to identify their unique identity. The assets include patients' medical records, transactions and product information. The product information in this domain area is the implant which include type of implant, materials, size/ dimension, gender, position (left/ right), etc. A more complicated implants such asa knee implant, consists of tibial, femoral, patellar components. Table 1 shows an example of the block variables included in the patients' block data structure.

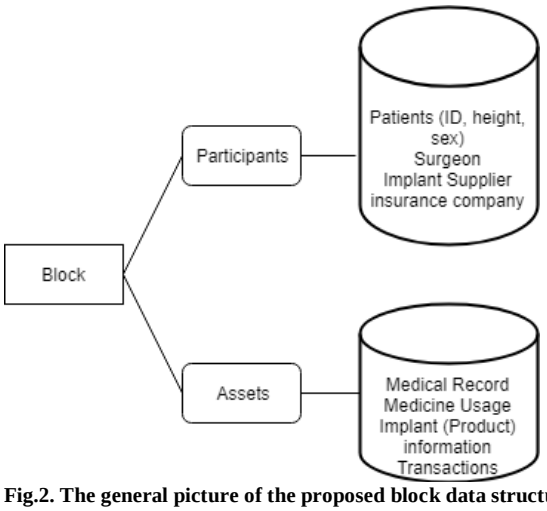

Fig.2. The general picture of the proposed block data structure.

Table1: Block variables included in the patients'block data structure

Variable Type	Variable	Description
String	ID	Unique user ID
String	Name	Name of the participants
Asset	Medical Record	Treatment record of the patient
Asset	Medicine Usage	Medical usage record of the patient
Asset	Implant	Implant specifications
Asset	Token	Token used for transactions

IV. IMPLEMENTATION

4.1. Data Collection

In order to collect personal data such as heart beat, medical record, medicine usage, etc., we propose to develop a system which can collect and input data by the patients and doctors.Figure 3shows the interface of the proposed system.

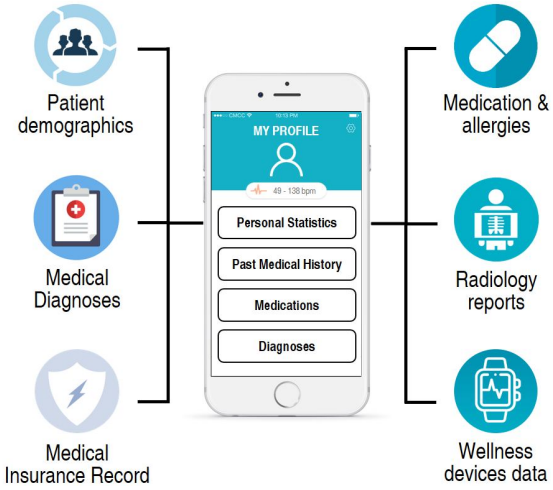

Fig.3. Interface and communication of the proposed system to collect patients' personal data.

4.2 Data Integrityand Validation

To facilitate scalable, effective data verification and data integrity protection process,atree-based approach in cryptography and computer science called the Merkle tree [17]is used. The Merkle tree is a tree in which every leaf node is labelled with the hash of a data block, and every non-leaf node is labelled with the cryptographic hash of the labels of its child nodes. By using this approach, all data are encrypted using hash functions [18]. The hash trees allow efficient and secure verification of the contents of a large data sets by checking the Merkle root. Figure 4 illustrates an example of the Merkle tree,where h(i) is the hash function the i^{th} transaction/ data. A large data set can be verified by using the encrypted Merkle root at the top of the tree diagram.

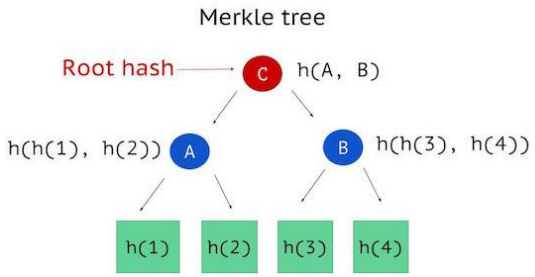

Fig.4. An example of the Merkle tree.

4.3 Data Sharing and Collaboration

Nowadays,there is a lack of transparency between all parties involved. Patients have no immediate access to their health records diagnosed by the surgeons. Surgeons are not able to share data quickly across different organization and hospitals in Hong Kong. Insurance companies can only access patient information through a claim from the patient. By using Blockchain technology, patients have fully control on their personal records. They can authorize the right to different participants. All data are encrypted on the peer-to-peer network which allows data sharing immediately between different nodes, once their access right is granted.

4.4Smart Contracts

Smart contractsare self-executing contracts in a blockchain network. The contracts are usually converted to computer code, stored and executed by the blockchain network. This can also result in ledger feedback such as transferring money and receiving products or services.In implant surgery, token is the cost, implant is the product and implant surgery is the service. On the other hand, patients can sharepersonal data with other institutes or researchers, and be compensated by a token in return. The smart contract can be executed once the patients satisfy certain terms of the insurance contract in order to pay for the surgical fees. Transactions among patient, surgeon and the insurance company are validated by proof-of-work in the blockchain network.

CONCLUSIONS

In this article, we propose to integrateblockchain technology to improve data sharing among different parties in order to improve collaboration in implant surgery for facilitating operations processes. Despite the implementation framework being proposed, the computer programming part of this project is still in progress. We propose to adopt the Hyperledger as the modelling language to define the domain model for the network. In the future, tests will also be implemented to verify the feasibility of the proposed domain model,and to measure the improvement in the collaboration of implant surgery qualitatively and quantitatively.

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