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Pre-analytical workstations: A tool for reducing laboratory errors

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ABSTRACT

Laboratory testing, a highly complex process commonly called the total testing process (TTP), is usually subdivided into three traditional (pre-, intra-, and post-) analytical phases. The majority of errors in TTP originate in the pre-analytical phase, being due to individual or system design defects. In order to reduce errors in TTP, the pre-analytical phase should therefore be prioritized. In addition to developing procedures, providing training, improving interdepartmental cooperation, information technology and robotics may be a tool to reduce errors in specimen collection and pre-analytical sample handling. It has been estimated that >2000 clinical laboratories worldwide use total or subtotal automation supporting pre-analytic activities, with a high rate of increase compared to 2007; the need to reduce errors seems to be the catalyst for increasing the use of robotics. Automated systems to prevent medical personnel from drawing blood from the wrong patient were introduced commercially in the early 1990s. Correct patient identification and test tube labelling before phlebotomy are of extreme importance for patient safety in TTP, but currently few laboratories are interested in such products. At San Bassiano hospital, the implementation of advanced information technology and robotics in the pre-analytical phase (specimen collection and pre-analytical sample handling) have improved accuracy, and clinical efficiency of the laboratory process and created a TTP that minimizes errors.

1. Introduction

Laboratory testing is a highly complex process. The testing cycle, commonly called the total testing process (TTP), was well described several years ago by Lundberg [1]. In the performance of any laboratory tests, Lundberg described the brain-to-brain turnaround time as a series of nine steps consisting of: ordering, collection, identification, transportation, preparation, analysis, reporting, interpretation and action.

The laboratory testing process starts outside the laboratory with the physician ordering the test, followed by the nurse or phlebotomist obtaining the specimen, the courier delivering the specimen, and the laboratory personnel performing the test; the loop is completed when the laboratory delivers the correct result back to the physician, who may rely upon the laboratory's expertise and clear presentation to interpret the result [2].

Although TTP is usually subdivided into the three traditional (pre-, intra-, and post-) analytical phases, the pre-analytical phase can be further subdivided into the "conventional" pre-analytical phase, which occurs under the control of the laboratory, and pre-pre-analytical phase, which occurs outside the laboratory and consists of the selection of appropriate tests on the basis of clinical question, ordering, collecting and handling, transportation and reception of samples prior to testing. The "conventional" pre-analytical step involves the processes required to make a sample suitable for analysis: centrifugation, aliquotting, diluting and sorting the specimens into batches for their introduction into automated analyzers [3].

2. Errors in laboratory medicine

The laboratory service plays a key role in patient care, and laboratory data are estimated to affect 60–70% of the most important decisions on admission, discharge, and medication [4]. Consequently, laboratory testing is an important source of medical errors affecting patient safety. Moreover, errors can occur in each and every step of TTP. Of all errors in TTP, approximately one fourth have consequences for the patient [5–7], which include a delayed test result or new sample collection, but may also have a life threatening impact [8], and tragic consequences, such as the administration of unnecessary chemotherapy or the onset of coma [9].

Since the few studies available on laboratory errors are heterogeneous, the frequency of errors in clinical laboratories reported in the literature varies greatly, there being differences in definitions used, methods used to identify frequency and nature, and study design and setting (Table 1) [10].

3. Strategies for preventing errors

Although, most of the laboratory quality improvement efforts once focused on improving the analytic process, findings reported in the

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Table 1
Types and rates of error in the three stages of the laboratory testing process (modified from reference [10]).

Phase of TTP	Type of error	Rates
Pre-analytical (Outside the laboratory)	Inappropriate test request	46–68.2%
	Order entry errors	
	Misidentification of patient	
	Container inappropriate	
	Container improperly labeled	
	Sample collection and transport inadequate	
	Specimen collected from infusion route	
	Inadequate sample/anticoagulant volume ratio	
	Insufficient sample volume	
Pre-analytical phase (Within the laboratory)	Sorting and routing errors	
	Pour-off errors	
	Labelling errors	
	Biohazard exposure event	
Analytical phase	Equipment malfunction	7–13%
	Sample mix-ups/Interference	
	Undetected failure in quality control	
	Procedure not followed	
Post-analytical phase	Failure in reporting	18.5–47%
	Erroneous validation of analytical data	
	Improper data entry	
	Excessive turn- around time	

literature showed that pre-analytical factors call for an equally thorough consideration and investigation, and indicated that laboratories should implement a series of effective interventional measures to reduce pre-analytical errors, thereby enhancing patient safety.

A comprehensive plan to prevent pre-analytic errors has five interrelated steps [11–13]:

1. Developing clear written procedures.
2. Enhancing healthcare professional training.
3. Automating functions, both for support operations and for executive operations.
4. Monitoring quality indicators.
5. Improving communication among healthcare professionals and fostering interdepartmental cooperation.

Written procedures should clearly explain how to reliably identify a patient, collect and label a specimen, and subsequently transport the specimen and prepare it for analysis. To ensure that written procedures are consistently followed, those who perform pre-analytic activities must understand not only what the proper procedures are, but also why these steps are important and how failure to correctly follow instructions can cause serious errors. This calls for ongoing training, beginning in the new employee orientation period and continuing in annual proficiency and competency assessments. Moreover, because many pre-analytic steps are often performed by non-laboratory personnel, the laboratory's program should include efforts to train them to properly follow collection procedures.

Modern technologies such as robotics and information management systems can also help reduce errors. Pre-analytical workstations allow the automation of some steps, thereby reducing both the number of people involved in the pre-analytic phase, and the number of manual steps required; moreover, barcodes simplify specimen routing and tracking. A computerized order entry systems (COES) that simplifies test ordering for the clinician obviates the need for a second person to transcribe the order.

The success of efforts made to reduce errors must be monitored in order to assess the efficacy of measures taken. Quality indicators, such as the rate of sample label errors, which focus on specific problems, should be used for assessment. It is also important to bear in mind that, as many pre-analytic activities are performed by non-laboratory personnel, interdepartmental cooperation is of crucial importance in avoiding errors. It is thus clear that the entire health care system is involved in improving the total testing process.

4. Pre-analytical procedures performed within the laboratory

Specimen preparation, which involves all the activities required to render a sample suitable for analysis, includes log-in, centrifugation, aliquotting, pipetting, dilution, and sorting specimens into batches for their introduction into automated analyzers. When performed by technologists unaided by automation, the pre-analytic tasks account for the most labor intensive phase of testing in the medical laboratory. The risk of human error in this phase is exacerbated by the fact that currently laboratories are handling ever-increasing workloads while experiencing a reduction in personnel: the consequent physical and mental fatigue also leads to errors.

The specimen preparation step, which contributes to approximately 19% of the overall cost of analyzing a single specimen, is also time-consuming (37% of time spent in producing a result) [10]. The manual handling of potentially infectious samples exposes laboratory staff to biohazards whenever samples are splashed or test tubes broken.

5. Pre-analytical workstations

The automation of the pre-analytical phase is therefore a means to preventing errors. In a paper on this issue, the use of automated pre-analytical robotic workstations effectively reduced the labor associated with specimen processing, and reduced the number of laboratory errors occurring on sorting, labeling, and aliquotting specimens; it was also found to improve the integrity of specimen handling throughout the steps of specimen processing [14].

Before choosing an automated pre-analytical workstation, laboratory professionals must establish specific quality goals: avoiding mistakes calling for new sample collection; reducing sample volume; ensuring secure patient and specimen identification; tracking throughout the process; achieving effective preservation; decrease sample handling; contain biohazards; minimize human labor and number of test-tubes used [15]. These quality goals may then be applied to various steps of sample handling, including sample log-in, sorting, centrifugation, detection and aliquotting. It should also be ensured that the system, on installation, will have no adverse effects on the working environment in terms of generation of excessive heat or noise, and that it will minimize occupational exposures; nor should it call for major renovations to fit into the available space. The available components/options for pre-analytical workstations and some of their advantages and disadvantages are shown below [16,17]

1. Sample specimen input area: a loading module where bar code-labeled specimens are introduced into the system. These input units often separate stat specimens from routine specimens, or specimens requiring centrifugation or decapping, into different trays or racks so the system's process control can determine the steps to be performed based on the specimen's loading location.
2. Sample identification: although all systems initially read the specimen bar code to identify the sample, there are two options for sample identification: (1) multiple linear bar code readers, and (2) radio-frequency identification (RFID) of specimen carriers combined with 1 or more bar code readers. The robustness of sample identification is critical; when specimens are identified by bar codes the sensitivity of the system to bar code-label quality and orientation is important and, when specimens are identified by RFID fixed in their carriers, it is of crucial importance to prevent the manual removal of tubes from the carriers in order to maintain the link between the tube bar code and the carrier's identification. Some systems have multiple bar code readers placed at critical locations in the processing system to track specimens and provide information for their proper routing to the various stations in the processing system.

Table 2
Types and features of pre-analytical workstation (Subtotal automation) (modified from reference [18]).

Name of system	Pathfinder MK2	LabFLEX 2500	AutoMate™ 800	AutoSorter III	HCTS 2000 MK3	OLA2500 High Speed Full Size System	TCAutomation enGen (in US)	RSA Pro	FE 500	PVS
Company	AI Scientific	Aloka	Beckman Coulter	Motoman	Mutt	Olympus	Ortho/Thermo	PVT	Tecan	Sarstedt
Automated sorting	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Centrifuge	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Automated aliquoting	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Decapper	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Recapper or sealer	Yes	No	No	Yes	No	Yes	Yes	Yes	No	No
Specimen integrity monitor available	No	No	No	No	No	No	No	Yes	No	No

3. Tube types: systems differ with regard to size and type of tubes for processing. Some systems have tube carriers or racks that can handle tubes of any size, but the centrifuge, decapper, aliquotter, and/or recapper may not be so versatile. In some of these systems, larger tubes must be decapped or centrifuged manually.
4. Transport system: segments of conveyor belt line that move specimens in transport carriers to the appropriate destination. Some carriers hold only one specimen, while others may hold several specimens.
5. Sorting or routing device: this separates specimens by order code, specimen type (e.g., tube height or cap color), or information derived from the input unit as (see point 1), and directs or routes the specimens to either the transport system or racking system.
6. Automated centrifuge: a module in which specimens for centrifugation are removed from the conveyor and placed in a centrifuge. The capacity and functionality of each centrifuge differ, depending on the system. Centrifuge capacity, tube sizes and types accommodated (i.e., pre-spun, decapped), throughput, and temperature of spin were all evaluated metrics. The presence of the mechanism that balances different-sized tubes is important because pre-balancing the tubes or placing the tubes individually in the centrifuge may delay processing. It is also important to consider the number of centrifuges available especially in higher-volume laboratories or in laboratories with frequent stat test requests. Moreover multiple centrifuges may be necessary for laboratories planning to install automated coagulation testing.
7. Level detection and evaluation of specimen adequacy (specimen integrity): an area in which sensors are used to evaluate the volume of specimen in each container and to look for the presence of clots, hemolysis, lipemia, or icterus. In some systems, integrity checking is included in the main automation system and in others, the interfaced analyzers perform these functions. Most aliquotting systems can measure specimen volume, and some can check for interfering substances.
8. Decapping station: a module in the automated system by which specimen caps or stoppers are automatically removed and discarded into a waste container. While most systems contain a decapper, not all have can decap hemogards and rubber stoppers and/or screw caps.
9. Aliquotter: a module that aspirates appropriately sized aliquots from each original specimen container, as directed by order codes and the system's process control software, placing them into bar coded secondary specimen containers. Most aliquotters can perform clot detection and level sensing. Some systems record the volume remaining in the tube optically, notifying the technologist if enough volume is available for an add-on.
10. Interface to automated analyzer: a direct physical connection to an automated analyzer that allows the analyzer's sampling probe to aspirate directly from a decapped specimen container. In some TLA designs, the specimen container is robotically removed from the transport carrier and inserted in the analyzer.
11. Specimen delivery/sorting: the system may be designed to accommodate aliquots and/or primary tubes. A sorter usually sorts into different sort groups in racks or carriers. In some systems, the racks are specific to certain analyzers for convenience. One manufacturer routinely produces aliquots from the primary specimens, delivering them to the analyzers. Although the system records the location of the primary specimens and aliquots, the aliquots are not individually labeled.
12. Recapping station: a module in the automated system by which specimen tubes are automatically recapped with new plastic cap or heat-sealed aluminum foil, in preparation for online or offline storage. An automated mechanism to subsequently decap the specimen for add-on testing is not always available.
13. Take-out stations: a module for temporarily holding specimens before or after analysis. The take-out station may be the same as that for the above-described specimen delivery/sorting, specimens being sorted for manual delivery to off-line laboratory sections.

Vendors supply both stand-alone independent specimen processing systems that automate several pre-analytic activities but do not transport tubes with conveyors (Table 2) and pre-analytic workstations interfacing directly with the automation system that combines analytic activities (analyzers) and post-analytic functions. (Table 3).

Table 3
Types and features of pre-analytical workstation interfaced directly to the automation system (TLA).

Name of system	Accelleretor	Open LA21 Module System (Clinilog III)	Power Processor	The Efficiency series	Flexlab	enGen	Modular Analytics Evo	StreamLab	Advia LabCell
Company	Abbott	A&T	Beckman Coulter	iLAS	Inpeco	Ortho	Roche	Siemens	Siemens
Automated sorting	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Centrifuge	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Automated aliquoting	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Decapper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recapper or sealer	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Specimen integrity monitor available	No	No	Yes	No	No	Yes	No	Yes	Integrated on chemistry instrument

Modified from reference [18].

The first type of automation may be considered "subtotal automation", these systems sorting processed specimens and putting them into racks for manual transport to the testing areas. They may be a suitable choice for laboratories with low or medium daily workloads of specimens, laboratories with space limitations, or laboratories requiring an upgrade path and ease of use with different analyzers from different vendors. The second type of automation is defined as total laboratory automation (TLA) [17].

In CAP Today's 2008 annual survey of the automation vendors, it was estimated that there are more than 2000 clinical laboratories worldwide with total or subtotal automation supporting pre-analytic activities, showing a markedly higher rate of increase than that in 2007 [19]. (Table 4)

After nearly a decade of interest in laboratory automation systems, the need to reduce errors, not the anticipated return on investment from labor cuts, appears to have acted as the catalyst in the increased use of robotics [20].

6. Implementation of the change

In order to re-engineer sample handling, one of the major issues in clinical laboratories that involves many manual processing steps, the following should be undertaken: mapping the process; measuring the performance model; showing the results; using simulation tools; simplifying and redesigning; gaining consensus [21].

7. Pre- pre-analytical procedures performed outside the laboratory and strategies to prevent errors

The pre-pre-analytical phases performed outside the laboratory are: formulating a clinical question and selecting appropriate examinations, ordering, collecting, handling and transporting samples. Errors can occur in each of these steps, the most common being inappropriate test requests, incorrect or incomplete information on the test request, patient or specimen identification errors and use of inappropriate container.

Paper-based test requests in themselves pose a risk because they may be completed only partially, placed in the wrong collection box, or simply lost. Computerized order entry systems (COES) replace the paper-based test request by allowing the ordering information to be directly fed into a computer. This type of system is often combined with the electronic delivery of the test result, sometimes accompanied by a digital signature. A COES eliminates many sources of error, above all those connected with paper-based information, such as transcription error and lost requests or results [22].

Strict adherence to blood-collection procedures is the most effective means to ensure specimen quality during the collection and processing phases of laboratory testing. Although a relatively common, potentially fatal pre-analytical error is improper patient identification or mislabeling of test tubes, many hospitals worldwide have not yet set up adequate patient identification procedures or systems. This handicap is attributed to economics, management, and educational issues in the organizations involved. Critical patient identification errors in TTP occur in approximately 1 out of every 1200 test requests or on average in 1 out of 2600 billable tests [23]. Failure to correctly identify patients can lead them being treated, diagnosed, medicated, and managed on the basis of the health status of other patients' health status. Patient identification and test tube labeling are tasks of importance not only in TTP, but in all areas of health care.

According to the Clinical and Laboratory Standards Institute (CLSI) an inpatient should be asked to state her/his full name, address, birth date, and/or unique identification number. The information provided must be compared with the information on the identification wristband that must be worn by the patient, and the test requisition or computer-generated labels brought to the patient's bedside. If the patient is unable to say her/his name due to language barriers or his/her state of consciousness, the standards in force require a caregiver or family member to provide the information on the patient's behalf, before any specimen can be drawn.

For outpatients, CLSI recommends that patients should state their name address, birth date, and/or unique identification number and comparing that information with the requisition or forms they brings with them to the draw station. Neither inpatients nor outpatients should be asked questions such as "Are you Robert Smith?" Patients may answer in the affirmative without understanding the question. The correct approach is to ask the patient his/her name. To prevent mix-up, specimen containers, which should be properly and permanently labeled while the collector is at the patient's side, should bear at least the following information: the patient's first and last names; identification number, date and time of sample-taking (as required); and the collector's identification [24]. If a bar-coding system is used, the service protocol should be followed.

The problem of patient misidentification may be approached by using non-technical methods (patient safety guidelines and procedures) and/or technical solutions (identification wristbands containing the patient's name and identification number, and sometimes also a barcode or RFID). Non-technical solutions usually involve the definition of hospital risk management procedures that the medical staff must follow; these procedures help reduce the risks and improve patient safety. Technical solutions such as barcodes and radio frequency identification can also be the means to enforcing patient identification procedures and reducing the risk of patient misidentification.

Automated systems to prevent medical personnel from drawing blood from, or infusing blood into, the wrong patient were introduced commercially in the early 1990s. At the AHA's annual meeting in 1988, Karen Longe presented an integrated system for applying a bar-coded wristband, and using it to follow a patient through the entire admission/treatment/discharge process, including laboratory, radiology, and pharmacy tests and interventions.

Subsequently several laboratory information systems vendors have introduced positive patient ID systems for phlebotomy, but the vendors were soon to realize that laboratories were not interested in such products (Table 5) [25]. Labeling test tubes is an equally important pre-analytical step and a focal point for improvement in TTP.

Valestein reported that primary specimen label errors occur often, accounting for >55% of identification errors [27]. Mislabeling of test tubes for blood transfusion pre-testing, a highly regulated task, is

Table 4
Numbers for live sites installed in N. America/Europe/Asia–Australia.

	N. America		Europe		Asia–Australia	
	2007	2008	2007	2008	2007	2008
Accelerator	1	3	10	21	0	1
PathFinder 350S/2007		0		0		1
PathFinder 900/2007		0	38	38		14
Beckman AutoMate 800	0	0	20	45	0	4
Beckman Power Processor	285	325	70	85	60	68
iLAS The Efficiency series	1	1	0	0	0	0
Motoman Autosorter II/III		32				
OLA 2500/OLA 2500A/HS	40	50	200	200	3	3
Ortho enGen L.Automation	5	9	18	23	0	0
PVT RSAPro/former versions	5	42	96	220	19	44
PVT RDS/compact	3	8	53	76	5	16
Modular pre-analytics	50	69	109	300*	105	300*
Advia LabCell	20	24	46	55	10	14
Advia WorkCellCDX	105	105	74	86	12	22
StreamLab A.Workcell		70		60		10
Dimension Lynx		28		25		0
TCAutomation	5	9	43	70	0	0
A&T Clinilog	0		0		85	
Totale	520	775	777	1004	299	197

Modified from reference [18,19]. * No division between the 2 areas.

Table 5
Positive patient identification system and products.

Company	Name of system/product	Number of contracts for US sites	Number of contracts for foreign sites
Cardinal Health (formerly Care Fusion)	Carefusion specimen collection verification	36	0
Cerner Bridge Medical	Cerner specimen collection	–	–
DataRay	DataRay Healthcare advanced Printserver	57	2 (Canada)
Endur ID	Endur ID	32	0
Intellidot Corp.	CAREt	–	–
Korchek Technologies,LLC	CareCheck	1	0
Lattice	MediCopia	61	0
McKesson	Horizon MobileCare Phebotomy	20	0
Precision Dynamics Corp.	Bar code wristbands	–	–
Siemens Medical	Patient Identification Check	7	–
Sunquest Information Systems	Sunquest Collection Manager	76	0
The St. John Companies customer service	Bio-Logics	654	0

The systems featured focus primarily on inpatient phlebotomy (modified from reference [26]).

reported to occur on average in 1 out of 165–200 cases [28]. Correct patient identification and test tube labeling before phlebotomy are therefore crucial factors in patient safety in TTP. The use of automatic integrated technologies instead of repetitive manual operations, which are error prone, in the laboratory and hospital departments is a further important tool for reducing errors occurring during sample preparation.

Automated phlebotomy tray preparation, currently used with great success in Japan and Europe, provides for the automatic preparation of a complete set of labeled blood tubes and labels for hand labeling in a single tray for each patient, based on the physician's test order; the drudgery and danger involved in the manual blood tube preparation thus being obviated.

The following 3 vendors supply different systems: Olympus: BC-ROBO — mini 20. Single tray system; throughput, up to 150 patients/h; BC-ROBO — mini 40 multi-tray system; throughput, up to 150 patients/h; BC ROBO 585 multi-tray system; throughput, up to 300 patients/h; RADIM: SprintLab mingle tray system; throughput, 150 patients/h (with 4 test tubes); Becton Dickinson: EOS Lab.E.L.® 8 multi-tray system; throughput, up to 308 patients/h; EOS Lab.E.L.® 16 multi-tray system; throughput, up to 308 patients/h.

8. The experience at "San Bassiano Hospital" Bassano del Grappa

The experience gained at the "San Bassiano Hospital" illustrates how a series of decisive and thorough interventional measures taken effectively reduced pre-analytical errors.

The following interventional strategies were implemented over a 24-month period:

1) Implementing wireless network to provide fast access to medical records, images, and other clinical applications at the point of care and electronic recording of treatments at patient's bedside. Also installing network using wireless phones to provide reliable, continuous mobile communications through Internet protocol (IP) phone, high call quality, roaming, and reliable connection throughout the hospital premises.
2) Introducing laptop with 802.11b wireless connectivity and computerized order entry systems (COES) for inpatients. Clinical staff used the COES to electronically request services such as radiology and laboratory tests at the patient's bedside. The system allows physicians greater mobility in patient wards and, more importantly, instant access to patient information, laboratory results and

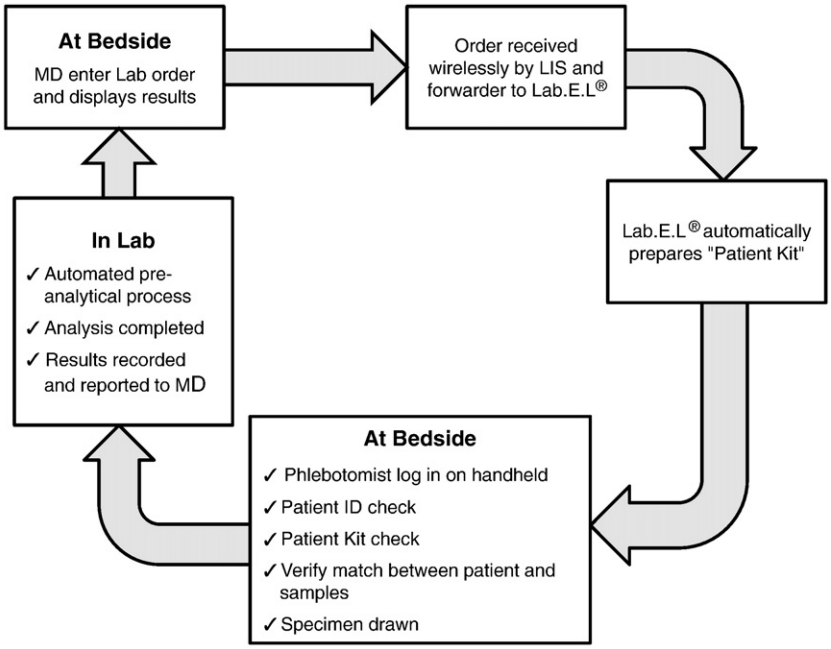

Fig. 1. Workflow for inpatients at Bassiano Hospital.

X-ray findings by means of a laptop with 802.11b wireless connectivity. COES have replaced paper-based test requesting by allowing information to be directly archived in a computer. This system is combined with the electronic delivery of test results and a Picture Archiving and Communication System (PACS) fully connected to the patient's electronic medical records.

3) Introducing automated samples labeling system (Lab.E.L.® Eos) for inpatients and outpatients, which automatically prepares the "Patient kit", a paper-sealed box containing a complete set of labeled blood tubes and labels for hand labeling based on the physician's test order. The patient's ID number, identity, barcode and the date and the time of sample collection are printed on the cover. Necessary alerts (e.g., for storage or transport temperature) are be printed on the box-cover.
4) Introducing bar-coded ID wristbands for inpatients and the Lab.E.L.® Track system, a handheld-based patient identification system that uses bar code and 802.11b wireless networks to identify patients; each patient being given a wristband containing the appropriate demographic information (patient ID number, patient summary). A handheld device equipped with 802.11b wireless connectivity and a bar-code reader is then used by the medical staff to read the patient's wristband, identify the patient and then to read the "Patient Kit" bar-code to verify correspondence between sample and patient; this, done immediately before sample drawing, has led to a substantial reduction in the risk of patient error identification or mislabeled specimens. Moreover, system track processes performed by each phlebotomist, with dates and times, including collection time, specification of material used (e.g. needles, tubes) and number of tubes labeled for the patient, also tracks "near misses" (mismatch) with a further reduction in the risk of future further errors along the processing line. Our team considered bar-coding and radio-frequency identification (RFID) as possible options, but found that RFID was too new and costly for a hospital such as ours.
5) Standardizing collection. A key intervention implemented for the standardization of phlebotomy procedures calls for a new process, and nurses must receive training, coaching and monitoring for this new procedure.
6) Utilizing a pre-analytic workstation interfaced with analyzers (TLA) ADVIA® LabCell® Automation Solution. Pre-analytical automation eliminates front-end sample handling, reduces the number of steps needed to sort and process samples, the time to result, and the potential for error by minimizing the physical handling of samples prior to, and in between, testing. Moreover, it minimizes the exposure of laboratory staff to biohazards. The workflow for inpatients shown in Fig. 1.

Technology has been implemented according to the state of the art in order to promote its effective use. This has called for a member of staff responsible and accountable for the implementation, pilot testing of the system so that the results can be applied to the rest of the service, and appropriate end-user participation in all phases of the implementation. Patient-safety technological tools such as computerized provider order entry or bar-coded wristband identification systems for patients have been chosen on the basis of their ease of use and usefulness (enables improved task performance, efficiency and/or quality). The approach, requiring strong clinical leadership, cannot be envisaged as a mere technologically driven enterprise [29].

9. The advantages of the redesigned workflow

Healthcare professionals are being asked to care for an ever-increasing number of patients. The wireless network enhances hospital staff productivity and response time. COES eliminates the need for a second person to transcribe an order, thus reducing transcription errors.

Patient identification is the cornerstone of patient safety. With bar-coding, the key to success lies in helping nurses and clinicians confirm the patient's identity with the greatest possible ease and reliability. Lab.E.L.® Track System and bar-coding provides the high level of accuracy needed to confirm that the right kind of sample is taken from the right patient; moreover, the Lab.E.L.® Track System provides a permanent record of the patient's sample collection history.

The automatic preparation of the complete set of labeled blood tubes is provides a gain of nursing time of about 1 min for every sample collection. In 2007, about 120,000 samples obtained from inpatients at San Bassiano Hospital were performed: the total time gain achieved was therefore in the region of 2000 h: time that can be used for other health-care activities. On developing the project, collaboration between nursing and laboratory personnel was enhanced. Improvements yielded by the system are: promotion of patient safety, enhanced specimen collection efficiency with consequent laboratory workflow efficiency.

10. Conclusion

Since the majority of the errors in the total testing process originate in the pre-analytical phase, this step, which is made outside the laboratory, should therefore be focused upon in the attempt to enable further reduction in TTP errors, thereby maximizing patient safety. A key goal in this quest must be ensuring that specimens are obtained from the right patient, into the right container, and linked back to the right patient the first time, and every time thereafter.

Pre-analytic workstations are an important tool for reducing errors. At San Bassiano hospital, the combination of strategic thinking, farsighted management planning, advanced information technology and robotics has led to more reliable specimen collection and pre-analytical sample handling and enhanced clinical efficiency as an integral part of the laboratory process. Errors in the total testing process have thus been almost completely eliminated

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