Improving Blood Specimen Quality and Patient Care

Gary Parish, MS
Clinical Sales Manager
Pre-analytic Error
• 70% of errors originate during pre-analytic phase.¹,²,³
• Poor specimen quality accounts for 60% of PAEs.³

Most prevalent sources of error⁴:

- **Hemolysis**: 43.6%
- **QNS**: 16.9%
- **Clotting**: 7.6%

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Specimen Errors: QNS

QNS accounts for 16-22% of all rejected specimens. 5,6

Citrate samples may produce the highest rejection rate of all tube types received. 7

**Under-filled citrate:** prolonged PT, APTT and TT; low fibrinogen and D-dimer results 8

**Under-filled EDTA:** decreased MCV, HCT, RBC, WBC, PLT changes in leukocyte morphology 9

**Under-filled heparin:** increase CK and GGT test results 9

CLSI clearly addresses this quality imperative:

“Venous blood collection tubes must be capable of retaining a vacuum for the stated shelf life if the tube’s method of collection is by means of evacuation only.” \(^{10}\)

“When a collection device is tested for draw and fill accuracy at the time of manufacture, the draw shall be within 10% of the stated draw. At the expiration date, the draw volume shall be no more than 10% below the stated draw volume of the manufacturer.” \(^{10}\)
Causes

• Insufficient volume from syringe
• Collection at high altitudes
• Loss of vacuum in tube (within 4 months of expiration) \(^{11,12}\)
• Collapse of fragile veins

Precautions

• Eliminate syringe collection if a transfer step is required
• Collect with tubes that are unaffected by altitude changes
• Test vacuum tubes monthly to verify complete filling
• Prevent collapse of delicate veins by using a gentle syringe-style blood draw technique

Specimen Errors: Clotting

Clotting accounts for 14% of total specimen rejections\(^\text{13}\) and 65% of hematology specimen rejections.\(^\text{14}\)

EDTA microtube samples for CBC testing have the highest rejection rate of all tube types received by the laboratory.\(^\text{14}\)

Clotted citrate:  Prolonged PT, APTT and TT  
Loss of fibrinogen, FII, FV and FVIII  
Loss of HMW vWF  
Obstructed flow in PFA 100 \(^\text{15}\)

Clotted EDTA:  Inhibits sample aspiration by instrument  
Interferes with cell counting and morphology

CLSI clearly addresses this quality imperative:

“The following are not suitable for testing and are causes for specimen rejection:

- specimens that are clotted.”

“[plasma and whole blood] Specimens that are clotted, … are not suitable for testing and should be rejected.”
Specimen Errors: Clotting

Causes

- Collection into untreated syringe \(^{17}\)
- Inadequate mixing \(^{18}\)
- Collection into microtubes \(^{18}\)
- Difficult draws (dwell time in catheter or butterfly tubing)

Precautions

- Eliminate collection with untreated syringe
- Ensure proper mixing
- Minimize use of microtubes for venous draws
- Use equipment and techniques that prevent vein collapse and minimize difficult draws
- Never “rim” clots! Always recollect clotted samples.

Specimen Errors: Hemolysis

The release of RBC components during hemolysis changes chemistry values.
Specimen Rejection

- Overall ~3% \(^{19}\)
- ED / ICU 8-12% \(^ {19}\)

Hemolysis is No. 1 source of ED specimen rejection (52-85%). \(^ {20,21}\)

EDs & CCUs:

- 2-5 times higher rates of specimen rejection
- Produce > 50% of rejections facility-wide.\(^{22}\)

**Major Implication:**

We accept the worst specimen quality and reliability for our most critical patients!

## Hemolysis Alters Lab Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low hemolysis (≥ 30-60 mg/dl):</th>
<th>Moderate hemolysis (≥ 60-200 mg/dl):</th>
<th>Strong hemolysis (≥ 200 mg/dl):</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Creatinine</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cl</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilirubin</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CK</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDH</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triglycerides</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-dimer</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FVIIa</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lipase</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PT</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>aPTT</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amylase</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEPI</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALP</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CADP</td>
<td>++</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discredited / Unsupported Causes of Hemolysis:

- Vigorous mixing 27
- Order of draw 28
- Alcohol from wipe 29
- Prolonged tourniquet
- Pneumatic tubes 30,31
Remember, EDs & CCUs have 2-5 times higher rates of rejection and generate >50% of rejections facility-wide. 32

“The ED nursing staff believed that the determination of hemolysis was highly dependent on who was working in the ED laboratory on a particular shift. The laboratory staff thought hemolysis was related to who was working on the nursing staff.” 33

Factors Affecting Hemolysis in Blood Samples Drawn in the Emergency Department

**Abstract**

Hemolysis is a major concern in blood analysis. Hemolysis can lead to inaccurate test results, which can affect patient care and outcomes. The purpose of this study was to identify the factors that contribute to hemolysis in blood samples collected from intravenous catheters in the emergency department. The study was conducted in a tertiary hospital emergency department and included 100 patients who had blood samples drawn from newly placed intravenous catheters. The factors that were evaluated included the following:

1. **Type of Catheter:** The type of catheter used for blood sampling was evaluated. The study found that the type of catheter used had a significant impact on the rate of hemolysis.
2. **Duration of Placement:** The duration of catheter placement was another factor that was examined. The study found that the longer the catheter was in place, the higher the rate of hemolysis.
3. **Techniques Used:** The techniques used for blood sampling were also evaluated. The study found that the use of gentle techniques could help to reduce the rate of hemolysis.

In conclusion, the study found that hemolysis in blood samples collected from intravenous catheters in the emergency department is influenced by several factors, including the type of catheter used, the duration of placement, and the techniques used for blood sampling. The results of this study can help to guide best practices for blood sampling in the emergency department, which can help to improve patient care and outcomes.

**Keywords:** Emergency Department, Intravenous Catheters, Hemolysis, Blood Sampling, Best Practices
### ED Hemolysis Rates

<table>
<thead>
<tr>
<th>Study</th>
<th>IV catheter &amp; vacuum tube</th>
<th>IV catheter &amp; syringe/transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ong, et al.</td>
<td>36% (29/81)</td>
<td>11% (16/146)</td>
</tr>
<tr>
<td>Wollowitz, et al.</td>
<td>15% (544/3727)</td>
<td>---</td>
</tr>
<tr>
<td>Grant, et al.</td>
<td>77% (151/195)</td>
<td>28% (17/60)</td>
</tr>
<tr>
<td>Dugan, et al.</td>
<td>13% (35/278)</td>
<td>14% (14/104)</td>
</tr>
<tr>
<td>Kennedy, et al.</td>
<td>---</td>
<td>14% (12/87)</td>
</tr>
<tr>
<td>Straszewski, et al.</td>
<td>23% (72/315)</td>
<td>---</td>
</tr>
<tr>
<td>Schmotzer, et al.</td>
<td>20% (130/660)</td>
<td>18% (131/715)</td>
</tr>
</tbody>
</table>
Root Cause of Hemolysis

- IV catheter & vacuum tube $^{34,35,36,37}$
  **Strong Vacuum force**

- IV catheter & syringe and transfer $^{38,39,40}$
  - Clotting & QNS
  - Double Transfer
  **Strong Vacuum force** $^{41}$

Source of ED Hemolysis

2 IV ‘Line Draws’ – a common source of poor quality specimens

on hemolysis below, this occurs as a result of mechanical trauma caused, mainly, by excessively high flow rates of blood from the catheter to the syringe or the evacuated tube. For syringe collections, the use of
Flow simulation in an IV catheter

Local variation of shear stress

Shear stress [Pa]

Axial position in a catheter system [m]
Vacuum tube collection results in 3-10 times higher velocity (IV)
Collection equipment

Syringe + transfer to vacuum tubes
Controlled collection force, but requires transfer

Access device + vacuum tubes
Enables direct collection into blood tubes
**Pros**

- Quick, easy, needleless (safe), inexpensive
- Improved patient comfort & patient safety
- Excellent quality specimen if hemolysis is prevented \(^{42,43}\)

**Cons**

Vacuum tube collection technology → Hemolysis

**Recommendations:**

- Eliminate IV collections with dedicated phlebotomy.
- For IV line draws, use gentle syringe collection without sample transfer to practically eliminate specimen rejection due to hemolysis. \(^{44,45,46}\)

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Consider blood collection technology that…

- Allows for gentle, syringe-style blood collection
- Directly into pre-treated tubes
- Without a sample transfer step
<table>
<thead>
<tr>
<th>Blood Tube</th>
<th>Vacuum</th>
<th>Syringe-style</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct, dual-collection system</td>
<td>31%</td>
<td>&lt;2%</td>
<td>&gt;15-fold reduction in</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>hemolysis versus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>vacuum tube</td>
</tr>
<tr>
<td>Vacuum tube A</td>
<td>29%</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

Prevention of hemolysis in blood samples collected from intravenous catheters

Giuseppe Lippi a,c, Paola Avanzini a, Gianfranco Cervellin b

a. Laboratory of Clinical Chemistry and Hematology, Academic Hospital of Parma, Parma, Italy
b. Emergency Department, Academic Hospital of Parma, Parma, Italy
Influence of the serum collection system on hemolysis

<table>
<thead>
<tr>
<th>Blood Tube</th>
<th>Strongly Hemolyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum Tube A</td>
<td>11.7 %</td>
</tr>
<tr>
<td>Direct, dual system</td>
<td>0.6 %</td>
</tr>
<tr>
<td>Vacuum Tube A</td>
<td>14.1 %</td>
</tr>
<tr>
<td>Vacuum Tube B</td>
<td>11.3 %</td>
</tr>
</tbody>
</table>

>20-fold reduction in strong hemolysis versus vacuum tubes

exact: p < 0,0001). For the Emergency Department, hemolytic serum samples were rare (< 1%) during collection in S-Monovette® tubes. A possible expla-
• 25% of rejections result in negative real patient outcomes. 47

• Including: hematoma, pain, cellulitis, anemia and fainting with injury

• Repeat phlebotomy is bad enough…

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Consequences of Rejection

- 21% of rejected specimens are abandoned.  
- Median processing delay of 65 minutes!  
- “Lack of timely reporting may cause delays in treatment. In some cases, patients may leave against medical advice or be transferred before another specimen can be obtained.”

Case Study:

Patient Safety Advisory

In Vitro Hemolysis: Delays May Pose Safety Issues

Specimen grossly hemolyzed; called to recollect specimen. About an hour later, emergency room called for results. Doctor called lab and wanted hemolyzed specimen run. Ran and reported.

Grossly hemolyzed specimen; patient transferred before specimen recollected. The test was canceled.

• “90% said a second stick was required. Almost 90% of these patients suffered bruising and 84% felt more pain.”

• 8 out of 10 patients report that their blood collection experience influenced their satisfaction level.

• Blood collection is an extremely intimate point of patient contact.

Low cost investment…huge impact!

40% of the average hospital payer mix is Medicare.  

Because CMS Value Based Purchasing (VBP) “thresholds for earning incentive points are set at the 50\textsuperscript{th} percentile, it would be reasonable to expect that about half of all participating hospitals will experience reduced Medicare payment.

Patient Experience of Care is an applicable domain based on HCAHPS scores, with a weighted value of 30% through at least 2015.

VBP Diagnosis-Related Group (DRG) payment percentages increase from 1% in 2013 to 2% in 2017.

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- Patient Experience of Care is an applicable domain based on HCAHPS scores, with a weighted value of 30% through at least 2015.  
- VBP Diagnosis-Related Group (DRG) payment percentages increase from 1% in 2013 to 2% in 2017.
## Total Cost of Specimen Rejection

<table>
<thead>
<tr>
<th>Source</th>
<th>$ / Year</th>
<th>Facility Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carson, et al 54</td>
<td>$222,000†</td>
<td>Average - Medium</td>
</tr>
<tr>
<td>Ong, et al 55</td>
<td>$203,000#</td>
<td>Large metro</td>
</tr>
<tr>
<td>Latino, R 56</td>
<td>$311,000†</td>
<td>Large</td>
</tr>
<tr>
<td>Jacobs, et al 57</td>
<td>$87,000 ^</td>
<td>Medium - Large</td>
</tr>
</tbody>
</table>

† Total, all-in cost of specimen rejection

# Total, direct cost of ED specimen rejection due to hemolysis

^ Direct material and/or labor cost of ED specimen rejection due to hemolysis.

Specimen recollection costs per hospital due to hemolysis:

Technical Staff Costs to process a routine hemolyzed specimen is $25.91 each.  

Calculation:
- 3 rejections / day = $28,400.00 per year
- 5 rejections / day = $47,300.00 per year
- 10 rejections / day = $94,600.00 per year

## Cost-Benefit Analysis

- Costs of $400-700K / year
- To capture $200-300K / year in savings
- Increased delays, patient discomfort

### Source

<table>
<thead>
<tr>
<th>Source</th>
<th>FTE</th>
<th>$ / Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheppard, et al 59</td>
<td>8.4</td>
<td>$561,000</td>
</tr>
<tr>
<td>Latino 60</td>
<td>25.0</td>
<td>$697,000</td>
</tr>
<tr>
<td>Calculated 61,62</td>
<td>9.0</td>
<td>$404,000</td>
</tr>
</tbody>
</table>

60. Rob Latino.  LEAP Analysis, System analyzed: blood drawing process opportunity analysis. Specimen Integrity OA, Reliability Center, Inc. 2011.
Phlebotomy Solution is Difficult to Implement and Maintain


Recommendations:
Adopt evidence-based best practices to reduce specimen rejection rates, improve TAT, reduce costs and positively affect patient satisfaction.

• Avoid syringe draws that require subsequent transfer (QNS)
• Use blood tubes that are unaffected by altitude changes (QNS)
• Avoid collection with untreated syringe (Clot)
• Avoid transfers into microtubes for peds draws (Clot)
• Do not use vacuum tubes for I.V. line draws (Hemolysis)
• Do not use syringe and transfer style collection (Hemolysis)