Tackling the Toughest Challenges in Preanalytics:
Effective Troubleshooting and Best Practices to Improve Specimen Quality, Analytical Accuracy, and Patient Satisfaction and Minimize Unnecessary Costs

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Disclosures

Employed by Greiner Bio-One
Objectives

Discuss considerations in root cause analysis and troubleshooting of preanalytical errors.

Describe the causes of the most common preanalytical errors and potential impact to specimen quality.

Briefly discuss the impact of errors to patient perception and facility cost.

Identify best practices for optimal venous blood specimen collection as well as benchmarks to track sample quality.
Three Phases of Testing Process

Preanalysis
- Test Order
- Patient Identification
- Specimen Collection
- Transport
- Sample Receipt
- Processing

Analysis
- Chemistry / Immunoassay
- Hematology
- Coagulation
- Urinalysis
- Transfusion Service
- Microbiology
- Anatomic Pathology

Postanalysis
- Result Verification and Release
- Sample Storage
TAT by Phase

- 2,200 bed facility with 8,000 outpatients daily
- LIS time stamps; TAT beginning with barcode printing

**Reception to Report TAT (minute):**
- Mean = 43.6
- Median = 43.4
- SD = 7.7
- 95th percentile = 55.7
- 99th percentile = 63.9

**Preanalytical phase (minute):**
- Mean = 29.7
- Median = 29.7
- SD = 6.9
- 95th percentile = 0.5
- 99th percentile = 6.1

**Alytical phase (minute):**
- Mean = 13.9
- Median = 13.1
- SD = 4.1
- 95th percentile = 20.1
- 99th percentile = 30.2

**Postalytical phase (minute):**
- Mean = 0.02
- Median = 0.01
- SD = 0.13
- 95th percentile = 0.10
- 99th percentile = 0.60

## Error Occurrence

<table>
<thead>
<tr>
<th>TTP Phase</th>
<th>Frequent</th>
<th>(Plebani, 2010)</th>
<th>(Lippi et al, 2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Preanalytical</td>
<td>46 – 68%</td>
<td></td>
<td>60 – 70%</td>
</tr>
<tr>
<td>Preanalytical</td>
<td>3 – 5%</td>
<td></td>
<td>60 – 70%</td>
</tr>
<tr>
<td>Analytical</td>
<td>7 – 13%</td>
<td></td>
<td>5 – 15%</td>
</tr>
<tr>
<td>Post Analytical</td>
<td>12 – 20%</td>
<td></td>
<td>15 – 20%</td>
</tr>
<tr>
<td>Post-Post Analytical</td>
<td>25 – 45%</td>
<td></td>
<td>15 – 20%</td>
</tr>
</tbody>
</table>
Pre-preanalytic Phase Errors

- Incorrect test requested (up to 58% of missed or delayed diagnoses)
- Order entry
- Patient identification
Post-post-analytical Phases

- Incorrect result interpretation (up to 38%)
- Failure to inform patients or document communication of clinically significant results
- Discharge with tests pending
To Err is Human…

but how do we minimize the potential?
Troubleshooting Methods & Tools

- **Root Cause Analysis:** Identifying basic or causal factors underlying variation in performance that, once removed, resolve the problem. Latent conditions that allow the problem to occur should also be addressed.
  - Fish Bone Analysis / Causal Tree

- **Six Sigma / Lean:** Assessment of process outcomes and calculation of the defect rate (sigma metric).
  - Define, Measure, Analyze, Improve, Control

- **5 Whys**

- **Plan, Do, Study, Act:** Model used to establish a causal relationship between changes in a process and outcomes to assess impact and modify as necessary prior to systemwide implementation.

- **FMEA:** Means to identify and eliminate potential failures and errors before they occur by evaluating all probable ways a process can fail.
Investigating Error

✓ Assess risk
✓ Careful review of each step of the process
✓ Eliminate preconceived notions
✓ Look for patterns:
  - Department
  - Phlebotomist
  - Equipment (including instrumentation and associated result flags)
  - Trending
  - Transport method
Specimen Workflow

1. Patient Related Factors
2. Patient Identification
3. Sample Collection
4. Sample Transport
5. Sample Processing
6. Analysis
7. Sample Storage
General Considerations

- Collection Methods
- Technique
- Standardized procedures
- Competency
- Centralized vs Decentralized Phlebotomy
General Considerations

Centralized
- Lab staff
- Laboratory control of quality
- Issues
  - Certification / standardized requirements
  - Turnover / staff shortages

Decentralized
- Nursing / CNA / Technicians
- Departmental
- Issues
  - Training
  - Needlestick rates
  - Statistically higher rates of error (equipment, underfill, site selection) and redraw
  - Cost

Efficiency?
So what are the most frequent collection errors?
Types of Preanalytical Errors

Table 4. Types of preanalytical errors registered during the year 2000 at the Laboratory of San Raffaele Hospital.

<table>
<thead>
<tr>
<th>Type of error</th>
<th>Inpatients</th>
<th>Outpatients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemolyzed sample</td>
<td>8494</td>
<td>256</td>
</tr>
<tr>
<td>Insufficient sample</td>
<td>3256</td>
<td>102</td>
</tr>
<tr>
<td>Incorrect sample</td>
<td>1824</td>
<td>289</td>
</tr>
<tr>
<td>Clotted sample</td>
<td>792</td>
<td>80</td>
</tr>
<tr>
<td>Incorrect identification</td>
<td>287</td>
<td>2</td>
</tr>
<tr>
<td>Lack of signature (blood group)</td>
<td>266</td>
<td>8</td>
</tr>
<tr>
<td>Empty tube</td>
<td>238</td>
<td>8</td>
</tr>
<tr>
<td>Lack or wrong compilation of the accompanying module</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Sample not on ice</td>
<td>75</td>
<td>6</td>
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<tr>
<td>Tube broken in the centrifuge</td>
<td>57</td>
<td>36</td>
</tr>
<tr>
<td>Test not reserved</td>
<td>31</td>
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</tr>
<tr>
<td>Urine not acidified</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Open container</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>Module without signature</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Urine volume not indicated</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>15503</td>
<td>792</td>
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</table>

Bonini et al, 2002
## Types of Preanalytical Errors

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Haemolysed</td>
<td>12,161</td>
<td>2.90</td>
<td>16,202</td>
<td>2.80</td>
<td>15,075</td>
<td>2.80</td>
<td>10127</td>
<td>3.00</td>
<td>12,262</td>
<td>3.00</td>
<td>65,827</td>
<td>2.90</td>
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<tr>
<td>Clotted</td>
<td>2264</td>
<td>3.70</td>
<td>2410</td>
<td>3.70</td>
<td>2090</td>
<td>3.80</td>
<td>1907</td>
<td>3.80</td>
<td>1937</td>
<td>3.80</td>
<td>10,608</td>
<td>3.70</td>
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<tr>
<td>Inadequate container</td>
<td>176</td>
<td>4.60</td>
<td>121</td>
<td>4.70</td>
<td>118</td>
<td>4.70</td>
<td>79</td>
<td>4.80</td>
<td>73</td>
<td>4.90</td>
<td>567</td>
<td>4.70</td>
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<tr>
<td>Insufficient sample</td>
<td>483</td>
<td>4.30</td>
<td>596</td>
<td>4.20</td>
<td>643</td>
<td>4.20</td>
<td>471</td>
<td>4.30</td>
<td>422</td>
<td>4.30</td>
<td>2615</td>
<td>4.20</td>
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<tr>
<td>No blood sample sent</td>
<td>1940</td>
<td>3.80</td>
<td>1972</td>
<td>3.80</td>
<td>2138</td>
<td>3.70</td>
<td>1734</td>
<td>3.80</td>
<td>1993</td>
<td>3.80</td>
<td>9777</td>
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<tr>
<td>No urine sample sent</td>
<td>2487</td>
<td>3.70</td>
<td>2561</td>
<td>3.70</td>
<td>2588</td>
<td>3.70</td>
<td>2307</td>
<td>3.70</td>
<td>2518</td>
<td>3.70</td>
<td>12,461</td>
<td>3.70</td>
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<tr>
<td>Total incidents</td>
<td>19,511</td>
<td>2.60</td>
<td>23,862</td>
<td>2.50</td>
<td>22,652</td>
<td>2.60</td>
<td>16,625</td>
<td>2.80</td>
<td>19,205</td>
<td>2.70</td>
<td>101,855</td>
<td>2.70</td>
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<tr>
<td>Non-Cftty critical error</td>
<td>37</td>
<td>2.8</td>
<td>28</td>
<td>3.3</td>
<td>33</td>
<td>3.6</td>
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<td></td>
<td></td>
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<tr>
<td>LIS critical error</td>
<td>60</td>
<td>4.8</td>
<td>48</td>
<td>4.8</td>
<td>48</td>
<td>4.8</td>
<td>26</td>
<td>4.9</td>
<td>31</td>
<td>4.9</td>
<td>213</td>
<td></td>
</tr>
<tr>
<td>Total critical errors</td>
<td>85</td>
<td>4.8</td>
<td>76</td>
<td>4.8</td>
<td>59</td>
<td>4.9</td>
<td>67</td>
<td>4.9</td>
<td>67</td>
<td>4.9</td>
<td>287</td>
<td>4.90</td>
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<tr>
<td>Total requests</td>
<td>141,561</td>
<td>100*</td>
<td>149,511</td>
<td>105.62*</td>
<td>153,402</td>
<td>108.36*</td>
<td>151,057</td>
<td>106.71*</td>
<td>155,910</td>
<td>110.14*</td>
<td>751,441</td>
<td></td>
</tr>
</tbody>
</table>

*Requests (Base 100 = 2007)

Overall error rate = 13.54% over 5 years and 751,441 test requests

Highest error rate was due to hemolyzed samples at 8.76% (over 13% at the highest)

Giménez-Marin et al, 2014
Hemolysis

- Bias in approximately 39 tests
- 40-70% of unacceptable specimens (5X higher than other causes)
- ASCP benchmark of 2% or lower rates
- Higher rates common in particular departments
  - ED samples up to 8X more likely to be hemolyzed
  - ED hemolysis rates of up to 30% reported
  - Standardized protocol can reduce hemolysis by more than 7-fold
Troubleshooting Hemolysis

* in vivo vs in vitro *

Site selection
- Venipuncture
- Line Draw

Equipment
- Needles
  - Straight or winged collection set
  - gauge
- Tube vs Syringe
- Draw volume
Collection via VAD

Benefits of Vascular Access Device (VAD) Collection

- Saves patient a stick
- Ease of access
- Efficiency
- Patient satisfaction
Vascular Access Devices

- Intravenous (IV) Line
- Peripherally Inserted Central Catheter (PICC)
- Central Venous Catheter
- Heparin or Saline Lock
- Arterial Line
- Port
- Shunt or Fistula
Collection via VAD

Problems outweigh the benefits…

- 3x more likely to have hemolysis
- Delay in test results
- Contamination
- Inappropriate treatment
- Negative patient perception
- IV starts for phlebotomy may result in new line when moved to floor
Facts about VADs for blood collection

- Hemolysis rates significantly reduced (up to 84%) by venipuncture with a straight needle.
- Use of antecubital space for VAD placement could reduce hemolysis by up to 55%.
- Use of low volume tubes to collect from VADs may reduce hemolysis (results suggestive).
- Some studies indicate that needle/catheter 21g or larger significantly reduces hemolysis by up to 63% (results not controlled for placement and evidence insufficient).
Tube vs Syringe

**Tube**
- Pre-evacuated for accurate fill
- Pre-measured additive for fill volume
- Multiple tubes at once
- Convenient

**Syringe**
- Poor vein condition
- Control of vacuum
- No additives
- Larger volumes
- Transfer device
Hemolysis with Syringe Use

- Evacuation
- Bore of needle used
- Draws in anticipation of lab order
- Method of transfer
- Delayed transfer to evacuated tube
Hemolysis Due to Sample Handling

- Temperature
  - Lock boxes
  - Seasonal fluctuations

- Transport method
  - Courier
  - Tube position
  - Pneumatic tube system (partial fill tubes???)

- Rimming of tube not advocated
Pseudohyperkalemia

Definition: elevated potassium level without clinical symptoms

Variation in serum vs plasma
- Plasma preferred
- Serum variation based on degree of clot retraction
  - Platelet degranulation
  - Red cell leakage – up to 0.4mmol/L difference

False increase with thrombocytosis, leukocytosis and erythrocytosis

Consequences
- Patient recall
- Misdiagnosis
- Inappropriate treatment
Preanalytic Causes of Increased K+

- Hemolysis
- Collection
  - Fist pumping
  - Tourniquet time
  - IV contamination
    - Avoid same arm
    - Shut off IV and utilize discard volume
  - Incorrect order of draw
  - Fear
Preanalytic Causes of Increased K⁺

**Processing and Centrifugation**
- Delay in separation
- Cells trapped above gel*
- Gel barrier integrity*
- Re-spinning or inadequate centrifugation

**Transport and Storage**
- Temperature (ATPase mediated)
- Seasonal increase and decrease

*exacerbated with refrigeration
Quantity Not Sufficient (QNS) or Short Draw

- Up to 16% of samples
- Primarily an issue with coagulation samples
- Tubes with other additives are of concern
  - LiHep: CK, GGT increase (method dependent)
  - EDTA: red cell parameters
- Manufacturer recommendations
Causes of Short Draw

- Needle not in vein
- No discard when using a winged collection set
- Push back or tube not pushed fully forward in holder
- Tube removed from holder prior to vacuum depletion
- Syringe use
- Equipment compatibility
Other Preanalytic Errors

- Fibrin / clots
  - Fill tube to appropriate level
  - Mix with proper inversion
  - Allow serum tubes to clot

- Tube Type

- Patient-related variables

- Centrifugation
Patient Risk Associated with Error

- 2.7% to 12% of laboratory errors associated with risk of an adverse event or inappropriate care

- 24.4-30% laboratory errors impact patient care
  - Unnecessary testing (repeat or additional)
  - More invasive testing
  - Additional consultations

- Most errors have little direct impact but can contribute to risk of harm to the patient and overall quality of care
Consequences of Error

✓ Redraws
✓ Time
  ▪ Investigation
  ▪ Personnel
  ▪ Length of stay
✓ Misdiagnosis
✓ Inappropriate or delayed treatment
✓ Patient satisfaction
✓ Result Reporting
  ▪ Flagged with comment
  ▪ Recollect
Cost of Preanalytical Error

Cost, depending on patient type, can be as high as $357 per error.

Preanalytical errors account for up to 1.2% of hospital cost or over $1,000,000 USD for a 650-bed facility.

Estimated ~24K hours lost per year due to redraws and additional patient treatment (850-bed facility).
“For every action there is an equal and opposite reaction...”

Newton’s Third Law of Motion
Strategies to Implement Change

- Strong leadership / Appropriate stakeholders
- Culture of Safety
- Multidisciplinary teams
- Communication
- Recognition of problem and cause
- Standardization
- Flexibility
- Use of technology
- Resources
- Ongoing analysis
- Change is difficult and takes time!
Reducing Preanalytical Error

- Observe standards and guidelines, i.e. Best Practices
  - CLSI GP41
  - CAP
  - ISO
  - EFLM-WG-PA
  - IFCC-WG-LEPS
  - WHO

- Education and training

- Checklists
- Training modules
- Observation / Audit

- Certification

- Technology

- Ongoing tracking and benchmarking

- Tools
# Proposed QI for Preanalytical Phase

**IFCC-WG-LEPS**

<table>
<thead>
<tr>
<th>Step in process</th>
<th>Associated quality indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient identification</strong></td>
<td>● Number of requests with errors concerning patient identification (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of requests with errors concerning patient identification detected before the release of results (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of requests with errors concerning patient identification detected after the release of results (%)</td>
</tr>
<tr>
<td><strong>Data entry of the request</strong></td>
<td>● Number of requests with errors concerning test input (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of requests with errors concerning test input (missing, %)</td>
</tr>
<tr>
<td></td>
<td>● Number of requests with errors concerning test input (added, %)</td>
</tr>
<tr>
<td></td>
<td>● Number of requests with errors concerning test input (misinterpreted, %)</td>
</tr>
<tr>
<td><strong>Sample identification</strong></td>
<td>● Number of inadequately labelled patient samples (%)</td>
</tr>
<tr>
<td><strong>Sample collection</strong></td>
<td>● Number of samples collected with inappropriate sample tube type (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of samples collected in inappropriate container (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of samples with insufficient sample volume (%)</td>
</tr>
<tr>
<td><strong>Storage and transport of samples</strong></td>
<td>● Number of damaged sample tubes/containers (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of samples transported at an inappropriate time (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of samples transported at inappropriate temperature condition (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of improperly stored samples (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of samples lost/not-received (%)</td>
</tr>
<tr>
<td><strong>Suitability of samples</strong></td>
<td>● Number of samples with inadequate sample anticoagulant ratio (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of samples haemolysed (haematology, chemistry, immunology) (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of samples clotted (haematology, chemistry) (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of lipaemic samples (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of unacceptable samples (microbiology) (%)</td>
</tr>
<tr>
<td></td>
<td>● Number of contaminated blood cultures (%)</td>
</tr>
</tbody>
</table>
Phlebotomy practices to improve sample quality...
Collection

- Properly ID patient, sample and tests to be completed
- Appropriate equipment for venipuncture
- Appropriate site
- Limit tourniquet application to 1 minute
- Follow Order of Draw
- Fill tubes to capacity
Sample Handling

- Mixing with gentle inversion
- Proper temperature
  - Prior to transport
  - During transport
- Tube position upright
Processing

**Centrifugation**
- 2 hours from collection to separation
- Horizontal or swing-bucket
- Delayed separation may increase $K^+$ and risk of hemolysis
- Appropriate time and g-force
- Temperature control
- Re-centrifugation not recommended

**Aliquotting**
References

Thank you for your time and attention!