Blood Gas Testing and Other Contemporary Issues in POCT in the Operating Room:
* Evaluating Two Models for Blood Gas Testing
* Need for Better POC Methods for PTH and Fibrinogen

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Objectives for Talk

- Evaluate different models of POC blood gas (etc) testing in the cardiovascular operating rooms (CVORs) for costs and test menu.
- Relate the location of parathyroid glands to the need for intra-operative PTH measurements.
- Describe cases that illustrate use of intra-operative PTH measurements.
- Describe an ideal POC testing device for PTH measurements.
- Interpret algorithm to determine need for blood products during open-heart surgery.
- Describe challenges of giving cryoprecipitate and the need for a rapid fibrinogen assay.
Factors That Promote Increase In POC Testing

• Test panel or menu provides useful information.
• Testing requires minimal additional effort:
  – Testing is rapid and convenient
  – Test ordering, billing, and documentation automatic (connected to lab information system)
• Analyzer has reliable accuracy and precision:
  – No puzzling results to investigate
  – Results agree with laboratory results
• POC testing improves finances, outcomes, satisfaction of users/patients.
Connectivity Is Key to POC Testing

ORs, Cath Labs:
- BG, Lytes, Glu, Lact

Blood Gas Lab

ORs, ICUs, Cath Labs:
- Coag (ACT)

Emergency Dept:
- BG, Lytes, Glu, Lact, hCG, Cardiac

Glucose Meters
- (many locations)

Data Management System
- (Within-Lab)

Laboratory Information System
- (Orders, billing)

Hospital Information System
- and Data Repository

Data Viewing System
- in ICUs

Browser
- (viewing patient data and records)

ROP Interface
- (automatically orders and bills tests)

Red dots = Data stream (free or $)

Yellow star = LIS Interface ($$$)
Evaluating Two Models of Point-of-Care Blood Gas/Electrolyte/Etc. Testing in the Cardiovascular Operating Room
Blood Gas POC Model #1

• Blood gas analyzers with single-use cartridges used in operating rooms:
  – Used by perfusionists, CNAs, and (if needed) anesthesia technicians.
  – Supplies, maintenance, and regulatory responsibilities under Clinical Laboratories.

• Completed test is automatically ordered, billed, and archived in information system.
• Blood gas analyzers with multi-use reagent packs used in 4 cardiac/thoracic operating rooms:
  – Used by perfusionists and anesthesia technicians.
  – Maintenance, quality control, and regulatory responsibility are under Clinical Laboratories.

• Completed test is automatically ordered, billed, and archived in information system.
Disclaimer:
The following cost data are based on larger hospital test volumes than shown for these Operating Rooms: ie, ~25K tests/yr and ~130K tests/yr

So, this cost data should NOT be used to negotiate a better price than you have now!!
## CVOR Blood Gas POC Model #1
Blood Gas Analyzers with Single-Use Test Cartridge

<table>
<thead>
<tr>
<th>Test Card Menu</th>
<th>Test Vol / yr</th>
<th>Yearly Cost ($)</th>
<th>Average Cost/Test Menu</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH, pCO₂, pO₂, Na, K, Ca_{ion}, HCT, calc HCO₃, sO₂, Hb</td>
<td>829</td>
<td>$5770</td>
<td></td>
</tr>
<tr>
<td>pH, pCO₂, pO₂</td>
<td>632</td>
<td>$3215</td>
<td></td>
</tr>
<tr>
<td>pH, pCO₂, pO₂, lact, calc HCO₃, sO₂</td>
<td>63</td>
<td>$390</td>
<td></td>
</tr>
<tr>
<td>Na, K, Cl, BUN, calc HCT</td>
<td>1398</td>
<td>$8460</td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>230</td>
<td>$860</td>
<td></td>
</tr>
<tr>
<td>Creatinine</td>
<td>372</td>
<td>$1930</td>
<td></td>
</tr>
<tr>
<td>Controls, Cals, etc</td>
<td></td>
<td>$750</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL OR Vol/Costs (approx)</strong></td>
<td>3524</td>
<td><strong>$21,400</strong></td>
<td><strong>$6.06</strong></td>
</tr>
</tbody>
</table>
CVOR Blood Gas POC Model #2
Blood Gas Analyzers with Multi-Use Reagent Packs

<table>
<thead>
<tr>
<th>Test Menu</th>
<th>OR Test Vol / yr</th>
<th>Yearly Cost ($)</th>
<th>Cost/test panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR Panel</td>
<td>3577 (OR 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“</td>
<td>3751 (OR 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“</td>
<td>2957 (OR 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“</td>
<td>2971 (OR 4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>13,256</td>
<td>$55,000</td>
<td>$4.14</td>
</tr>
</tbody>
</table>

OR Panel: pH, pCO₂, pO₂, Na, K, ion Ca, glucose, lactate, tot Hb, %O₂Hb, %COHb, %metHb
Relative Costs of Blood Gas/Lytes POC Models vs Test Volume

<table>
<thead>
<tr>
<th>System</th>
<th>Test Volume / Year</th>
<th>Average Cost / Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 (single-use)</td>
<td>5,000</td>
<td>$7.20</td>
</tr>
<tr>
<td>#1 (single-use)</td>
<td>20,000</td>
<td>$5.40</td>
</tr>
<tr>
<td>#2 (multi-use)</td>
<td>5,000</td>
<td>$14.50</td>
</tr>
<tr>
<td>#2 (multi-use)</td>
<td>25,000</td>
<td>$4.00</td>
</tr>
</tbody>
</table>

Note: The test menus are distinctly different between the single-use and multi-use cartridges, so these are not equal comparisons.
Pros/Cons of POC Model #1: Single Use Test Cartridge

• Advantages
  – Excellent portability
  – Wider variety of tests available; ie. ACT, TnI
  – Financially suited to lower volume settings
  – Very good accuracy and reliability

• Disadvantages
  – A complete critical care panel may require 2-3 cartridges (adds time and $/test)
  – Cooximetry parameters are not measured
Pros/Cons of POC Model #2: Multiple-Test Reagent Pack

• Advantages
  – Cost, throughput, and speed are well-suited for high test volume settings
  – Complete BG/lytes/glu/lact/coox available with one analysis
  – Excellent accuracy and potential agreement with laboratory results

• Disadvantages
  – Not portable
  – Changing reagent packs takes ~40 min
Opportunities for Improved Assay Devices for Intraoperative Parathyroid Hormone (ioPTH) Measurements
PTH Workload at Duke Medical Center

Fiscal Year

PTH Core Lab

BG Lab (IntraOP)

Core Lab

2005-6
2006-7
2007-8
2008-9
2009-10
2010-11
2011-12
Facts about Surgery on the Parathyroid Glands

- The 4 parathyroid glands located behind the thyroid glands:
  - Each gland about the size of a grain of rice
  - Not related to thyroid glands in function
  - In ~90% of cases, only one PT gland is hyperactive.

- Types of hyperparathyroidism:
  - Primary HPTH due to parathyroid adenoma (a benign tumor)
  - Secondary HPTH due to renal disease.

- Surgery is the only treatment for hyperparathyroidism.
Rear-View Diagram of Parathyroid Glands in Relation to Thyroid Glands

- Carotid Artery
- Thyroids
- Parathyroid Glands
- Parathyroid Adenoma
Using Intraoperative PTH Measurements

- In most cases, 4 PTH measurements are taken:
  - Two baseline levels: (1) at induction of anesthesia; (2) after parathyroid glands are isolated.
  - 5 min post resection of parathyroid gland.
  - 10 min post resection of gland.

- Interpretation:
  - PTH level at 10 min should be $\leq 50\%$ of the highest baseline value.
  - If not, wait a period of time then measure PTH again.
  - If level still not $\leq 50\%$ of baseline, the neck is explored further for other abnormal parathyroid glands.
Percent Change in Intraoperative PTH in Patient with Two Enlarged Glands

![Graph showing percent change in intraoperative PTH after gland resection. The graph illustrates the time after resection and the percent of baseline PTH value. The data is from Point of Care 2007; 6: 253-260]
Benefits of Intraoperative PTH Testing

- Helps identify multiple-gland disease that is present in approximately 12% of patients with primary hyperparathyroidism.
- Helps surgeon know that parathyroidectomy has been successfully completed:
  - Avoids having to tell the patient the next day that the operation did not cure the disease and they will need another operation.
Sample Stability for PTH

- PTH is not stable in blood circulation
  - \( \frac{1}{2} \) life of 5-10 min.
- Depending on the assay, PTH is stable in serum/plasma for about 8 hours at RT.
- EDTA appears to stabilize PTH in plasma for 24 – 48 hours at RT.
What Is Needed for an Intraoperative PTH Test System?

• Small and portable analyzer.
• Easy test setup after days of non-use.
• No water or plumbing needed.
• No reagent preparation.
• Analysis on whole blood:
  – Saves time AND you do not need a centrifuge.
• Results ASAP, but ideally in less than 10 min.
  – Some rapid PTH methods on bench-type analyzers have few desirable features, but assay takes about 11 min.
  – One smaller analyzer has some desirable features, but assay takes 17 min.
Achieving Proper Anticoagulation and Minimizing Transfusions in the CVOR: What Novel Test Devices are Needed?
Useful Coagulation Tests in the CVOR

- ACT (Activated Clotting Time)
- Heparin level by protamine inactivation
- Prothrombin Time / INR
- Rotational Thromboelastometry
- Platelet count
- Fibrinogen
Complications of RBC Transfusion in Cardiac Surgery Patients

• A UK retrospective study of 8724 adult cardiac surgery patients linking outcomes with transfusions:
  – 3689 not transfused; 4909 transfused.

• RBC transfusion was strongly associated with:
  – Infection (strong dose-response relationship).
  – Complications from ischemia (stroke, MI, etc; also strong DRR).
  – Early complications post surgery.
  – Longer ICU and post-op hospital stays.
  – Increased 30-day mortality: 6X higher
  – 40% higher costs.

Reducing Transfusions in Cardiac OR by Appropriate Testing

- Cardiac surgery accounts for about 1/3 of all intraoperative transfusions.
- Mortality correlates linearly with the number of transfused blood products.
- When to give RBCs, platelets, fresh frozen plasma (FFP), fibrinogen (as cryoprecipitate)?
Transfusion Algorithm Proposed at Duke Med Center

- Hemoglobin:
  - Keep above 7.5 g/dL for general cases
  - Keep above 8.0 g/dL for high-risk cases
- Platelet count <50,000: Tx one platelet pool.
- PT: INR > 1.5: Tx 2-4 units of FFP.
- Fibrinogen < 125: Tx 1 pool cryoppt.
Availability of Methods Used for Transfusion Algorithm

- We Have Reasonably Good POC Devices for Blood Hb, PT, and Platelet Count.
- I am not aware of a good POC device for fibrinogen on whole blood.
- Our anesthesiologists believe that having a rapid fibrinogen assay would save on use of cryoprecipitate.
  - Fibrinogen in Coag Lab (Clauss) takes about 1 hour TAT.
Evaluating Need for Fibrinogen/Cryoprecipitate in OR

• When to give cryoprecipitate (fibrinogen)?
• Multiple problems with giving cryo:
  – *1 dose of cryo exposes recipient to 10 donors!*
  – Giving cryo empirically is often wasteful ($$).
  – Cryo has to be thawed to use (takes 20-30 min)
  – Cannot thaw and refreeze cryo.
  – *But not giving cryo when needed can cause major problems.*
• A rapid WB fibrinogen assay would be very helpful.
  – No current method/device is satisfactory.
Concept of Oscillating Thromboelastometry Devices

Provides information on clotting factors, platelets, fibrinogen.
Adding Platelet-Inhibiting Reagent in Rotational Thromboelastometry Gives a Fibrinogen of Questionable Accuracy

The MA with platelet inhibitor added (plavix) is now more related to the fibrinogen level. However, our brief comparisons to the Clauss method were not very good.
Need For Rapid Fibrinogen Assay

• Efforts to minimize transfusion of blood products appears to be here for good
• Decisions on thawing and using cryoprecipitate require rapid fibrinogen results
• Clauss-type methods are based on clot formation: optical or mechanical.
  – Can this be adapted to a whole-blood assay?
Actual, Totally True Incident (Years Ago) in Our Point-of-Care Glucose Testing Program

• A lab person in the POCT program called a caregiver about a result being an “outlier” on a proficiency test sample.

• Caregiver heard this slightly differently and told their supervisor: “The lab said I was an ‘out and out liar’ on my [PT] result.”

• Moral: Effective communication is a must in POC testing.