Critical Elements and Lessons Learnt from the Implementation of an RFID-enabled Healthcare Management System in a Medical Organization

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Abstract

Healthcare services are complex and life-critical. One mistake in any procedure may lead to irremediable consequences; numerous researchers, thus, introduce information and communication technology to improve quality of services and enhance patient safety by reducing the medical errors. Radio frequency identification (RFID) is considered as one of the emerging tool assist in meeting the challenges of the present situation. In recent years, RFID has been applied in medical organizations for the purpose of managing and tracking medical equipment, monitoring and identifying patients, ensuring that the right medication is given to the right patient, and preventing the use of counterfeit medicine. However, most of the existing literature focuses on demonstrating how RFID can benefit the healthcare industry, whereas little attention has been given to the management issues involved in constructing an RFID project in medical organizations. In this paper, an exploratory case study is conducted in a medical organization to illustrate the development framework and critical issues that should be taken into consideration in the preparation, implementation and maintenance stage of constructing such a project. All the experiences and results discussed in this paper offer valuable and useful insights to steer those who would like to start their journey using RFID in medical organizations.

Keywords: Healthcare, Critical success factors, Lessons learnt, RFID project, Healthcare management system

Introduction

Radio frequency identification (RFID), one of the newly emerging technologies, has demonstrated its potential to affect a wide spectrum of the population among different industries. It is considered as a new form of barcode that supports automatic data capturing without a line of sight, and has proved its benefits in various applications such as animal behavior analysis [1], supply chain management optimization [2, 3], business automation [4], intelligent asset management [5, 6], and anti-counterfeiting [7]. According to the ten-year academic review conducted by Ngai et al. [8], RFID is a hot topic in the field of retailing, library services, animal detection, food, logistics and supply chain management. Given the spectacular results of adopting RFID in the business field, there is an increasing growth of researchers and practitioners considering implementing RFID in the healthcare industry for reducing medical errors and improving patient safety [9]. In particular, Lahtela et al. [10] state that RFID is critical in facilitating healthcare and medication care processes.

Generally, the development of an RFID system in medical organizations is still in the infant stage. Wu et al. [11] discuss a number of challenges that have hampered the adoption of RFID in organizations, including technical settings, standard settings, lack of infrastructure, high cost, and migration problems (e.g. barcodes to the RFID system). Thus, numerous researches have been focused on discussing the critical success factors (CSFs), lessons learnt, cost-benefit analysis, research agenda, and methodical approach to deploying an RFID system in order to provide more insights and to share experience in developing RFID projects [5, 12, 13, 14]. However, few publications have reported on how RFID systems for healthcare are designed and developed. Lee & Shim [15] examine the RFID adoption decision process and propose a model predicting the likelihood of adopting RFID within organizations in the healthcare industry. However, the study is limited to investigating the RFID implementation and maintenance in the actual environment. This paper aims to address the design and development issues of an RFID system throughout a real life case study. Through dividing the RFID project into three different stages, namely preparation stage, implementation stage and maintenance stage, various critical elements are discussed in order to offer useful information and share experiences with those working in medical organizations who would like to begin the journey of RFID deployment.

The rest of the paper is organized as follows. In Section 2, the relevant literature on RFID and its current applications in the healthcare industry are discussed. In Section 3, the framework and critical elements of implementing an RFID-enabled healthcare

management system during the preparation, implementation and maintenance stages are discussed. The lessons learnt which provide valuable insights into managing RFID projects in a healthcare environment are summarized in Section 4. Section 5 concludes the paper with suggestions for future research.

Research background

Overview of radio frequency identification (RFID)

RFID stands for Radio Frequency Identification which is a kind of wireless transfer. It is a generic system applying the principles of physics as used in radio broadcasting where radio waves, a form of electromagnetic energy, transmit and receive various types of data [16]. In the early stage, RFID was mainly used in the military services for target detection. After continuing development and improvement, RFID now acts as one kind of automatic identification technology for increasing the visibility of items in a supply chain context [2].

Typically, an RFID system consists of several components, including tags, reader, and antenna. The tags are used to store the unique identification information of tagged-objects whereas the readers are responsible for detecting and communicating with tags to extract information through the antennas coupled to them. Compared with traditional scan-based data collection technologies such as barcodes, RFID operates at higher data communication speeds, has a larger data storage capacity, and performs the automatic retrieval of data without physical line of sight [17]. Furthermore, integrating the RFID and Electronic Product Code (EPC) technologies creates an "Internet of things" that enables automatic information acquisition and effective information sharing, in a supply chain [18]. EPC is a collection of interrelated standards for hardware, software, and data interfaces, together with core services operated by the EPCglobal [19]. Therefore, in theory, with the Internet of things in place it is possible to track every tagged item on earth.

Current applications of RFID adoption in medical organizations

While most attention has focused on adopting RFID in retail and manufacturing, Wang et al. [9] consider healthcare is the next room of RFID. In recent years, there has been a variety of research on using RFID as a form of information system to reduce medical errors and improve patient safety. In particular, the use of RFID in asset tracking and management is already a popular application in many medical organizations. For instance, O'Connor [20] discusses an active RFID solution to track IV pumps and other high-value medical equipment whereas Bacheldor [21] reports that 300 assets, from wheelchairs to pulse oximeters, are tagged to provide real-time

location monitoring capability via an RFID-based real time location system (RTLS). With such applications, doctors and nurses can be more efficient and effective in managing medical assets like wheelchairs and surgical equipment as well as utilizing the resources in hospitals.

The use of tagging capability in medical environment is not only beneficial in asset tracking. In recent years, many researchers and hospitals have adopted RFID in patient tracking. The tagging of patients like inpatients and psychiatric rehabilitants involves more complex values. Sandberg et al. [22] address RFID is an emerging technology used for automated data capture of patient flow through the hospital and immediate alert when patients turn up at the wrong operating room or other location. Indeed, in order to alert the clinical officer about real-time patient location information, Kwok et al. [23] integrate mobile technology with RFID to improve patient safety and medical services by actively monitoring patient flow throughout the medical institution providing an alert when abnormal patient behavior is observed. To avoid performing incorrect treatment and surgery to patients, Bacheldor [24] employs RFID-enabled passive wristbands to identify surgical patients, thereby allowing medical staff to save time in identifying and verifying the patients.

In the existing literature, applications of RFID can be classified into five disciplines, namely medical asset tracking, patient identification, patient tracking, anti-counterfeiting, and medication safety. Table 1 presents various application domains in the medical area. By viewing the results of these applications, it can be concluded that RFID is a prominent tool to assist the healthcare organizations to reduce operating costs, improve patient safety and decrease the number of medical errors.

Challenges in deploying RFID in medical organizations

From the above literature review, it is observed that RFID adoption in medical environments is increasing at a tremendous speed. However, a number of challenges are hindering the implementation of this technology in medical organizations. To improve certain situation, numerous researchers have discussed and provided useful insights for successful deployment, however, the currently available critical success factors and lessons learnt are in the fields of retail, manufacturing and in the logistics industry, and they cannot be transferred to the medical environment without modification [9]. For example, electromagnetic interference (EMI) from RFID is one of the critical issues that need to be examined and discussed during the deployment of RFID in medical organizations [33].

Table 1 RFID applications in the medical area

Discipline	Applications
Medical asset tracking	• Locate medical assets by using an RFID-based real-time location system (RTLS) [21] • Monitor the temperature of blood during the transport process [25] • Facilitate the nursing ward in tracking the IV pumps and other high-value mobile equipment [20] • Ensure the removal of a tagged items of surgical equipment during an operation [26]
Patient identification	• Classify and transport injured people effectively by using an RFID-based triage system [27] • Help physicians to streamline patient admission to acute bed or ICU in the emergency department more effectively via the patient's identity [28] • Reduce errors in patient identification and enhance quality of care using passive RFID wrist bands [39]
Patient tracking	• Provide a real time unauthorized access alert to clinical staff by integrating instant messaging technology and RFID [23] • Track the location and status of patient and hence streamline the process of assigning each a bed [24] • Monitor patient flow and provide immediate alert when patients turn up in the wrong operating room or other locations [22] • Position and identify persons and objects both inside and outside hospital when disease is present [29]
Anti-counterfeiting	• Combat the growing problem of counterfeit drugs by employing RFID technology, coupled with the EPC and electronic pedigree (ePedigree) [30] • Track pharmaceuticals in the supply chain and counter the growing threat of counterfeit drugs by means of RFID technology [38]
Medication safety	• Ensure the right patient has the correct doses and right drugs by using RFID to track the medication [31] • Detect and alert the mismatch, over-dosage, and drug-error events by comparing the patient identity and the drug given [32]

To our knowledge, few academic publications discuss the critical success factors in

designing and implementing an RFID-enabled system in the healthcare industry. Concerning issues about the failure of adopting information technology solution in hospitals, there is a pressing need to conduct a research on evaluating the critical success factors in deploying RFID in medical organizations. It is noted that Lee & Shim [15] have pointed out three critical factors (i.e. technology-push, need-pull and the presence of champions of RFID) for a successful RFID adoption, but their study is mainly focused on the deployment pre-requisites, rather than the critical issues about the implementation and maintenance stages. As a result, we adopt a case study approach to inquire about the approach and lessons learnt from an RFID project.

Research Methodology

A case study approach was employed to identify the critical elements that facilitate and inhibit the success of RFID implementation. Data was collected primarily through interviews, observations, and archival documentations. To acquire the direct feedbacks from the users, interviews were conducted with clinical staff who were accompanied in the RFID implementation progress; whereas on-site observations were used to get information on how the clinical staff performing a task with and without the use of RFID technology. In addition, archival documentations were the third major source of data used in the research. Feasibility study reports, minutes of meetings, proposals, newspaper articles, academic publications and case reports that were available were reviewed and analyzed. These documents were collected and analyzed to identify and/or validate data.

During the data collection, special attention was given to ascertaining whether evidence from different sources converged on a similar set of facts. Guidelines in the existing literature on the enhancement of retrospective data accuracy were followed in the process of data collection. When all the evidence had been reviewed, and after an initial case study narrative was documented, the factual portion of the case study was reviewed by the major informants in the company. Such a review was not only a minimal procedure for validating the data collection process, but also a courtesy to those who had cooperated with the research.

Case study: from operational challenges to development of an RFID-enabled Healthcare Management System

In this paper we suggest an RFID-enabled Healthcare Management System that adapts the automatic identification capability of RFID to facilitate asset management (i.e. paper-based medical records and medical equipment), reduce the medication errors and streamline the registration process. The main idea of this section is to

discuss and present the critical elements of implementing an RFID system in a medical organization. First, the case study background is given to illustrate the motivation of adopting RFID in the case company. Then, the architecture of the proposed system and an 11-step development framework concerning the preparation, implementation and maintenance stage are discussed to evaluate the important issues leading to a successful adoption.

Case study background

In order to investigate the critical success factors of RFID deployment in the healthcare industry, a medical organization, named Humphrey and Partners Medical Services Limited (HPMS), is selected in this study. In short, the company specializes in providing health care for ambulatory patients by several general practitioners and medical professionals. To serve its clients better, HPMS employs some advanced diagnostic equipment such as X-ray machines to provide specialized healthcare services. As a consequence, issues in managing these items of advanced equipment arise. Together with some old problems such as handling of medical records and drugs, the company is looking for a breakthrough to enhance its operation.

In recent years, the healthcare industry has been investing an enormous amount of money in information and communication technology (ICT) to reduce the operation costs and to improve communication, productivity as well as the information flow within the organizations [34]. This is also true in the case of HPMS. Therefore, we collaborated with HPMS to develop a RFID-enabled solution for its operation in order to improve the current situation.

Operational challenges

Healthcare is an old yet complex industry. Operations in hospitals, medical centers and even clinics can be complicated, with management of medical records and drugs being the two largest challenges in everyday administration. In the case of HPMS, handling paper-based medical record is still the bottleneck of everyday operations. Apart from this, administering the large amount of drugs being prescribed and dispensed is another hard task. To illustrate thus complex situation, a snapshot of HPMS in (a) patient records and (b) medicine cabinet shown in Figure 1 illustrates the main facts.

Figure 1 Snapshot of HPMS in (a) Patient Records and (b) Medicine Cabinet.

On the other hand, since HPMS employs some advanced diagnostic equipment, managing this equipment is another challenge. In normal circumstances, these items of equipment will be taken back to their original areas after use; however, in some circumstance like the peak hour of visiting time, there may be time-lapses and subsequent errors in handling the equipment, leading to delayed service time.

Development framework of an RFID-enabled solution

Figure 2 depicts the 11-step development framework for implementing an RFID system in a medical organization. In order to provide a full picture of the deployment process, we cluster the framework into three stages, namely preparation, implementation and maintenance. The preparation stage focuses on defining the business case, and gathering and analyzing the solution constraints. This helps us to understand more about how the existing business process works. When the situation is understood by the researchers, the implementation stage will start. In this stage the aim of the practitioners is to design and deploy the system in the actual environment to conduct a pilot test and carry out debugging. In this stage, valuable user feedback is collected for fine-tuning the system. Finally, maintenance stage is used for maintaining the system, supporting users and upgrading the system with further extensions. Table 2 summarizes the critical elements that correspond to each step and stage. The details of each stage are further explained below.

Step 1: Information gathering, analysis and diagnosis

In this step, the situation in HPMS is analyzed and an understanding of the situation emerges. The analysis mainly focuses on the workflow across different departments and functions which are used for the formulation of a tailor-made RFID solution for

the company. It should be noted that the purpose of RFID technology is to streamline the operation and optimize the workflow of the services, thus several steps in the existing workflow will be simplified and altered. As stated by Basu and Kumar (2002), workflow reengineering approach is adopted when implementing new technology. To facilitate the reengineering process, it is required to review and analyze the processes currently used by the organization, and hence reveal critical points where significant improvements in quality can be made. Thus, in this study, we first conducted interviews with 5 nurses and 5 doctors to understand their current operations and then discussed which processes could be improved by implementing the RFID solution. All these actions not only helped us to understand the processes and workflow of HPMS, but they helped both the company and ourselves to have the same expectations regarding the improvement that the RFID can make.

Throughout the business process analysis and discussion with several medical staff, numerous critical elements were observed which made this step successful. First, good project management is vital. Introducing new technology into a business involves lots of people and a large amount of money, thus those taking part in the implementation must focus on results, constantly review the progress being made, and keep track of schedules and budget. Second, a clear vision is required to steer the project in the same direction for both us and the company. Third, top management support is required in this step. By receiving the approval from the board of directors in HPMS, it was found that all the medical and administrative staff became more cooperative to provide the information that we needed. Forth, the staff should be told about what to expect and the probable results well beforehand. This can help the company to have a clear mindset before resources are allocated for developing the solution.

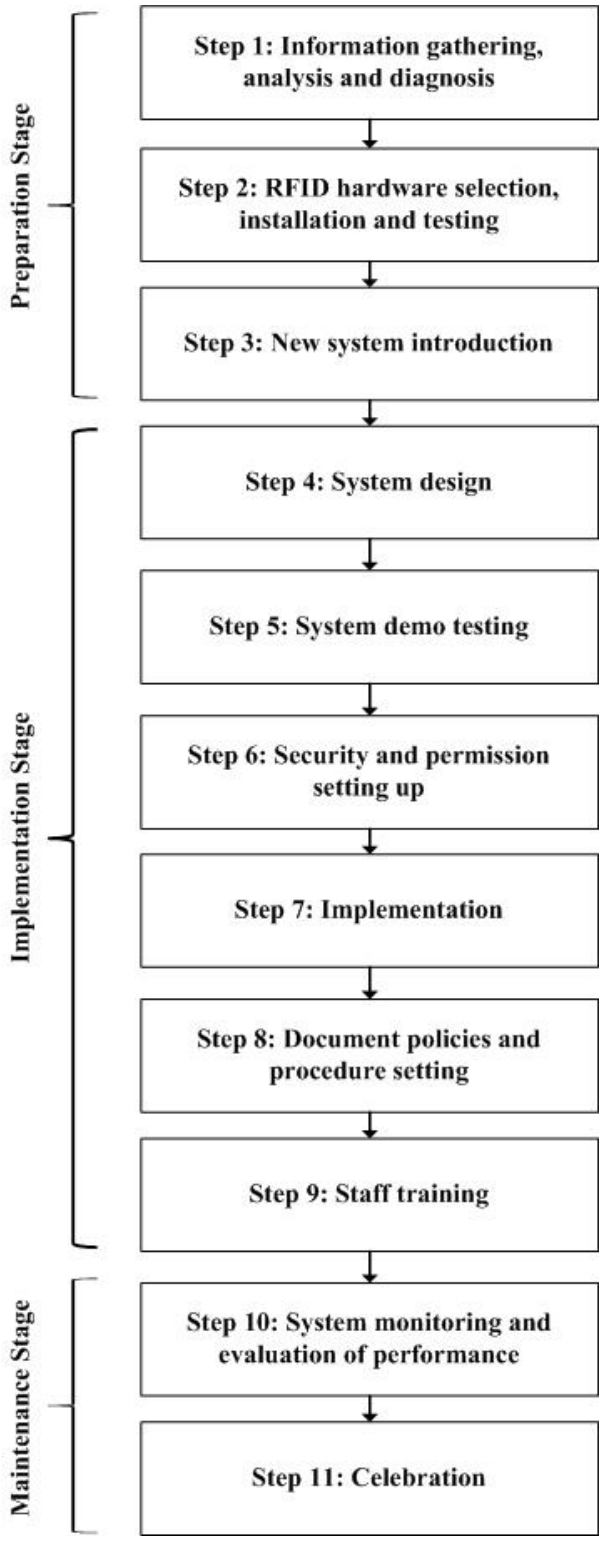

Figure 2 Development framework of the RFID-enabled solution

Step 2: RFID hardware selection, installation and testing

An RFID-enabled system must be supported by appropriate hardware (such as tags, readers and antennas) that HPMS must find the suitable hardware for the implementation. Testing can ensure the hardware is reliable enough to operate as

expected to support the desired implementation. The operating system, database and any communication links to legacy systems (such as electronic medical records) may also be considered. In addition, the hardware and operating system should be installed well in advance of the beginning of the implementation stage.

Table 2 Corresponding critical elements in each step and stage

Stage	Step	Critical element(s)
Preparation	● Information gathering, analysis and diagnosis	● Good project management ● Clear vision ● Top management support ● Effective communication
	● RFID hardware selection, installation and testing	● Appropriate vendor selection ● Effective testing
	● New system introduction	● Change management ● Introduction of organizational learning
Implementation	● System design	● Well-structured system architecture ● Match the function with problems encountered
	● System demo testing	● Participation of all users ● Collection of valuable user feedbacks ● Effective on-site testing
	● Security and permission setting up	● Effective communication ● Benchmarking other countries' regulations
	● Implementation	● Segmentation of services ● Reconfiguration
	● Document policies and procedure setting	● Well-structured and clear documentation
	● Training	● Patient to answer queries ● Ongoing education and training
Maintenance	● System monitoring and evaluation of performance	● Clear system maintenance disciplines ● Reporting
	● Celebration	● Don't be forgotten

An effective evaluation of RFID hardware is important to help the company to select

the appropriate hardware from the wide selection that is now available from vendors. Even though the company can afford the most expensive RFID hardware, there is a risk that such hardware may not really operate smoothly and efficiently in the actual medical environment. Thus, it is advisable to benchmark the vendors and their corresponding partners and evaluate them by finding out how satisfied the customers who have adopted their products are. Furthermore, effective testing of RFID hardware is critical when constructing an RFID project in a medical organization. Van der Togt et al. [35] points out that RFID readers can, under certain conditions, induce potentially hazardous incidents in medical devices. Thus, implementation of RFID in a healthcare environment needs on-site electromagnetic interference (EMI) tests and attention must be paid to updates of international standards. In this study, we test the EMI performance when an RFID system is moving towards a medical device. We initially start to test 200 centimeters between the devices, and then move the RFID in increments of 50 centimeters until an incident of EMI is observed. The result indicates that there is no interference with or degrade the performance of medical equipment in HPMS when an RFID system is 30 centimeters far apart from a medical device.

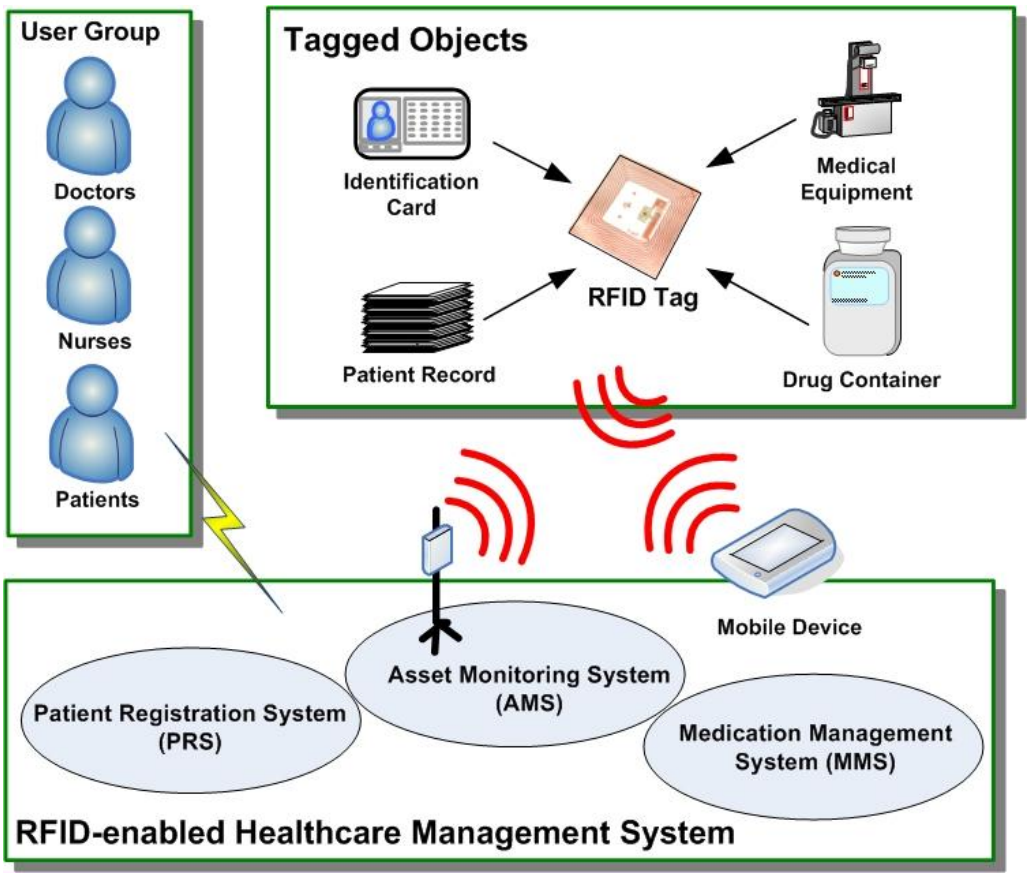

Figure 3 System architecture of RFID-enabled Healthcare Management

Step 3: New system introduction

The complexity of the RFID solution means that the system introduction to medical staff is an important issue especially during the early stages of implementation. It is not an afterthought; but a part of the initial design of the system. It requires users to understand the business processes and genuine needs of the new system in addition to the user's own job tasks.

During the introductory stage, a change management program is important to forestall any resistance to change by the staff. As mentioned above, the workflow of the existing operation will be changed from the traditional process; therefore some medical staff may avoid these changes by simply automating the old and inefficient processes rather than obtaining the benefits of the new system. In this study, we conducted interviews with medical staff so as to understand their concerns and hence educate them and point them in the right direction (e.g. identify how the system will change business processes and how effectively and efficiently the system can help them in their work). Furthermore, we also introduced organizational learning theory in HPMS to address the organizational defensive routine. Defensive behavior usually protects members against the anxieties of uncertainty and unpredictability. In addition, it is found that when the fear of not changing (survival anxiety) is greater than the fear of entering the unknown and unpredictable (change anxiety), learning will be facilitated. Thus, the same theory can apply to HPMS since medical staff would have a kind of change anxiety when adopting the new system, while at the same time realize they will experience the survival anxiety of maintaining or covering up current risk. To facilitate learning, the organizational culture should be one that reduces change anxiety.

Step 4: System design

The overall system design is established before deployment, taking into account the functions and services that the system should provide to improve the current situation. In this study, we propose an RFID-enabled healthcare management system to cope with the above mentioned challenges. Figure 3 depicts the generic architecture of the system. It consists of three subsystems: asset monitoring system (AMS), patient registration system (PRS) and medication management system (MMS). Each system can obtain real-time information from the RFID-tagged objects through the Internet at anytime and anywhere. AMS is responsible for keep tracking and locating the equipment by displaying the result in a user-friendly interface; while PRS provides a platform to patients for membership registration and for making an appointment to see a doctor in an automatic and self-service manner; and MMS ensures the medical

safety and pharmaceutical safety by alerting both the doctors and nurses during the drug prescription process if any errors are detected.

For the AMS, RFID tags are attached to diagnostic equipment and to the identification card of each nurse. Meanwhile, RFID readers are mounted on the each zone door. Once the tags are within the reading range of readers, information such as the current location of equipment can be obtained easily. As a result, the amount of misplaced equipment and the time spent hunting for specific assets can be dramatically diminished. The logic flow of AMS is shown in Figure 4.

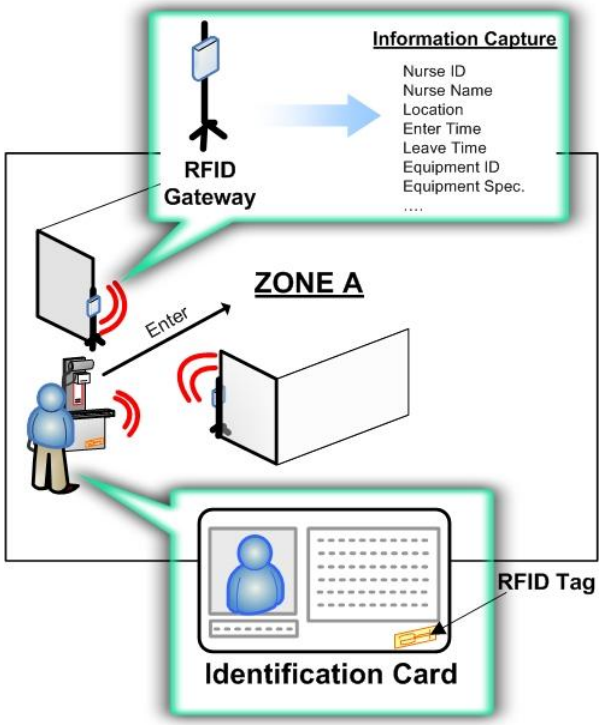

Figure 4 Logic flow of asset monitoring system (AMS)

"Other than the equipment, patient records are another important asset in the clinic", said one of the directors of HPMS. "We need to keep the patient records for about 20 years. The huge amount of records makes it difficult and time-consuming to retrieve a record when a patient wants his record back. Hunting among thousands of records is troublesome!" However, RFID technology can help in such cases. Powered by its identification capability, nurses can use a mobile RFID embedded handheld device to locate the RFID-tagged records in a pile of records shelves within a second.

Similar to AMS, in the Patient Registration System (PRS), each patient is given a unique RFID membership card which contains their own personal information. Once

they enter the clinic, they can simply register themselves by scanning the card over the RFID reader in the registration counter. If the card is authentic, patient information and the doctor booking schedule will be automatically displayed to the patients. Through the user-friendly interface, patients can view the schedule of doctors as well as making an appointment to see a specific doctor, conveniently. Furthermore, a liquid crystal display (LCD) is mounted above the door of the doctor's room in order to display the patient list (either visiting the doctor or waiting); so that patients can clearly know their status (e.g. how much time to go before their turn) compared with the traditional approach – asking the nurses. All these features of the self-check-in functionally streamline the doctor booking and visiting process.

In the final module, the Medication Management System (MMS), in contrast with the traditional handwritten prescription form, an electronic and systematic format proves to be more convenient and easier to use when writing prescription. Doctors can simply select the required medicine from a drop list box; and at the same time, alert messages will pop up when doctors mistakenly select drugs that a patient are allergic to. Thus, this is conducive to reducing human errors and facilitates the drug prescription filling process. Moreover, at the drug bottle level, employing the identification features of RFID is suggested. Figure 5 illustrates how RFID eases the drug replenishment process.

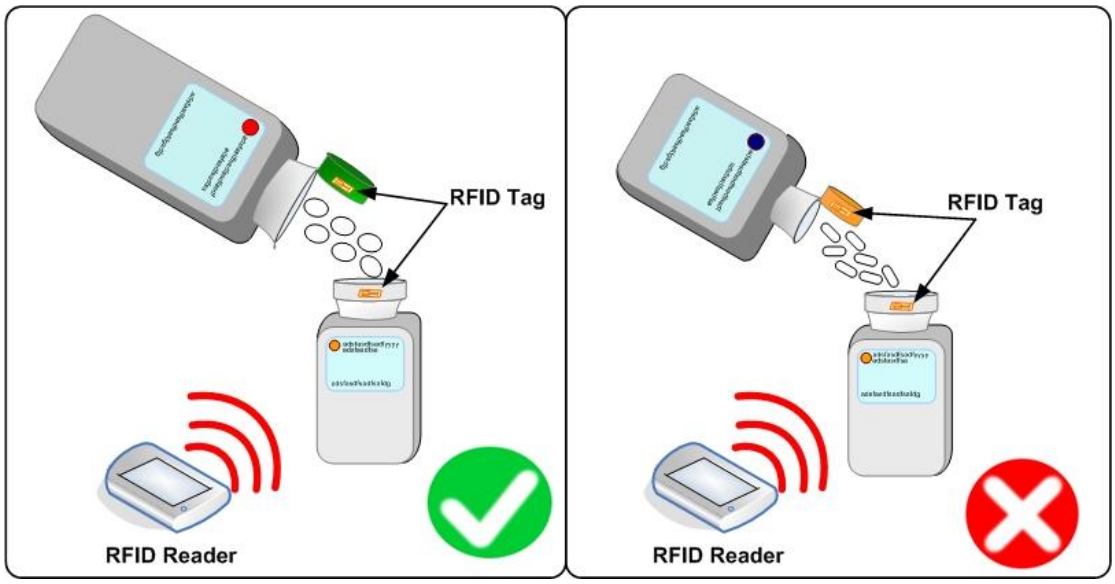

Figure 5 Drug replenishment process

Step 5: System demo testing

This step is to exercise the demo system and test the users' understanding of the system. The main aim of this demo testing is to identify the interrelationship between

each functional area's actions and the problems encountered by HPMS; in other words, each functional area can determine how actions taken in its area are useful in addressing the challenges. When the demo testing is conducted in the laboratory, it is the time to enter a real-life part that is built by the company.

In this study, we carried out several trials in HPMS during its non-office hours to see if any errors would occur in the real situation. Several scenarios have been set up for testing the system. Table 3 lists out all the scenario testing conducted in this study and their corresponding results. All the errors are recorded for further discussion with the system engineering and the clinical staff. Responses to these failures will be debugged afterwards. For example, poor tag receptivity can be addressed by testing the RFID tags at various orientations and positions of the tagged objects; and mismatch drug ID can be solved by double-clicking the drug database in advance.

Table 3 Scenario testing during system demo testing step

Scenario	Problem(s) occurred (in percentage)
Asset Monitoring System (AMS) 1. Transfer the medical equipment to different room 2. Search for misplaced equipment	● Cannot detect the RFID tag (40%) ● Display wrong location of the asset (45%) ● RFID tag is lost (10%) ● System error (15%)
Patient Registration System (PRS) 1. Register for making visit appointment 2. View the booking schedule of particular doctor=	● Forget to bring the membership card (12%) ● Cannot detect the RFID tag (10%) ● Display wrong schedule of doctor (50%) ● Display screen is out of order (5%) ● System error (25%)
Medication Management System (MMS) 1. Select the required medicine during the prescription process 2. Replenish the drug from one container to another	● Cannot detect the RFID tag (15%) ● Mismatch drug number (30%) ● Display wrong drug information (20%) ● RFID tag is lost (3%) ● System error (45%)

Although this was a demo testing phase, all users participated and provided feedback to us for tailor-making the system. In particular, the user interface is one of the challenges in system adoption. Many medical experts refuse to use computerized programs due to the complex and non-user-friendly interface [36]. Therefore, this step serves as a finalizing stage of designing a tailor-made user interface before the implementation of the system. In addition, it is observed that the controlled laboratory environment is somewhat different with the actual environment (such as the humidity, temperature, and local EMI). Effective on-site testing is important to guarantee the system performance in the actual situation.

Step 6: Security and permission setting up

This step is to prevent any untoward incident during the process. It consists of setting the security and permission levels to assure everyone of what rights they have. This simulates the access that will be available in the real system. Data security is one of the major concerns in adopting ICT in the healthcare industry [34]. Recently, loss of patient information has occurred in many hospitals in Hong Kong. In case of HPMS, the board of directors is concerned about the same issue when applying the new system. Therefore, an effective communication system has been set up to determine the access rights among the medical staff in controlling the patient data. Furthermore, benchmarking other countries' regulations is another security measures. For example, we proposed HPMS to follow the Health Insurance Portability and Accountability Act (HIPAA) regulations enacted by the U.S. Congress in 1996 about the privacy and data security issues.

Step 7: Implementation

Unexpected problems and issues will probably occur during the actual implementation. Therefore, to prevent this from happening, it is recommended that before the actual uses of the system, a part of the business that can be segregated and brought online should be identified. This segment of the business, which should be something that is expected to continue after the completion of implementation, should have no major production or technical issues, and will be a credible test of the overall system. In this way, it allows for the new policies and procedures to be tested in actual use with a minimum data set that people are familiar with before the entire company is committed.

Furthermore, software reconfiguration is required to fit the system into the company. In HPMS, an intranet is used for connect to the system server for acquiring the

captured RFID data such as the location of particular medical equipment. However, the path for connecting intranet is different because of random assigning of the directory for the server Internet Protocol (IP) address. Thus, it is important to reconfigure the software setting after implementing the standard package in each computer of the company.

Step 8: Document policies and procedure setting

This step is to provide templates for policies and procedures as part of the base system. These templates can then be modified to fit the unique needs of the enterprise. The best policies and procedures are no more than one page, such as a process flow procedure. This procedure fit onto one side of a piece of paper in a flow chart format.

Step 9: Staff training

Training on the technical operation of the system is provided to staff. During the training session, the instructor develops an atmosphere that staff comments (both positive and negative) on the new system are welcomed. The company can realize the difficulties and concerns of staff, and try to resolve them.

In case of HPMS, most of the medical staff is not skillful in using electronic products. Therefore, we should be patient and polite when answering their queries and teach them in such a way as to provide them with feeling that they are being supported. The final end users are medical staff. It is important that they understand how the RFID solution can be used for their benefit. Furthermore, we also introduced the medical staff in HPMS to the user manual created in the previous step and encouraged them to read it so they can find out how the system works, what the differences are between the modules, and how to acquire information from the system. In addition, on-the-job training was found to be useful for encouraging the medical staff to use the system.

Step 10: System monitoring and evaluation of performance

System maintenance and monitoring is essential in any ICT areas. After the whole company has completed employed the system, this is an excellent time to review the performance measures established at the beginning of the project for the system, and evaluate the results. In the case of HPMS, expected results should include the satisfaction rate of those using the system, increased level of productivity, less searching time, and an improvement in the overall patient safety level. These benefits enable continuous improvement without additional resources. By administrating a questionnaire to clinical staff in HPMS (i.e. 5 nurses and 5 doctors) for evaluation of system performance, Table 4 depicts the overall satisfaction rate among the operation

of the RFID system. According to the result, the users were satisfied the performance of the proposed RFID system, especially in the mediation errors reduction and information retrieval. Concerning the data input, users appreciated the design of user interface for the simplicity in data entry. In addition, around 80% users were satisfied and agreed that RFID system was good at rapid retrieving the necessary information of patient and fasten the tracking of medical equipments. As a result, the interactions between the doctors and patients were significantly increased compared with the conventional practice. Also, the errors in drug management are significantly reduced, in particular in the area of drug replenishment (100% satisfied) and drug interactions (90% satisfied), when compared with the conventional approach (i.e. based on the human judgment). All in all, all the users agreed the worthy of the RFID system.

Table 4 User feedback for the RFID system performance

	Very dis-satisfied	Dissatisfied	Normal	Satisfied	Very Satisfied
Overall system performance					
Data input	0%	5%	20%	50%	25%
Information retrieval	0%	0%	15%	70%	15%
Mediation errors reduction	0%	10%	20%	40%	30%
Data input					
Simplicity	0%	10%	25%	50%	15%
Design of user interface	0%	15%	25%	40%	20%
Information retrieval					
Correctness of content	0%	5%	15%	60%	20%
Sufficiency of content	0%	10%	30%	45%	15%
Ease to understanding	0%	5%	25%	30%	40%
Mediation errors reduction					
Efficiency (compared with the old process)	0%	0%	30%	35%	35%
Usefulness of mismatch ID checking in drug replenishment	0%	0%	0%	10%	90%
Detection of drug interactions	0%	0%	10%	60%	30%

In order to better communicate the errors that occur in the system, a reporting system is highly recommended in HPMS. This will also provide a way of handling any skepticism. Medical staff is educated to report the system errors through either email or phone; so we can immediately be made aware of any problems and addresses them in the early stages.

Step 11: Celebration

Celebration has been found to be the most important step, but many companies frequently forget to do it. When the whole company has just completed a major project and passed through an exhausting time, celebration recognizes the accomplishment and clearly demonstrates the importance of this achievement to all the staff within the organization.

Lessons learnt

In this section, we will discuss some lessons learnt from the successful implementation of an RFID-system in a medical organization. In short, we divide these useful experiences into three dimensions: technological, economic and operational. These are discussed and described in further detail below.

Technological dimension

Determine any hazardous interference

When tracking all the assets within the medical organization, every object, ranging from patients to medical equipment, needs to be tagged. However, some studies discovered that active RFID can interference with other medical equipment, thereby leading to a significant barrier which hinders the adoption of RFID technology. In our study, we carried out several RFID tests to rule out hazardous interference between RFID signals and medical equipment employed in the organization. In addition, we also measured the “safe distance” to see how far RFID should be kept away from the medical equipment.

Know the limitations of RFID

RFID technology is not as powerful as we think. For example, its low readability rate is one of the limitations of RFID [11]. It is important to identify and inform the users about all the limitations during the preparation stage. In our study, the company originally wanted to adopt the item-level tagging for tracking paper-based medical records; however, according to our experience and experimental results, multiple-tag simultaneous-reading of tagged papers is impossible. Thus, we proposed an

alternative method to the company for solving the problems as well as to avoid any over-expectations and disappointments.

Economical dimensions

Identify implementation cost beforehand

A large amount of money needs to be invested in a RFID project. According to the survey of Yankee Group, the total cost of implementing RFID ranges from US$9 million to 25 million in hardware, software, internal labor and consulting services [37]. Therefore, it is significant to identify all the expected costs for a successful project implement. In our study, we estimated the implementation costs after recognizing the scale of the RFID project. Moreover, approval of budgets from top management (i.e. the board of directors in the case study) is also a critical factor to influence the success of the implementation.

Formulate a clear Return On Investment (ROI)

A sound and clear Return On Investment (ROI) is a promising tool for successful implementation. The primary issue is to compare the cost of tagged objects and the cost of RFID hardware from different suppliers [2]. But in the case of medical organizations, patient safety is by far the most important factor of all. According to the user comments of the case company it is worthwhile to adopt RFID technology in optimizing the workflow, reducing medication errors and improving the quality of services provided. Furthermore, we estimated that the cost of implementing RFID in the long run is lower than the salary of hiring more medical staff to do the same work offered by the technology.

Operational dimension

Set up a time schedule for the RFID project

The time schedule is one of the key factors affecting the success of RFID projects. Apart from a well-structured business plan and clear steps for implementation, setting up a detailed plan of each activity can insure that sufficient resources have been prepared before the actions are taken. In addition, the time schedule can serve as a tool for monitoring progress and for controlling the project.

Conduct risk management and plan for emergency

It is clear that we don’t know what will happen in the next few seconds, therefore risk management and emergency plans should be thought through carefully in order to meet and address future incidents efficiently. In other words, we need to think about all the possibilities that will happen during the implementation and hence think of the

solution in advance to make the process more efficient.

Conclusion and further study

A development framework for the implementation of an RFID-enabled system in a medical organization has been described in this paper. With the use of RFID technology, the medical staff can efficiently manage and track medical equipment, patients and paper-based medical records; in addition, we have further extended the capability of RFID to serve as a risk reduction tool in providing the right medicine to the right patient. Only a limited amount of research has been carried out on investigating the essential elements for achieving successful RFID deployment in the medical organizations. We have added to this research by presenting twenty three critical elements that should be noticed in different stages of the implementation. It is expected that the experience gained and lessons learnt from this study can assist those medical organizations that would like to implement an RFID project.

Overall, implementing an RFID project is a complex task and many challenges are still not yet addressed. We are waiting for information systems and operations management researchers to provide a more meaningful stream of interdisciplinary research in RFID technology [5]. To contribute to the RFID deployment in the healthcare industry, future research should be carried out in the following areas:

- The development of international standards for the applications of RFID technology in combination with medical technology;
- Secure data security should be investigated and developed to protect the loss and spread of patient information;
- More comprehensive tests should be conducted on medical devices (i.e. sources of interference with RFID) in different environmental settings;
- Extension of RFID technology to the supply chain partners to enhance the patient safety, especially in the area of medicine authentication; and
- Artificial intelligence and data mining technique for enhancing the readability rate of captured RFID data should be investigated.

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