THE IMPORTANCE OF PRE-ANALYTICAL PHASE IN LABORATORY TESTING AND DIAGNOSIS

Tg Jiu, September, 2010

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Introduction

- Three phases of laboratory testing: pre-analytical, analytical and post-analytical
- Pre-analytical—specimen collection, transport and processing
- Analytical—testing
- Post-analytical—testing results transmission, interpretation, follow-up, retesting
Laboratory testing errors

There is a heterogeneity of available data and a lack of definition of laboratory error:

- pre-analytical 46%
- analytical 7%
- post-analytical 47%

Advances in instrument technology and automation have simplified tasks in lab diagnosis and improved quality of test results. Meanwhile, errors occurring during the pre-analytical (from the time the test is ordered by the physician until the sample is ready for analysis) can account for up to 93% of the errors currently encountered during the total diagnostic process.
Pre-analytical errors

- Most errors affecting laboratory test occur in the pre-analytical phase
- Errors at any stage of the collection, testing and reporting process can potentially lead to a serious patient misdiagnosis
Types of Collection Errors

- Patient Identification and Preparation
- Selecting the site and site preparation for Phlebotomy Technique
- Test Collection Procedures (proper venipuncture technique, order of draw, proper tube mixing, correct specimen volume)
- Specimen Handling and Processing
- Specimen Transport
Patient Identification Errors

- Errors in correctly identifying the patient are indefensible

- Reasons for patient identification errors
  - Proper positive patient identification procedures not followed
    - Patient identification from identification bracelet (inpatients)
    - Patient identification by asking patients to state or spell their full name (inpatients/outpatients)
    - Patient identification by staff or family member if patient unable to identify him/herself
Patient Identification Errors

- **Specimen tubes unlabeled**
  - Requisition or collection tube labels not or wrongly affixed to tubes
  - Requisition or collection tube labels in bag containing collection tubes
    - Requisition or collection tube labels rubber-banded to tubes
    - Collection tube labels not affixed to all tubes
    - Specimen collection tubes labeled insufficiently with at minimum patient’s full name, date/time of collection, phlebotomist’s initials
Patient Identification Errors

- Collection tubes labeled with the wrong patient
  - Wrong computerized labels/barcodes affixed to collection tubes at bedside
  - Collection tubes not labeled at the time of collection
  - Collection tubes incorrectly labeled by someone other than the phlebotomist who collects the specimen
Patient Complications and Variables

- Some patient variables that affect blood specimens
  - Diet
    - Fasting
  - Exercise
  - Obesity
  - Allergies to alcohol or iodine used to clean venipuncture site
Timing of collections

Humans: biorhythmic changes occur during a 24h period. Fluctuations occur in the blood analyte levels due to the biorhythmic changes

Most blood normal values have been determined at :
- **BASAL STATE** (early morning, 8-12h after last ingestion of food; not more>14h)
- FASTING restrictions (abstinence from food, not from water!!!)
- **NO SMOKING OR DRINKING COFFEA OR TEA**
- **AVOID DIAGNOSTIC OR TREATMENT REGIMENS-interferences**
The pre-analytical influence of exercise

- Moderate to strenuous exercise can change the laboratory test results
- CK, UA, LDH, cortisol, ACTH, creatinine will change in blood levels due to physical exercise

E.g. bike race 50 miles/jogging prior to blood collection will most likely alter the lab test (false results)
Phlebotomy Technique Errors

- Phlebotomy technique is important
  - Ensures test result validity
  - Minimizes trauma to patient
  - Minimizes potential for phlebotomist injury
  - Reduces recollections
- Vein selection essential for successful venipuncture
Phlebotomy Technique Errors

- Venous Access Difficulties
  - Obstructed, hardened, scarred veins
  - Veins difficult to locate
  - Use of Alternative sites
    - Top of hand/Side of wrist
    - Areas to avoid

- Vein Collapse
  - Use of appropriate needle size
  - Smaller evacuated collection tube
Phlebotomy Technique Errors

- **Tourniquet Application**
  - Tourniquet tied too close to the venipuncture site can cause hematoma
  - Veins may not become prominent if tourniquet is tied too high (more than 6-8 cm above venipuncture site)
  - Tourniquet left on longer than one minute can result in hemoconcentration, affecting some test results
    - Tourniquet should be released as soon as needle is in the lumen of the vein and blood flow established
    - Large molecular compounds and compounds bound to protein and blood cells (chol, triglycerides, albumin, Hb) cannot move through the capillary walls and their blood vessels level increase as the tourniquet remains on the arm—false results
Cleansing the blood collection site

- Sterile swab with 70% isopropyl alcohol
- 30-60 seconds to dry and to create a barrier to bacterial contamination
  - Allow alcohol to dry completely to avoid stinging sensation upon needle entry and hemolysis of sample
- The alcohol can interfere in test results
- If using iodine as cleansing agent for skin puncture, this antiseptic can lead to erroneous laboratory test results (elevate potassium, uric acid, phosphate)
  - Samples such as blood cultures should be collected using iodine to cleanse site to ensure sterility of sample
Specimen handling and processing

- **Test Collection Errors**

Hemolysis
- Blood collected insufficient to amount of additive in tube,
- Traumatic venipuncture
- Blood collected from area with hematoma
- Vigorous shaking of tubes after collection
- Blood collected using a small diameter needle.

Order of Draw
- Order of draw affects the quality of the sample and can lead to erroneous test results due to contamination with the additive from the previous blood collection tube.
Order of draw

CLSI (former NCCLS) recently revised the specific order for collection of tubes and recommends this order:

- Culture tubes (yellow top) or culture Non-additive or serum tubes (red top)
- Citrate tubes (light top)
- Gel separator tubes and clot activator tubes (incolor top)
- Heparin tubes (green top)
- EDTA tubes (lavender top)
- Other additive (color depends on manufacturer)
Order of draw -reasons for that-

1. Blood culture tubes first-decrease possibility of bacterial contamination
2. Heparin (green top) tube for K measurement must be collected before EDTA (lavender top) because if this orders is switched, K is falsely elevated since the blood rupture release K into plasma
3. EDTA is usually bound to K as EDTA K 3 or to sodium as EDTA Na 2 and it is important to collect electrolytes (K and Na) before collecting blood with EDTA tube to avoid falsely elevated results
4. Citrate (light blue top) tube for coagulation must be collected before the heparin (green top) tube to avoid erroneous coagulation results
5. If numerous blood collection tubes are to be collected, the tube with an additive should be collected LAST so it can mixed as soon after collection as possible
Posture changes

- Preanalytical errors can also result if the blood collectors are not aware of the standardized posture guidelines.
- Sometimes these guidelines do not exist and need to be implemented.
- Sitting versus lying can vary lab test results of some chemical constituents (cholesterol, aldosterone).
Specimen Transport Errors

- Transport of blood specimens in the proper manner after collection ensures the quality of the sample.

- **Timing**
  - Some specimens must be transported immediately after collection, for example Arterial Blood Gases.
  - Specimens for serum or plasma chemistry testing should be centrifuged and separated within two hours.
Transport Errors

- **Temperature**
  - Specimens must be transported at the appropriate temperature for the required test
    - On ice - Ammonia
    - Warmed - cryoglobulins
    - Avoid temperature extremes if transported from via vehicle from other collection site

- **Transport Container**
  - Some samples need to be protected from light, for example, bilirubin
  - Transport in leak-proof plastic bags in lockable rigid containers
Transportation of the Specimens

All specimens must be handled according to the Standard/Universal Precautions written by the Centers for Disease Control and Prevention (CDC):

1. Be transported vertically in leak proof plastic bags and/or in lockable rigid containers with a biohazard sign on the outside.
2. Have lockable rigid containers that contain “dry ice” for specimens to be maintained on ice and cold packs to keep other specimens from becoming hot during transport in the warmer months.
3. The specimens must be delivered to the laboratory within 45 minutes of collection in order to ensure the centrifugation and separation of the specimen within 1 hour (CLSI/NCCLS set the maximum time limits for separating serum or plasma from the blood cells at 2 hours from time of collection.

If more time is needed, separator tubes for collection should be used!
Sampling kits

KIT type I (ambient)

KIT type II (frozen-dry ice)
Sampling kit components

Combo – box Sampling laboratory kit:
- 1 EDTA K3 3 ml (lavender-stopper)
- 2 SST gel separator tubes 5 ml (yellow – stopper)
- 1 Urine tube 9.5 ml and 1 urine container 100 ml
- 2 Transferring pipettes
- Needle, holder
- 2 Secondary tubes for serum
- 2 thermo bags
- 2 gel-packs
- 2 shipment containers
- requisition form
- barcode labels
- 1 Combo box
Materials Provided to the sites in CT

- Visual of kits and components
- Study specific kit types
- Extra supply “kit”
- Additional supplies shipped
Review of the literature on lab reports

*Clinical Chemistry 48:691-698, 2002*

<table>
<thead>
<tr>
<th>Data collection period</th>
<th>1 year</th>
<th>6 years</th>
<th>6 months</th>
<th>3 months</th>
<th>3 years</th>
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</thead>
<tbody>
<tr>
<td>No. of tests</td>
<td>997.000</td>
<td>ND</td>
<td>ND</td>
<td>40.490</td>
<td>676.564</td>
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<tr>
<td>No. of patients</td>
<td>249.000</td>
<td>ND</td>
<td>160.714</td>
<td>ND</td>
<td>ND</td>
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<tr>
<td>No. of errors</td>
<td>120</td>
<td>133</td>
<td>180</td>
<td>189</td>
<td>4135</td>
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<tr>
<td>Frequency</td>
<td>0.05% of patients</td>
<td>ND</td>
<td>0.11%</td>
<td>0.47%</td>
<td>0.61%</td>
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<tr>
<td>Preanalytical phase</td>
<td>31.6%</td>
<td>53%</td>
<td>55.6%</td>
<td>68.2%</td>
<td>75%</td>
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<tr>
<td>Analytical phase</td>
<td>31.6%</td>
<td>23%</td>
<td>13.3%</td>
<td>13.3%</td>
<td>16%</td>
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<tr>
<td>Post analytical phase</td>
<td>30.8%</td>
<td>24%</td>
<td>30%</td>
<td>18.5%</td>
<td>9%</td>
</tr>
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</table>
Types of pre analytical errors registered -preanalytical metrics-

<table>
<thead>
<tr>
<th>Type of error</th>
<th>No of missing lab results</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Inpatients</td>
</tr>
<tr>
<td></td>
<td>Outpatients</td>
</tr>
<tr>
<td>Hemolyzed sample</td>
<td>8494</td>
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<tr>
<td></td>
<td>256</td>
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<tr>
<td>Insufficient sample</td>
<td>3256</td>
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<tr>
<td></td>
<td>102</td>
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<tr>
<td>Incorrect sample</td>
<td>1824</td>
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<tr>
<td></td>
<td>289</td>
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<tr>
<td>Clotted sample</td>
<td>792</td>
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<td></td>
<td>80</td>
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<tr>
<td>Incorrect identification</td>
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<td></td>
<td>2</td>
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<tr>
<td>Lack of signature(blood group)</td>
<td>266</td>
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<td></td>
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<tr>
<td>Empty tube</td>
<td>238</td>
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<td></td>
<td>8</td>
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<tr>
<td>Sample not on ice</td>
<td>75</td>
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<td></td>
<td>6</td>
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<tr>
<td>Tube broken in the centrifuge</td>
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<tr>
<td></td>
<td>36</td>
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<tr>
<td>Urine not acidified</td>
<td>24</td>
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<td></td>
<td></td>
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<tr>
<td>Open container</td>
<td>20</td>
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<td></td>
<td>13</td>
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<tr>
<td>Urine volume not indicated</td>
<td>5</td>
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<td></td>
<td></td>
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</table>

San Rafael laboratory, 2000
Error Prevention

- **Phlebotomy Education**
  - Phlebotomists should have completed a standard academic course in phlebotomy and undergo thorough on-the-job training under the supervision of a senior phlebotomist

- **Continuing Education**
  - Phlebotomists should participate in regular educational competency assessments (written and observational)
  - Professional Licensure

- **Phlebotomy Staffing**
  - Adequate staffing to maintain collection standards

- **Technology**
  - Use of barcode scanners for patient identification
Questions and Discussion

- How are pre-analytical errors prevented in your laboratory?
- What technology do you use to prevent human error?
- What systems does your hospital use to prevent errors by non-laboratory staff collecting blood?
- What pro-active improvements would reduce the number of pre-analytical errors?
CONCLUSIONS

- There is a need for better definition of laboratory errors and their causes.
- There is a distinction between 1) errors exclusively inside the lab and 2) lab errors caused by organizational problems outside the lab.
- The quantitatively largest reduction in lab errors are likely to result from inter-departamental cooperation designed to improve the quality of specimen collection and data dissemination.
- Clinical audit-increasingly recognized.
- It is impossible in medicine, as in any other human activity, to completely eliminate errors, but it is possible to reduce them.
- Educational programs and introduction of automation technology.
- To create a culture in which the existence of risk is acknowledged and injury prevention is recognized as everyone’s responsibility.

TRAINING, EDUCATION AND CULTURE!