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Business Process Re-engineering Of Bacteriology Laboratory Using Tablet PC

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Abstract—Many branches of the health care industry are being influenced by information and communication technology. Laboratory Information System is not an exception. Despite this fact, more than 75% of laboratory data are being collected on paper records. Recent advances in technology, such as broad acceptance of wireless networks and tablet PCs may soon reduce this percentage of paper supported laboratory data. In this paper we introduce a new approach to reduce the paper works in laboratories with the help of Wi-Fi enabled tablet PCs and computer generated barcodes. This system will change the current laboratory practices to a computer driven system, and it will eliminate the turnaround time for obtaining information from current records and encourage collaborative research. The system is currently under implementation in the Bacteriology Laboratory of National Institute of Research in Tuberculosis, in Chennai, a premier research institute of Indian Council of Medical Research.
Index Terms— Laboratory Information System (LIS), Ubiquitous computing, Medical informatics, Tablet PCs, Bacteriology automation system.

1 Introduction

Laboratory investigation is the prime means of diagnosis in modern medical practice. The process includes (a) registering of patient (b) sample collection (c) stages of investigation (d) result entry (e) result validation and (f) final reporting. The Laboratory Information System (LIS) provides a framework for the systematic completion of these activities. It is an important component of the Hospital Information Management System (HIMS)[1],[2]. Among the many challenges that need to be surpassed for an effective implementation of a computerised LIS are over burdened laboratory personnel, space constraints in the laboratory and limited computer and network access. LIS has to be implemented in each of the laboratories (Biochemistry, Haematology, Bacteriology, etc.) of the establishment and the instruments and practices in each will be different.

The investigation system in the Bacteriology laboratory is characterised by predominantly manual operations using human eye (assisted by microscopes) after chemical procedures like smearing, culturing and incubation. Some of the procedures can be completed in a few hours, but others require many months. Due to this, the laboratory will have to maintain a large number of samples in many stages. The LIS system tracks all these to ensure that there is no mixup in the sample creation, processing and reporting. This needs a fool proof strategy that precludes the chance of errors at each stage by a process of cross checking.

A manual LIS for bacteriology laboratory will involve maintenance of many forms, records, and registers where the testing technicians enter the results and verifiers verify them. The process becomes labour intensive and the resulting fatigue starts affecting the turn-around time for obtaining the final results. Computerisation of the LIS in the bacteriology Laboratory aims to solve these issues by automating the processes wherever possible. This requires a detailed study of the current practices in the laboratory to determine the most appropriate means of automation. We have undertaken such a study at the bacteriology laboratory of National Institute for Research in Tuberculosis (NIRT), Chennai.

NIRT is a premier institute of the Indian Council of Medical Research (ICMR) internationally recognized for Tuberculosis (TB) research. It is a Supranational Reference Laboratory and a WHO Collaborating Centre for TB Research and Training. Over the last 50 years, more than a million TB patients were screened and 1.5 lakh patients enrolled to various clinical trials, in this entre. The basic concepts that underpin the globally implemented DOTS strategy were evolved through these series of trials. The bacteriology department in NIRT is the largest facility of the centre. It provides the support for the core research activities (controlled clinical trials, basic research, operational research, drug resistance studies, etc.).

NIRT routinely collects thousands of sputum samples from patients per month. These samples undergo various tests during their preservation that lasts six months to one year. The current process in NIRT is based on human readable manual labels indicating a distinct lab number for each sample. These are generated and pasted to various samples. These are visually inspected by expert technicians periodically for microbe detection during this long period of incubation. The results are initially recorded in note books, verified by a second technician for confirmation and reentered into registers. The results are initially recorded in note books, verified by a second technician for confirmation and reenterd into registers. The entries from the registers are copied by the Statistics departme

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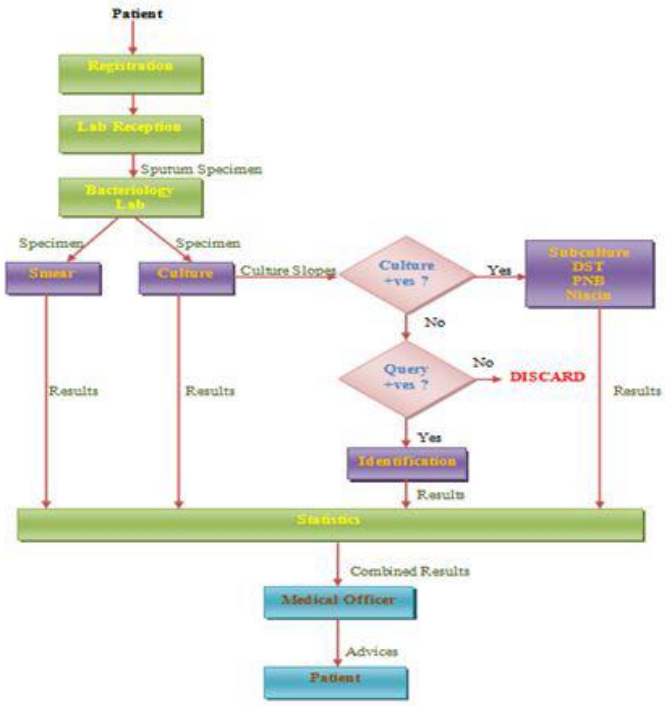

Figure 1. Current Workflow in Bacteriology Laboratory of NIRT

nt. It connects the lab number with the patient identification number and makes the result available in the medical record of the patient. The consulting doctor becomes aware of the result only after this.

It may be seen that the current process of manualrecording of test results to various records, forms, registers, etc. is tedious and prone to manual errors. The operations are spread over many locations. The inspection process requires space for keeping the samples and in many locations, space is a premium. An automation system with traditional desktop computer with its large footprint is not viable in these locations.

Emergence of tablet PCs operating with wireless communication presents a new opportunity of automation. Such an automation system requires machine readable labeling system. Bar codes provide the ideal solution here. We are proposing the business process re-engineering of the existing LIS to one using Wi-Fi enabled tablet PCs and bar codes. The system does not require any costly hardware. Use of Wi-Fi as the communication medium allows faster deployment.

This paper presents the salient features of the system proposed. It is organized as follows: Section 2 describes the current workflow in Bacteriology Laboratory in NIRT. It may be seen that the current workflow is predominantly manual. Section 3 gives list the major disadvantages of this manual system. The proposed automation system uses a set of Tablet PCs for the HMI interface and a separate Clinical Management Server for the business, logic and control functions. Section 4 gives the architecture of this system. The HMI interface consists of a number of control tasks each implemented as an Android application that would automate sections of the current workflow. Section 5 describes these applications and their functionality. Section 6 presents the re-engineered workflow using this setup. It may be seen that most of the problems described in section 3 vanishes now.

2 Existing Workflow of Bateriology Laboratory at NIRT

Figure 1 gives an overview of the present workflow in the bacteriology laboratory at NIRT [4].

2.1 Registration

The registration is the first process seen by the patient. It is done at the clinical reception and bacteriology lab is not involved in this. The process enters the demographic details of the patient into the registers and forms maintained by the system. From the reception, a bottle is provided to the patient to collect the sputum sample and the bottle number is recorded. After completing the registration process a treatment ID card is given to the patient for future reference. This ID is made available in the lab reception.

2.2 Lab Reception

After the registration the patient submit his sputum specimen at the lab reception. The unique lab number for each specimen is assigned over here. The tightly packed specimen bottle is kept immersed in disinfectant solution for a specified period. An analyst processes samples in batches. A batch consists of 12 samples. Then, each batch is send to the Bacteriology laboratory.

2.3 Smear Test

On receiving each batch the lab technician verifies the lab numbers and arranges them in order. In the laboratory, part of the specimen is used for smear test and the rest for culture test. For each sample one slide for smear and two slopes for cultures are then prepared. When the smear is ready for inspection, they are visually inspected under the microscope by concerned technicians and entered into a test result form. This is verified by other senior laboratory person and sent to the Statistics department.

2.4 Culture Test

Two slopes of cultures are prepared for each sputum sample and incubated for a minimum of 10 days. After the minimum incubation period, the senior laboratory people visually inspect them and the results are entered into the concerned registers. They are passed on to the Statistics department for analysis and further procedure documentation. Subsequent procedures are decided at this stage.

2.5 Drug Susceptibility Test and Confirmation Tests

If the culture result is positive Drug Sensitivity Test (DST) and Confirmation Tests are performed. The confirmation test Includes Para Nitro Benzoic acid (PNB) test and Niacin test. The results of these tests are also passed on to the Statistics department.

2.6 Identification and Subculture

If the culture result is either contaminated or shows unclassified mycobacterium (UMB) then the Identification (ID) is performed in the laboratory. If the study patients second sputum becomes positive subculture are performed for the confirmation of slopes.

2.7 Combining of results at Statistics

The transferring of each patient's lab test results to his corresponding case sheet is done at the Statistics department. This ensures that the identity of the patient is not known to other departments. The test results are entered on several registers manually. The existing system maintains at least two registers for each test. This is done for cross checking in case of later doubt and also for efficient retrieval of test results.

2.8 Advice by Medical Officer

Once the checking and verification by Statistics department is complete, the case sheet is send to the Medical Officer. After analysing the results, the medical officer gives necessary advices and drugs to the patient.

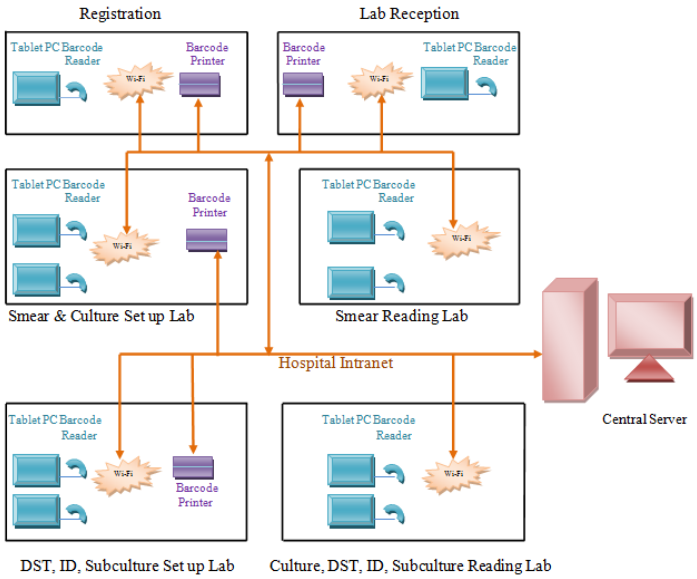

Figure 2. Proposed System Overview

3 Advantages and Disadvantages of Current Workflow

It may be seen that the current workflow of Bacteriology lab in NIRT is primarily manual. It involves only manual entry and copying of information from note books, tabulation tables, paper slips etc. The technician does not require any additional computer knowledge or training. Another advantage is that it is very flexible and is adaptable to any changes. Since all information is captured in hard copy form, that too in multiple registers, it is considered to be more robust than storing same information in computer disks that is susceptible to hardware failures and virus attacks that can erase the entire information store in one stroke.

However, the manual work has many disadvantages.

The major among them are:

1) Increased turnaround time
2) Tedious and prone to manual errors
3) Data Loss
4) Information extraction is difficult
5) Space wastage

4 Architecture of Bacteriology Laboratory Management System with Tablet PC

Figure 2 gives the architecture of the proposed system. It consists of seven segments. They are a) Registration b) Lab reception c) Smear culture set up lab d) Smear reading lab e) DST, ID, Subculture set up lab f) Culture, DST, ID, Subculture reading lab g) Central server. In registration segment a unique barcoded treatment number is assigned to each new patient. When an already registered patient comes the registry clerk scans the bar-coded treatment number from the ID card and continues with subsequent procedures. The lab reception segment provides a unique identification for each sample in the form of bar-coded lab numbers. Then these barcode labels are pasted on the specimen containers.

Each technician in the following four segments i.e. i) smear culture set up lab ii) smear reading lab iii) DST, ID, Subculture set up lab iv) Culture, DST, ID, subculture reading lab, will be guided by a tablet PC for each of his operations using visual icon based commands. The bar code readers are then used whenever the lab number need to be inputted to the system. Each segment consists of around two barcode printers, two barcode readers, and two tablet PCs [7]. The complete lab will be Wi-Fi enabled so that the information entered by the technician will be stored in a local server system within the lab. It will be moved to the central server at periodic intervals.

The final segment is the central server. The central repository is a unified database of all collected data, which includes patient details; daily filled various test results etc. This central database is intended to offer a better overview of data and easier follow up of patients. In order to prevent accidental loss of data, copies of backup of the database are created at regular intervals. It will be possible for clinicians with necessary access permissions to access the database from anywhere and create reports based on various query outputs. The access to central database can be restricted to selected personnel or

group of personnel based on access privileges set up for this purpose.

Finally, all the details regarding a patient will be available in the doctor's desk for the analysis and further treatment. It will eliminate the turnaround time for obtaining various test results from current records. It will substantially reduce the cost and time for completing epidemiological surveys.

5 Re-engineered Workflow

Offering an entirely computerized laboratory information management system [5],[6] to manage the whole of the laboratory information and administrative data flow during the patient treatment is the best way to alleviate the disadvantages d tailed in Section 3. The following subsections provide the reengineered workflow at the various sections described in section 2.

5.1 Registration

During registration the registry clerk captures the patient data and stores it in the tablet. A registered patient has to be identified by unique treatment number. The patient is also given a patient identification card in which the bar coded treatment number is pasted. At the reception, a bottle is given to the p tient and the bottle number is recorded in to the tablet by the concerned staff. Also, he mentions the type of specimen that is clinical or home sample.

5.2 Lab Reception

Submission sputum sample at lab reception will follow the same workflow as before, as far as the patient is concerned. On submission, the technician in the lab reception reads the bar-coded treatment number from the patient ID card and it leads to the patient profile, and checks the authenticity of the bottle number. Then, he can assign lab numbers to each sample and the computer generated barcode labels are pasted on to the bottles. Same procedure is followed for sending bottles to the lab as mentioned in section 2.2.

5.3 Smear Test

Smear set up procedure is same as existing. For the identification of smear slides, bar coded labels are duplicated and pasted on them. The technician then input the necessary information regarding smear set up in to the system. The smear reading technician scans each bar coded lab number and examines the slides. Then he makes corresponding result to the tablet. Since the entire lab is Wi-Fi enabled, initially these results are stored in a local server system. It will be moved to the central server system periodically.

5.4 Culture Test

Existing procedure is followed for the culture set up. For the two culture slopes the barcode labels are duplicated. After completing the minimum incubation period, the prepared culture samples are ready for reading. The technician who is responsible for culture reading examines the cultures and makes entry into the tablet by scanning the barcode labels. Based on the culture results all the subsequent lab tests are performed.

5.5 Drug Susceptibility Test and Confirmation Tests

For the positive cultures the drug tests is performed. For the setting up of drug containing slopes, duplication of barcoded lab numbers is essential. At the time of examination the technician scans the barcodes and then he can make necessary entries to the tablet PC. The same procedure is followed to the confirmation tests.

5.6 Identification and Subculture

Identification and subculture tests are performed for query positive culture slopes. Here also duplication of barcodes is needed. The test results are entered to the tablet by scanning the barcode labels.

5.7 Combining of results at Statistics

All the test results are immediately available on the Tablet PC with the statisticians. If they notice any error then they can inform about it to the concerned technicians, by a sending an alert message to the tablet PC of the technician as well as the head of Bacteriology department. This will ensure early resol tion of errors. The statistics department will also make a back up copy of patient details in periodic intervals. They may also take paper backup using a printer as a final precaution against possible deletion of electronic records.

5.8 Advice by Medical Officer

Finally, all the inputted test results are stored in the central server. Thus the medical officer can view the progress of all laboratory tests on his screen. However, he may be able to see the results only after the statistics department releases it. In cases of emergencies, the director could permit viewing of the result by doctors even before the statistics department has released them. This is an administrative rather than technical matter.

6 Conclusion

In this paper we present an approach for the reengineering of Bacteriology laboratory in NIRT. The proposed method is based on tablet PCs and barcodes. The key benefits of the system are reduction of turnaround time for getting the laboratory results and avoiding the manual errors. The system described here can be readily extended to for automation of other bacteriology labs of NIRT. The concept with appropriate modifications can be used for automation of other laboratory information systems, as well.

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