ICIC Express Letters
Part B: Applications
Volume **8**, Number **8**, August **2017**

 ISSN 2185-2766
pp. **1127–1133**

DESIGNING A VERIFICATION SYSTEM FOR ORGAN TRANSPLANTATION BASED ON RADIO FREQUENCY IDENTIFICATION

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Received March 2017; accepted May 2017

Abstract. *In the process of the organ transplantation, it is important to verify the organ information such as the donor's blood type and the serological test results. This job is typically done by transplant coordinators or laboratory technicians in hospitals. However, mistakes may occur due to human negligence, which could lead to serious medical malpractices. In order to prevent such accident, this study aims to build a verification system applying information technology in the clinical pathway of organ transplantation. In the pathway, each organ is attached with an RFID tag and monitored through Internet. When the donated organs are entering into the operation room, the RFID reader will automatically detect the organs and their associated information, which are sent back to the data bank through Internet for matching and verifying eligibility. If mismatching or other types of ineligibility is detected, error messages will be sent to clinicians. With this application, human error can be minimized and administrative efficiency can be enhanced, such as the decreased waiting time from file transferring. Moreover, quality of healthcare and patient safety can be effectively improved.*
Keywords: Organ transplantation, Patient safety, Verification system, Radio frequency identification, RFID

1. **Introduction.** In 2011, a major medical malpractice case broke out in Taiwan that caused a tremendous turmoil in all level. Organs from an AIDS (acquired immunodeficiency syndrome) donor were transplanted to four patients. As we know, AIDS is caused by the infection of HIV (human immunodeficiency virus) and has no cure except for those who are diagnosed in very early stage. For the rest of them, it can only be controlled by taking pills, turning into a pattern similar to chronic diseases. Thus, the number of HIV infected is high[1]. The route of infection is from human fluid exchange. If surgeons were not aware that patients or donors were HIV infected before operations, major medical malpractices are likely to occur. This type of malpractice incident may happen due to coordination or communication error. Physicians' assistants only checked donor's medical background with transplant team through casual conversation and misunderstood the inspection result of blood tests [1]. In order to avoid similar tragedy from happening again, this research applies modern technology to helping medical assistants to facilitate hospital operation efficiency and, in turn, to improve medical quality.

In order to avoid miscommunication among medical teams, a system that automatically provides the correct inspection results to transplant team before the procedure starts is urgently needed. It has to be able to detect whether patient or organ has entered the operation room. The task can be accomplished by radio frequency identification technology (RFID). Since its development several decades ago, RFID technology has

[1]According to CDC, Taiwan, the reported case number of HIV is 30,400 in Taiwan, with incidence rate approximately 0.132%.

been used in a broad range of areas [1-5]. As RFID technology has been implemented in patient care areas, safety concerns have been raised because of the emission of low levels of radiation from the devices [6]. RFID technology has been implemented in diverse environments providing significant benefits to the development of different processes [7]. The main components of RFID are the electronic tag, reader, and application software. The reader scans the tag for data and stores the data contained on the tag. Hence, RFID provides an automated data-capturing scheme that can electronically identify, track, and store information contained on a tag. The more technical details about RFID will be discussed in Section 3.

A system based on RFID technology and donation inspecting item database can be designed to automatically verify whether the transplant operation should be performed. Before the transplantation starts, each of the potential recipients and organs to be donated will be given an RFID tag with specific code. Since RFID has the function of reading and writing data automatically without direction restriction, data on the tag can be quickly identified. Therefore, as either patient or organ has entered the operation room, the reader can automatically identify the tag and match the identification from the database. When the donated organs are found with HIV antibody or other concerned infectious diseases, the system will immediately show glittering alarm message to medical assistants. In addition, this system also can judge whether or not the patient or organ enters the right room. In the cases of mismatching, the screen will also show red warning glittering message. With this system, it is believed that medical quality can be greatly enhanced and the rate of medical malpractices can be significantly reduced.

In the following sections of the paper, we first elaborate on system architecture. Secondly, we demonstrate the results of experiments. The paper concludes in Section 4 with a summary of our work and a discussion of our future challenges.

2. System Architecture.

Traditionally, physician assistants need to review the inspection report of donated organ before performing organ transplantation. Confirmation about medical procedures is only through verbal communication between physician assistants and pathological personnel. This could easily lead to message misrepresentation. To improve this matter and promote quality of healthcare and patient safety, a system based on RFID for organ transplantation was designed. The architecture of the system is presented in Figure 1. Before the transplantation is about to undertake, the system will spontaneously inspect the relevant information of both patients and donated organs and provide the matched result to the transplant team. Based on the pre-arranged operation schedule, the system's main page will provide the instant operation information for particular operation room.

In accordance with the clinical needs, the system mainly provides two functions. The first one is to look up for patient's detail information, i.e., "view patient's basic info". Doctor can choose particular operation room to look up for relevant information before the surgery. In cases that matched organs show positive reaction to HIV antibody or other infectious disease, the non-pass result will trigger the system to show warning message to alarm the clinician for re-confirmation. Another function of this system is to look up each organ's detailed inspected information and status, called "view organ inspected items", as shown in Figure 2.

This system is mainly designed for computer inside the office in operation room, and it can be automatically started by setting an assigned IP address for each operation room. When either patient or organ enters the room, they will be sensed by the RFID reader for verification before the operation starts. Then the reader will send the record through network back to the system to show the patient or organ's basic information on the screen. If any patient has entered the wrong operation room or the organ has positive reaction to

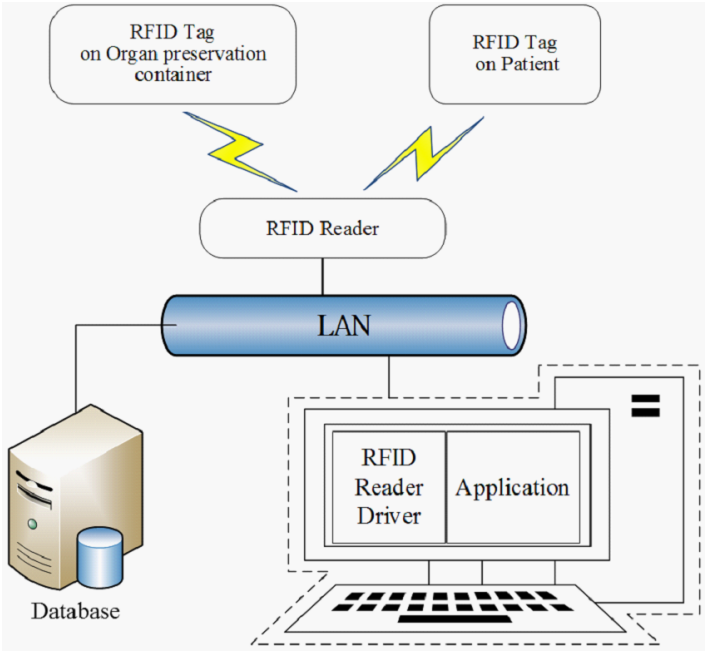

FIGURE 1. Architecture of the verification system for organ transplantation

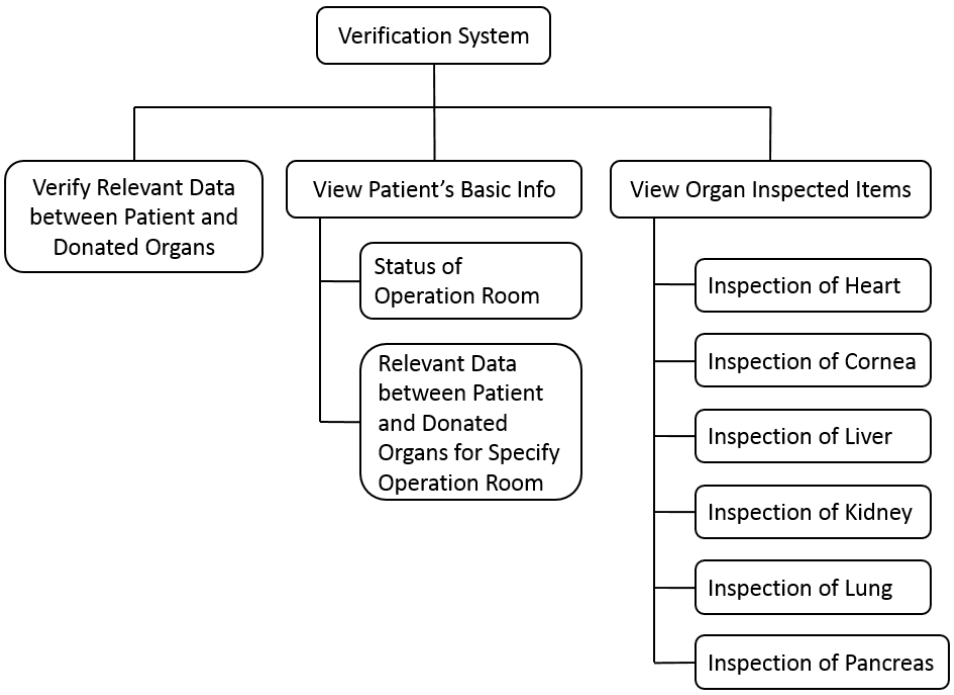

FIGURE 2. System functions

HIV or other infectious diseases, the system will glitter a warning sign to remind to stop the operation and, in turn, medical malpractice can be avoided.

Several steps for medical assistants to operate the system are as follows. First, start the RFID organ transplantation check-out system with selecting the function, such as: "view patient's basic info" or "view organ inspected items". Second, in the operation room, the operating process is to start the RFID organ transplantation check-out system and the reader to read the tag automatically.

Other than that, when the transplantation's patient entered the operation room, then the sensor will sense the patient or organ's entrance that turned the RFID reader on to

sense anything that has RFID tag on it through the waves sent by antenna. Therefore, we can use this system for verification before the operation.

3. **Experiments.** The proposed verification system for organ transplantation is implemented based on RFID. To simulate hospital information system, we utilized MS SQL Server 2012 to build a database for providing relevant information of the inspected items of donated organs and basic information of patients. The developing environment of the system is under the Windows 7 operating system, and the designing language is C#.

In practice, RFID reader need be installed on the door of operation room. For simulation, we place the reader and antenna on a frame in the experiment.

RFID is a technique that identifies the radio data in specific distance and counts for a kind of non-contact automatic identification technology. The reader can catch multiple tags that suit for the environment with low temperature and low humidity level, such as operation room [2]. In order to develop a prototype that satisfies the requirements of the system, we use RFID for detecting tags on organ transplantation containers or patients. The following subsections provide the specific details of RFID and experimental results.

3.1. **RFID facilities.** The main technology components of an RFID system are the tag, reader, and system application software. We adopt passive RFID technology from the company Intermec Inc. (www.intermec.com). In the system, each object, organ or patient, has a tag for identification.

3.1.1. *RFID tags.* Technically, RFID tags have two types: active and passive, depending on the energy source. Active tags have built-in batteries, and thus can actively send messages to the inductor. Their message delivery range is also broader than that of the passive type. Passive tags, on the other hand, have no battery; their required current is generated by wireless electromagnetic induction. As a result, this type of tag can only passively respond to the inductor after receiving messages from the inductor.

An RFID tag, or transponder, consists of a microchip and a coiled antenna. A microchip stores a unique serial number or other information based on the tag's type of memory, which can be read-only, read-write, or write-once read-many (WORM). The antenna, which is attached to the microchip, transmits information from the chip to the reader. Usually, a larger antenna indicates a longer read range. The tag is attached to or embedded in an object to be identified, such as a product, case, or pallet, and can be scanned by mobile or stationary readers using radio waves.

A tag's detecting distance is from several centimeters to a thousand meters. The tag's external dimensions are determined by the antenna. Antenna size is determined by signal frequency and required distance. According to regulations set by the International Telecommunication Union (ITU), there are four commonly applied frequencies: low frequency tags (125kHz or 134.2kHz), high frequency tags (13.56MHz), ultra-high frequency tags (868-956MHz), and microwave tags (2.45GHz). The higher the frequency is, the greater the effective distance and data transmission ratio are [8].

This system uses two kinds of passive RFID tags: IT36 and IT75 [9]. Model IT75 is anti-metallic that can be used at metallic object, such as sickbed, without interfering the ability to read the data inside it. Model IT36 is stuck on the container with organ.

3.1.2. *RFID reader.* In an RFID system, a reader is capable of reliably reading the tags and communicating the results to application software. A reader uses its own antenna to communicate with the tag. When a reader broadcasts radio waves, all tags within range are designated to respond to that frequency. Based on the radio frequency and the type of tag (active or passive) used, a reader has the capability to communicate with the tag without a direct line of sight. Readers can process multiple items at once, allowing for increased read processing times. They can be mobile, such as handheld devices that

scan objects like pallets and cases, or stationary, such as point-of-sale devices used in supermarkets.

Most of the available RFID readers can be used for this study. The one we adopted is Model IF2 reader [10,11] that equips antenna that reads RFID tags up to 7m in our laboratory. The IF2 is a network reader with radio frequency ranging 902-928MHz or 865-868MHz. The application can communicate with the IF2 reader by network. It can also detect multiple passive tags simultaneously. Hence, the proposed system can concurrently detect multiple containers with organ because a tag is stuck on each box. In this study, the RFID reader is equipped with two helical antennas. The antenna's model is IA33E [12].

3.2. **Testing for the verification system for organ transplantation.** When medical assistants log in the system, if there will be an operation within 3 hours, the system will show patient's basic information and organ's inspected items. As soon as the reader sensed the tag, the system will show the relevant message immediately. On the other hand, if there is no operation going on, then the system will show the message as shown in Figure 3(a).

As shown in Figure 3(a), the system offers two functions for user to choose. One may view patient's detailed medical history, and the user may also choose which operation room to view where all patients' basic information within the specific operation room is presented. If the user selects specify recipient, then the system will show results of the

(a)

(b)

FIGURE 3. (a) System overview, (b) alarm messages when there is any positive reaction found

inspected items of the paired transplantation organ. Should any of the inspected items shows positive reaction, the system will pop a warning message and display relevant information under the inspected items with none-passing sign.

To view all the patients' basic information within the specific operation room, the user may choose the "Individual Patient's Info" on the tab page: four options are offered for user to select: first record, previous record, next record, and the last record. Each selected option will be verified with the inspected items of the paired organ. When a positive reaction occurs, a "Positive Reaction Founded!" warning message will pop out immediately. Moreover, "Pass Fail. Please Recheck!" shows at the bottom of the page, as shown in Figure 3(b).

Another function of the system is automatic access checking. The access record is either under the function of "all the patient basic information" or "individual info". Within each specific operation room, the message box may show either an "Entered" status in green label meaning the patient or organ has already entered the room or a "not entered" status for patient or organ not entered in the room.

On the tab page of "Inspected Items of Organ", the user can check each inspected item of organ that has been recorded in database. If the inspected item of organ did not pass the test, implying the presence of a positive reaction, warning sign displayed in red text label will be alarmed.

4. **Conclusions.** Along with the rapid advancement in information technology, medical industry has become more dependent on it by taking advantages of the conveniences it brought. In this paper, we introduce an application not only that enhances operational efficiency in hospital, but manual negligence problems can be greatly reduced.

From the incidence of the organ transplantation mistake happened in Taiwan National University Hospital, we learned the lesson that human errors that cause disastrous results can be avoided. Assisted with new information technology, RFID technique can be applied to verifying the organ transplantation procedure in an instantaneous and automatic fashion. It gives confirmation or warning message of the pairing results between patients and donated organs. In the process of system design, coordination between departments is smoothened and the burdens of both the surgeons and the medical assistants can be relieved. With this automated verification system, pairing and inspecting the medical information for both patients and donated organs are made easier and more efficient, and the general operational procedure is greatly facilitated. Lastly, the key element for this system is the integral database, without which the system will not be completed. Moreover, the verification system should integrate with Laboratory Information System of hospital. When test results of donated organs are completed, it should be automatically and immediately sent to relevant physicians and assistants. This is our future challenge.

Acknowledgements. The authors would like to acknowledge the university students, Yu-Jou Lin, Hui-Lan Yang and Mei-Fung Haung, from the Department of Healthcare Information and Management, Ming Chuan University, Taoyuan, Taiwan, for their contributions.

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