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http://aisel.aisnet.org/amcis2008/251

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Error Reduction in Healthcare Delivery

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Abstract

Some major studies on patient safety have listed among other findings the need to improve the accuracy of patient identification to reduce laboratory errors. The studies have also found that most errors occur in the pre-analytical phase and suggest the implementation of a more rigorous methodology and technologies for error reduction.

In line with the findings of the studies, this paper introduces ATOMS (Advanced Test Order Management System), a knowledge-based system for the management of specimen ordering and collection. ATOMS enable complete automation of the laboratory ordering process, from the point of physician-patient contact until specimen delivery to the laboratory. With physicians performing tests orders on the Order Entry System, ATOMS results in a unique blend of technology which ensures that laboratories receive complete electronic laboratory orders and pre-labeled specimen tubes which are ready for direct analyzer placement. A pilot trial of ATOMS was conducted at a local government hospital for three months. The results of the pilot trial indicated that the application of ATOMS increased patient safety by significantly reducing the opportunity for mistakes and the actual number of errors in healthcare delivery.

1. Introduction

In 1999 the United States Institute of Medicine (IOM) reported in “To Err is Human: Building a Safer Health System” [1] that the medical community was responsible for many serious errors in the delivery of care. In 2002 a report by the Rand Corporation on the delivery of care in over 20 centers in urban United States, estimated that nearly half the patients treated for a variety of diseases had not met the approved standards of care. Of particular importance in this report was the frequent citation of the laboratory testing procedure as an important contributor in improper care delivery.

The United States 2004 National Patient Safety Goals lists, as an important priority, the need to improve the accuracy of patient identification. Between 32-75% of laboratory errors originate in the pre-analytical phase and most of these are identification errors, at steps which are beyond the control of the laboratory [2].

The 2005 US National Patient Safety Goals released by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) has highlighted the need to improve the accuracy of patient identification whenever retrieving bloods specimens and other specimens for clinical testing.

Bonini et al in [2] noted “The large heterogeneity of literature on laboratory errors together with the prevalence of evidence that most errors occur in the pre-analytical phase suggest the implementation of a more rigorous methodology for error detection and classification and the adoption of proper technologies for error reduction. Clinical audits should be used as a tool to detect errors caused by organizational problems outside the laboratory.” They further added in [3] “A body of evidence has been collected in the last few years to demonstrate that a large percentage of laboratory errors occurs in the pre- and post-analytical steps, in particular at the beginning (pre-preanalytical phase) and at the end (post-postanalytical phase) of the total testing process. These errors are especially related to requests for an inappropriate test and errors in patient and specimen identification, data interpretation, and actions taken on behalf of the patients.

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Given the above findings and calls for patient safety in the pre-analytical phase, a knowledge-based system for the management of specimen\(^4\) ordering and collection was developed and trial-tested in a Singapore government hospital. This system facilitates the automation of the specimen ordering and collection process, from the point of physician-patient contact until specimen delivery to the laboratory. The system is known as ATOMS – Advanced Test Ordering Management System. It was developed through a lengthy interview process with clinicians, phlebotomists, laboratory technicians, nurses, and doctors over a period of 6 months. Domain information relating to the workflow of test ordering, specimen collection and testing were gathered through this process. In this paper, we describe the motivations for ATOMS and discuss the design and implementation of the knowledge-based application. The applicability of ATOMS in a hospital environment was tested through a pilot trial conducted in a local government hospital. The findings of the pilot trial are also discussed in this paper.

2. Motivations for ATOMS

2.1. Specimen Collection Workflow

The specimen test ordering process begins with a doctor making request for blood/urine specimens. Patients’ information and test requests are recorded manually in a paper form and the form is passed to a phlebotomist to carry out the collection of blood/urine specimens from the patient. Paper forms are a bane to the staff receiving the test orders and there is an alarming incidence of illegible forms which usually results in best guesstimates as the tests ordered.

Different colored tubes are used to distinguish the specimens to collect. Knowing which colored tubes to use when the specimens are taken is a knowledge that phlebotomists have learnt through experience and this knowledge resides in their memory and needs to be refreshed occasionally. Tubes of blood specimens taken are then labeled with the patient’s name and identification number, which is readily available on labels in the ward, for transit to the laboratories, where they are registered into the LIS (Laboratory Information System).

An accession number, generated by the LIS, is then printed on a label which is stuck onto the previously labeled blood collection tube before it is put into the laboratory analyzers where relevant tests are conducted on the specimen.

Test results are subsequently transcribed into a typical LIS for further analysis and quality control. Figure 1 shows the typical workflow used in the hospital we studied and which this paper now reports.

![Fig. 1: Typical Workflow in Specimen Collection](image)

2.2. Source of Errors

There are many areas where errors can happen within the specimen collection workflow. For example, the manual recording of patient’s and medical professional’s information in the order form; the manual recording of test orders; the manual labeling of tubes containing blood specimens; and at the laboratory, a second label with a new laboratory

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\(^4\) A specimen could be blood, urine, stool or mouth swab specimen.
accession number is generated and this label has to be checked against the record to ensure that they tally.

2.3. Costs of Errors

Any error made in the pre-analytical phase can be serious and expensive. Studies carried out in the United States (e.g. [4]) estimated the cost to hospitals due to specimen-related errors at over US$200 million per year. The cost is not only limited to the hospitals, patients are also paying for it. For patients, specimen collection errors during the pre-analytical phase can lead to medication errors, inappropriate or delayed therapy, possibly prolonged hospital stays, increased disability or worse. For the hospital concerned, specimen collection errors can have a major negative impact on finances, as measured in time spent tracking and correcting errors, performing re-draws or repeat testing, as well as the costs associated with unnecessary treatment.

2.4. Modified Workflow with ATOMS

With ATOMS, test orders are sorted and presented to the nurses/phlebotomists as meaningful information for them to carry out their duties effectively. As the patient appears at the test collection station to provide his/her specimen (blood, urine, stool, mouth swab), ATOMS facilitates the right tests for the right patient by ensuring that there is synchronicity between patient identification and tests ordered. Matching patient identification to the tests ordered by the doctor and the actual tests to be carried out by the LIS system is ensured at this point of the pre-analytical phase through ATOMS. Figure 2 show the ATOMS workflow in specimen collection. Note that some steps in the typical workflow have been eliminated with the introduction of ATOMS and with it the probability of errors.

3. ATOMS

3.1. Design Objectives

ATOMS is designed to ensure that laboratories receive complete electronic laboratory orders and pre-labeled specimen tubes which are ready for direct analyzer placement without any further labeling. It is also designed to integrate seamlessly with the healthcare facility’s electronic medical records and laboratory information systems. One of the greatest benefits of the solution, besides ensuring patient safety, is the efficient flow of real-time information that is critical to implementing effective and safe treatment plans.

ATOMS is configured as a "closed loop" system, customized and designed to specifically maximize the efficiency of the specimen collection process, while eliminating any opportunity for error.

![Fig. 2: ATOMS Workflow in Specimen Collection](image-url)

3.2. The ATOMS Specimen Collection Process

The ATOMS specimen collection process begins with clinicians/doctors making order requests via electronic forms, instead of the hardcopy forms, and carried out through computer terminals from anywhere in the hospital.
At the core of ATOMS is a knowledge base developed through multiple interviews and discussions with clinicians/phlebotomists/nurses over a period of 12 months to get a thorough understanding of the typical workflow for specimen collection and labeling. During specimen collection, the phlebotomist or nurse can access the ATOMS application through computer-on-wheels that may be in a wired or wireless environment (see Figure 3). This facilitates mobility of the system right to the patient’s bedside in ward settings.

Figure 4 is a screen showing the test order selected for specimen collection. In this case, Renal Panel #1 is selected. A set of colored tubes for specimen collection is automatically determined by ATOMS and displayed (see Figure 5). This visual representation of colored tubes facilitates on-screen recognition for the specimen taker to quickly know which collection tubes to use for that particular patient. The tacit knowledge of matching the color-coded collection tubes to the biochemical tests ordered now resides in the knowledge base of ATOMS. On-screen graphical recognition facilitates efficiency and productivity during specimen collection while negating the opportunity for errors.

In addition to the normal cases of specimen collection, the design of ATOMS includes exceptions. Figure 6 shows a situation when the specimen collection was halted because the patient had gone missing and could not be located. As shown in the figure, there are four other possibilities such as failed attempt, difficult vein, patient refused specimen taking, or the patient did not fast prior to the test. With these cases included, the specimen taker can indicate the case that best describes the situation as a reason for unsuccessful specimen collection.

When all the tubes have been collected, they are labeled with the labels printed at the point-of-care before the tubes are sent to the laboratory for analysis. Printing the labels at the point-of-care ensures the correct labels are used for the specimens and removes the likelihood for errors common in manual systems.

4. Trial Testing ATOMS

To test out ATOMS, ATOMS was deployed in a Singapore government hospital and trial-tested for a period of three months. The hospital is a multi-discipline tertiary reference hospital with 1000 beds. It has a fully automated clinical laboratory processing 4000 tubes taken from 500 to 600 out-patients per day.

The specimen collection process undertaken by phlebotomists at an outpatient clinic was guided and enforced by ATOMS.
4.1. Objectives of the Trial

The objectives of the trial are two folds:
1. To determine the viability of ATOMS in increasing patient safety in test ordering and specimen collection.
2. To determine the inter-operability issues between ATOMS and other systems such as the LIS and a communications hub.

4.2. Deployment of ATOMS in the Trial

Figure 7 show the deployment of ATOMS in the trial.

The ATOMS server is connected to the hospital’s LIS server using HL7 messages. Connecting systems using HL7 standard messages ensures seamless interoperability among systems.

The required accession numbers for the patient specimens are retrieved from the LIS. With the accession number, labels for the tubes can be printed at the point-of-care where the specimen is collected. The purpose of printing the labels at the point-of-care is to reduce errors due to multiple tube labeling.

4.3. What are involved in the Trial?

A computer-on-wheel (COW) is deployed at the specimen collection station of the outpatient clinic in the hospital. It comprises of a touch sensitive LCD panel attached to one end of the standard hospital trolley and a holder containing a standard laptop below the top surface of the trolley. The LCD panel is connected to the laptop and they are both powered via rechargeable lithium-ion batteries. Connectivity to the ATOMS is via a wireless network access device attached to the laptop. Devices connected to the laptop include: a touch sensitive LCD panel, a standard barcode reader, and a standard barcode printer.

During the three-month period, the phlebotomist uses ATOMS to facilitate specimen collection. Previously, phlebotomists have to refer to a chart stating the colored tubes and the amount of specimens to collect.

With ATOMS, the types of tubes and the on-screen graphical display facilitate that in real time. In addition, tight control on the printing of tube labels ensures that the correct labels are used for the case at hand.

Fig. 6: Unsuccessful Specimen Collection

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4.4. Findings of the Trial

For reasons of confidentiality with the hospital, we are not able to report on the actual numbers in this paper. However, it is clear from the trial that the rates of mistakes arising from multiple labeling of tubes, patient identification, tube selection, and the amount of specimen to collect dropped to zero.

ATOMS also greatly reduced the time required to train a phlebotomist in specimen collection since much of that tacit knowledge required is now incorporated.
within the knowledge base of ATOMS and displayed in real time.

During the trial, besides the error rates dropping to zero, we also found that there was significant time savings in carrying out the collection process, reduction in manpower costs equivalent to two full-time equivalents in laboratory staff and savings in consumables like labels and tubes.

5. Conclusion

ATOMS provides unique but crucial workflow tool for phlebotomists and clinicians to eliminate errors during the pre-analytical phase of patient specimen collection, significantly enhancing patient safety during healthcare delivery. Some of our conclusions from the trial of ATOMS in the outpatient hospital setting include bedside pathology ordering by doctors and nurses for hospital patients, robust patient-positive identification and phlebotomy management at bedside or at specimen collection point.

When compared with the cost of errors, the total costs of developing ATOMS is considered small. This is because the cost of errors can go into the millions if the hospital is sued for negligence by patients who are wrongly diagnosed due to errors in the pre-analytical phase.

ATOMS is extensible and applies to most hospitals because the workflow incorporated in ATOMS is similar, although not necessarily the same, to all hospitals. The issues and errors encountered are generally common in all hospitals. ATOMS addresses an important safety enhancement in healthcare delivery.

Acknowledgement

The authors would like to acknowledge the contributions of the followings in the development of ATOMS5:
2. Mr. Peter Lim, Ms. Tan Chiew Hwee, Mr. Steven Tsai, and Ms. Wong Chooi Lai - Staff, Department of Laboratory Medicine, National University Hospital, Singapore.

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5 Patent has been filed in Singapore under Singapore Patent Application number: 200705750-8 on 14 August 2007.