Framework Design of Patient Phlebotomy Identification System (PPIS) Mobile Applications for RFID Blood Test Tube

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Abstract. Phlebotomy procedures is the venepuncture, it's an important tool for diagnosing many medical conditions. However, there are a lot of human error and sample rejection during the phlebotomy procedures due to sample and patient identification. Currently, there are various advance production of medical computing system which able to provide significant benefits to medical staff and society. With this explosion of Smart mobile medical computing systems, a Patient Phlebotomy Identification System (PPIS) is designed to minimize the human error in phlebotomy practice that can caused blood specimen being rejected. The key of PPIS is the continuous exchange and transfer of information between doctors and lab technologists. The conceptual framework of PPIS is designed in mobile application that can connect to RFID technology on the blood tube. The patient and blood sample identification data are stored in MySQL databases and real-time access by medical staff thru the PPIS mobile application. This mobile application able to perform data search and identification for work efficiency. This system is user-friendly and eco-friendly.

1. Introduction

Smart mobile medical computing systems (SMDCSes) able to provide services with significant societal benefits such as healthcare mobile applications (apps) [1]. Medical care is rapidly being transformed by the introduction of new information technology and computer science approaches. New and exciting opportunities exist for improvements for both patients in terms of health and satisfaction, and healthcare systems in terms of effective patient management and pay-for-performance reimbursement. [2] This healthcare mobile applications will also bring the improvement in medical laboratory services in the case of phlebotomy practices.

Commonly, the phlebotomy practice process is divided into three phases: pre-analytical, analytical, and post-analytical and each phase will have some contribution as a factor for errors and blood sample rejection [3]. However, pre-analytical process error is found to be the main factor for blood sample rejection that leads to diagnostic and treatment delay and even patient’s death [3]. Studies stated that about 70% of errors occurred in phlebotomy practices is from pre-analytical phase where the blood test requesting, patient and sample identification, sample collection and transportation of blood tube specimen is included in this phase [3–6]. Figure 1 shows that the percentage of errors throughout all the phase in the phlebotomy practices.
The objective of this paper is to design a mobile application system that able to minimize the human error in phlebotomy practice that can caused blood specimen being rejected. Thus, Patient Phlebotomy Identification System (PPIS) in term of mobile application is designed and explained in this paper. PPIS is basically a mobile application with patient identification system for phlebotomy practices, test tube tracking function and searching of patient detail’s function [7].

This project is mainly to create a mobile application to improve the patient identification system in order to reduce mislabelling of blood tube during phlebotomy process and also to ease the medical staffs while conducting the phlebotomy procedure which subsequently will reduce the sample rejection rate. When mislabelling occurs, it will cause misinformation and lastly will lead to wrong diagnosis of the patient. On the other hand, rejection of samples is time consuming as a new sample needs to be drawn from the patient.

2. Framework Design

Our new PPIS framework consist of three phases of phlebotomy process as shown in Figure 2. In pre-analytical phase it included of patient registration and blood test tube data record. For patient registration, the patient that request for the blood test will need to register their information in the register counter. The information such as name, identity card number (IC), and address will be recorded in the PPIS. All this information will be saved to the MySQL database in real-time mode. An ID will assign to the patient. After drawing the blood, the blood will inject into the blood tube with NFC tag. At this point, the NFC tag on the blood tube will read by the mobile phone, and the patient information will appear on the phone. This is important to make sure that the blood tube belongs to the patient, medical doctor need to check and verify the information whether tally or not. All patient information can be viewed through the mobile phone by using IoT technology. When the test tube is being delivered to the lab, the responsible person needs to check out the test tube and the time will be recorded.
In the analytical phase, when the test tube reached lab, the lab technologist needs to check-in the test tube and the time will be recorded. This can help to prevent the blood tube from being missing or the blood coagulated due to long time of delivery and ensure the patient information is correct and accurate. After that, lab technologist will do the blood test analysis of each blood test tube using the blood analyser machine. Then, analysed data will link to a computer and uploaded into the cloud. The report will be generated from the analyser. PPIS will send a notification the medical doctor. Medical doctor can access the report by using the PPIS mobile application.

| Preanalytical Phase | Analysis Phase | Postanalytical Phase |
|---------------------|----------------|---------------------|
| Patient Registration| Blood Tube Data Record| Link with Analyser |
| Unique Patient ID   | Unique Blood tube ID | Status info.         |
| Doctor              | Lab Technologist    | Reporting sends to Doctor |

**Figure 2.** Framework Design of Patient Phlebotomy Identification System Mobile Application

### 2.1. Entities
These are the entities of PPIS mobile application; medical doctor, laboratory technologist, patient and test tube as shown in Figure 3. Doctor diagnoses a patient. Doctor need phlebotomies a patient to draw his blood for testing during diagnosing and manages record of the patient. After the phlebotomy, the blood tube needs to be verified by the doctor and send to laboratory for analysis. When laboratory received the blood tube, they need to check in, analyses and report the result to doctors. Patient is an external entity who doesn’t interact with the system directly, but his record is to be maintained.

### 2.2. Attributes of Entities

#### 2.2.1 Doctor
Logins the system by giving username and password. Any other data about doctor is not being maintained by the system. The Doctor has following attributes:

- **D_User_Name**: Name of the doctor by which he/she is known to system
- **D_Password**: Password of the doctor against his/her user name to login the system
- **User_NAME**: There may be more than one doctors interacting with the system. So, the user name must be unique throughout the record, so it will be the identifier of the doctor.
- **D_Department**: The department of the doctor and patient current admitted in hospital.
• D_sign verified: Doctor signature verification is to ensure the correct blood test for each right patient is collected.
• D_check status: Doctor need identify the status of blood test is either sent to laboratory or still in their department.

2.2.2 Laboratory Technologist Logins the system by giving username and password. Any other data about nurse is not being maintained by the system. The nurse has following attributes:
• L_User_Name: Name of the Laboratory Technologist by which she/he is known to system.
• L_Password: Password of the doctor against his/her user name to login the system
• L_User_NAME: There may be more than one Laboratory Technologists interacting with the system. So, the user name must be unique throughout the system, so it will be the identifier of the Laboratory Technologist.
• L_Sign Verified: Laboratory Technologists signature verification is to ensure the correct blood test-tube for each right patient is collected from the department.
• L_check status: Laboratory need to check the blood tube in good condition when received from each department as check in status otherwise rejected the blood test-tube.

2.2.3 Patient has following attributes
• P_IC: Number of identity card of the patient in the record. We assume that the patient identity card number is unique in our record, so the patient identity card number is identifier for this entity.
• P_Name: Name of the patient
• P_Address: Name current staying address
• P_Phone: Phone number of the patient
• P_Status: Health status of the patient

2.2.4 Blood Tube is the blood that collected from patient by doctor, then it will send to the laboratory for analysis. Blood Tube has following attributes
• BT_ID: Identity number of the blood tube indicates individual patients.
• BT_Test: The test that going to analyse into the blood tube.
• BT_Date: date and time when the blood tube is collected from patients.

2.3. Relationships between Entities
Entity-Relationship (ER) Model of Patient Phlebotomy Identification System Mobile Apps is shown in Figure 3.

2.3.1 Doctor and Patients
Patient visit doctor or admitted hospital and doctor examine/diagnose a patient. There is one-to-many relationship between doctor and patient because one doctor can examine more than one patient. But one patient is examined by one doctor. Doctor can set appointment with patient to draw their blood sample for diagnosis purpose. Cardinality of doctor is mandatory-many. Cardinality of patient is mandatory-many [8].

2.3.2 Doctor and Laboratory Technologist
Doctor from each department would send the blood tube sample to the laboratory technologist for analysis. There is one-to-many relationship between doctor and laboratory technologist because many doctors can work with many laboratory technologists. Cardinality of doctor is many-many. Cardinality of patient is many-many. Blood tube is the number of blood sample need to be managed between doctor and laboratory technologist.
3. Development of Mobile Application

The software that used to develop the PISS mobile application are Tracerplus Desktop [9], TracerPlus Connect [10] and MySQL database. TracerPlus desktop is a software where the mobile data collection application can be developed. It is an easy functioning software which is compatible with Android, iOS and windows mobile. The developed mobile application can be customized in the way that user’s need. The mobile application can be tested using the NFC on the test tube label. In this project, mobile NFC scanning is used since it is a branch of high frequency (HF) radio frequency identification (RFID) technology. Figure 4 shows the interface of TracerPlus Desktop. The mobile application needs to be set up in term of the admin’s login password by using TracerPlus Desktop, as shown in Figure 5. Administration password setting is to ensure the data security is unable to be accessed by anyone that no allowed. The mobile application user interface can be designed in the way that we want by using the design page in TracerPlus desktop, as shown in Figure 6.

Figure 3. Entity-Relationship (ER) Model of Patient Phlebotomy Identification System Mobile Apps

Figure 4. TracerPlus Desktop Interface
After the mobile data collection application is developed, TracerPlus Connect I used to synchronize the data with other data source such as Excel, Access, Oracle, SQL Server and MySQL. In this project, TracerPlus Connect is used to organize data sharing without programming which can perform wireless synchronization. Live mode for real-time data syncing is designed in PPIS, which mean that the data will always be up-to-date. It also performed automated times syncs to run at specific times and intervals. The data can be sync to and from Android, iOS and windows mobile. Figure 7, Figure 8 show the user interface of TracerPlus Connect for blood tube registration, check-out and check-in respectively. In this project, MySQL database is used to store all patient information. Figure 9 and Figure 10 show the user interface of MySQL database for blood tube registration and the list of all activities respectively.
Figure 7. TracerPlus Connect (Blood Tube Registration)

Figure 8. TracerPlus Connect (Blood Tube Check In & Blood Tube Check Out)
4. Engineering Analysis and Implementation
The prototype and the mobile application were tested. Firstly, the NFC tag is scanned and the patient’s information is key in as shown in Figure 11. Then, the data is sync to the database which is MySQL database. As it has an automated synchronization, the data is updated automatically if there is an internet connection. The data can also be synchronized manually as shown in Figure 12, if the live mode of transferring the data have a problem. The blood tube is check-out from the department and check-in to the laboratory. Figure 13 and Figure 14 show the phone interface of check-out and check-in blood tube. The laboratory technologist is easier to check the condition of the test tube whether is acceptable or not and provide their signature in order to check-in the test tube to lab, as shown in Figure 14.
Based on this PISS mobile apps, it provides work efficiency automatization amongst the medical staff. It helps to reduce the human error in phlebotomy process than manual method which cause wrong labelling of patient identity on test tube. By using this PPIS mobile apps, we can reduce the human error such as misidentification, insufficient blood volume for specific test, mislabelling of the blood tube, and expired blood tube that occurred in the pre-analytical phase. This PPIS provide the real-time date record of blood tube. Thus, the blood sample rejection reduced. This PISS work real-time updated and link with related hospital facilities. This system is user-friendly and eco-friendly which provide paperless environment and waster control to our ecosystem.
5. Conclusion
This PPIS mobile app that had been developed can enhance the phlebotomy practice by creating a more systematic way of recording the patient information. By using the mobile application that had been developed, all the test tube with the NFC tag can be scan and the patient information can be key in and stored to the database. This approach will eliminate the manual hand-writing of patient information, thus avoiding some human error in patient registration. This step can also prevent the mislabelling of the test tube after the phlebotomy process as the information can be obtained directly by scanning with mobile phone and then double checking with the patient themselves or wristband of the patient. For the future work, this PPIS mobile application can be further improved by linkage to a portable phlebotomy device which able to provide blood test tube storage and delivery process.

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