The Effect of Standardizing Autologous Prime Techniques in Patients Undergoing Cardiac Surgery with Cardiopulmonary Bypass

Al Stammers, Stephen Francis, Eric Tesdahl, Randi Miller, Anthony Nostro, Linda Mongero

Blood Management during Cardiac Surgery with CPB

Autologous Prime (AP) as a Blood Management Technique

Purported Benefits

- Higher hemoglobin levels
- Reduced red blood cell transfusion
- Improved oncotic pressures
- Improved regional cerebral saturation
- Reduced extravascular lung water

Aryaratnam
Hou
Vandewiele
Hwang
Eising
Duong
Vandewiele

Autologous Prime (AP) as a Blood Management Technique

NZ/Aust. (n=9)             USA (n=32)

Autologous Prime Use [%]

20.1% (0.0-94.9)      80.5% (0.0-100)

References

Hwang J Cardiothorac Vasc Anesth. 2011:25:995-

4/25/2019
AP Results Non-Conclusive

Not Effective
✓ No benefit in RBC transfusion
✓ Intolerant to changes in hemodynamics
✓ Reduced circulating blood volume
✓ Can’t be used in anemic patients
✓ Takes too long
✓ Non-standardized with inter-clinician variation


Objectives

Hypothesis
Standardization of methods for autologous priming of the heart-lung machine will result in improved outcomes.

Study
✓ Non-randomized, sequential, alternating clinical study
✓ Goal-directed conduct of perfusion
✓ Electronic quality improvement perfusion database
✓ Adult cardiac surgery patients requiring CPB
✓ IRB approved

Disclosure: None

Methods

Groups
Non-Standardized AP technique (NST-AP) v. Standardized AP technique (ST-AP)

NST-AP
- Discretionary volume removal
- Early termination decision tree
- No end-targets

ST-AP
- Evidently review of literature
- Entire cardiac team buy-in
- Target AP volume displaced (1 L)
- Stabilization of hemodynamics

Primary End-Point
Allogeneic Transfusions

Secondary End-Points
Hemodilution, Hematocrit Drift

Perfusion Techniques
- Mild hypothermia with alpha-stat acid base maintenance
- Policy-algorithm directed therapies
- Perfusion directives: NIRS, SvO2, pH, temperature, HCT
- Limited surgical team

Anesthesia Techniques
- Standard induction and maintenance medications (NIRS)
- Conservative fluid management
- Standardized transfusion algorithm

Postoperative Techniques
- Standardized transfusion algorithm
Standardized AP Protocol

Demographic Data for all Patients

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<tr>
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<tbody>
<tr>
<td>Number</td>
<td>82</td>
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<tr>
<td>Age - years (mean±sd)</td>
<td>65.3±10.1</td>
<td>66.8±11.8</td>
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<tr>
<td>Gender - male (count, %)</td>
<td>52 (63.4)</td>
<td>75 (68.2)</td>
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<tr>
<td>Weight - kg (mean±sd)</td>
<td>90.7±22.4</td>
<td>86.5±20.1</td>
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<tr>
<td>Height - cm (mean±sd)</td>
<td>170.4±10.9</td>
<td>170.5±10.7</td>
<td>0.918</td>
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<tr>
<td>BSA (mean±sd)</td>
<td>2.02±0.28</td>
<td>1.97±0.24</td>
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Operative Data for all Patients

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<tr>
<td>CPB Time - min (mean±sd)</td>
<td>102.7±56.1</td>
<td>114.2±55.1</td>
<td>0.159</td>
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<td>XC Time - min (mean±sd)</td>
<td>70.6±41.0</td>
<td>69.2±44.0</td>
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Results

P<0.001
Results

Perioperative Volume Administration and Removal

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<th>Non-Standardized</th>
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<tbody>
<tr>
<td>NCPV - mL (mean (sd))</td>
<td>1,415.7 (295.4)</td>
<td>982.7 (282.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>APV - mL (mean (sd))</td>
<td>486.8 (259.6)</td>
<td>1,048.2 (218.7)</td>
<td>&lt;0.001</td>
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<tr>
<td>CPH Asangu. - mL (mean (sd))</td>
<td>1,198.4 (835.6)</td>
<td>776.8 (711.9)</td>
<td>&lt;0.001</td>
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<td>CPH Uringe. - mL (mean (sd))</td>
<td>226.3 (168.8)</td>
<td>320.0 (207.6)</td>
<td>0.001</td>
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<tr>
<td>UF Use - Yes (count (%))</td>
<td>62 (75.6)</td>
<td>10 (9.1)</td>
<td>&lt;0.001</td>
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<tr>
<td>UFV - mL (mean (sd))</td>
<td>563.5 (408.9)</td>
<td>170.9 (614.7)</td>
<td>&lt;0.001</td>
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<tr>
<td>Anesthesia Asangu. - mL (mean (sd))</td>
<td>1,497.6 (703.5)</td>
<td>1,877.4 (696.6)</td>
<td>&lt;0.001</td>
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<tr>
<td>Total Urine - mL (mean (sd))</td>
<td>517.3 (274.3)</td>
<td>753.2 (369.7)</td>
<td>&lt;0.001</td>
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<tr>
<td>IAT Returned - mL (mean (sd))</td>
<td>1,204.7 (572.7)</td>
<td>805.3 (488.8)</td>
<td>&lt;0.001</td>
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<td>ICU Chest Tube Output - mL (mean (sd))</td>
<td>1,301.0 (977.8)</td>
<td>1,447.1 (1,403.2)</td>
<td>0.427</td>
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</table>
**Results**

### Perioperative Hematocrit and Platelet Values

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<tr>
<td>HCT Postinduction - % (mean (sd))</td>
<td>36.2 (4.5)</td>
<td>36.4 (5.1)</td>
<td>0.758</td>
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<td>HCT Pre-CPR - % (mean (sd))</td>
<td>33.7 (4.8)</td>
<td>33.9 (4.9)</td>
<td>0.727</td>
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<tr>
<td>HCT First CPR - % (mean (sd))</td>
<td>25.7 (4.5)</td>
<td>27.9 (4.6)</td>
<td>0.001</td>
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<tr>
<td>HCT Low CPR - % (mean (sd))</td>
<td>25.7 (4.5)</td>
<td>25.7 (4.6)</td>
<td>0.01</td>
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<tr>
<td>HCT High CPR - % (mean (sd))</td>
<td>27.7 (3.5)</td>
<td>29.1 (3.6)</td>
<td>0.008</td>
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<tr>
<td>HCT Last in Room - % (mean (sd))</td>
<td>27.0 (3.1)</td>
<td>27.6 (3.5)</td>
<td>0.279</td>
</tr>
<tr>
<td>HCT ICU Entry - % (mean (sd))</td>
<td>33.5 (4.0)</td>
<td>34.5 (4.6)</td>
<td>0.003</td>
</tr>
<tr>
<td>HCT POD 1 - % (mean (sd))</td>
<td>32.0 (3.8)</td>
<td>32.6 (3.7)</td>
<td>0.279</td>
</tr>
<tr>
<td>Platelet Preoperative - ul/mL (mean (sd))</td>
<td>214.3 (67.3)</td>
<td>213.2 (62.9)</td>
<td>0.901</td>
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<tr>
<td>Platelet ICU Entry - ul/mL (mean (sd))</td>
<td>132.6 (45.2)</td>
<td>137.6 (48.7)</td>
<td>0.471</td>
</tr>
<tr>
<td>Platelet POD 1 - ul/mL (mean (sd))</td>
<td>135.8 (46.6)</td>
<td>135.9 (50.8)</td>
<td>0.983</td>
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**Results**

### Perioperative Transfusion Data

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<th>Standardized</th>
<th>p-value</th>
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<tbody>
<tr>
<td>CPR FFP - U (mean (sd))</td>
<td>0.32 (1.08)</td>
<td>0.34 (0.23)</td>
<td>0.009</td>
</tr>
<tr>
<td>CPR FFP - ml (mean (sd))</td>
<td>88.8 (201.5)</td>
<td>10.9 (49.5)</td>
<td>0.009</td>
</tr>
<tr>
<td>ICU RBC - U (mean (sd))</td>
<td>5.0 (3.2)</td>
<td>6.1 (1.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ICU RBC - ml (mean (sd))</td>
<td>607.1 (961.0)</td>
<td>191.8 (534.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ICU RBC Transfusion - % (mean (sd))</td>
<td>42 (31.2)</td>
<td>33 (26.2)</td>
<td>0.002</td>
</tr>
<tr>
<td>ICU FFP - U (mean (sd))</td>
<td>0.82 (1.89)</td>
<td>0.32 (0.60)</td>
<td>0.003</td>
</tr>
<tr>
<td>ICU FFP - ml (mean (sd))</td>
<td>238.7 (549.0)</td>
<td>68.1 (209.5)</td>
<td>0.003</td>
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<tr>
<td>ICU PLT - U (mean (sd))</td>
<td>9.7 (2.48)</td>
<td>9.0 (0.27)</td>
<td>0.003</td>
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<tr>
<td>ICU PLT - ml (mean (sd))</td>
<td>71.3 (232.2)</td>
<td>3.0 (7.20)</td>
<td>0.003</td>
</tr>
</tbody>
</table>

**Conclusions**

- Higher crystalloid prime volume reduction
- Higher intraoperative hematocrits
- Lower use of ultrafiltration with less volume removed

The application of a standardized AP protocol was effective in reducing hemodilution which was associated with higher hematocrits and lower postoperative transfusion rates.

*Thank You*

Al.stammers@specialtycare.net
Microvascular Integrity
Glycocalyx

When did the discussions start?

Syndecan-1 plasma levels during coronary artery bypass surgery with and without cardiopulmonary bypass


The glycocalyx covering the endothelium is shed during coronary artery bypass surgery. This shedding is accompanied by increased levels of the glycocalyx component syndecan-1 in the circulation. Our aim was to compare plasma levels of syndecan-1 before and 30 minutes after the initiation of anesthesia in the off-pump group. There was a significant difference in peak plasma levels of syndecan-1 plasma concentration between on-pump and off-pump patients. Plasma levels of syndecan-1 decreased significantly within 30 minutes after bypass surgery.
Acute Degradation of the Endothelial Glycocalyx in Infants Undergoing Cardiac Surgical Procedures

Dirk Bruegger, MD,† Florian Bremser, MD,‡ Isabel Rosberg, Claudia Nussbaum, MD, Christian Kowalski, MD, Katarzyna Janusiewska, MD, Bernhard F. Becker, MD, PhD, and Daniel Chappell, MD
Department of Anesthesiology and Dr. von Henners Children’s Hospital, University Hospital of Münster, Münster, Department of Cardiovascular Surgery, University of Münster, Münster, and Wiley-Blackwell Centre of Experimental Medicine, University of Münster, Münster, Germany

Background: There is no doubt today about the existence of the endothelial glycocalyx (EG) and its decisive role in maintaining vascular homeostasis in adult humans. Shedding of the EG has been demonstrated in adults with sepsis or trauma, in patients undergoing major operations, and after ischemia-reperfusion. The aim of the present study was to demonstrate whether shedding of the EG also occurs in neonates during cardiac surgery.

Methods: Two major centers of the EG glycocalyx and shedding were measured in the arterial serum of 42 infants during cardiac operations in a prospective observational study. The groups were defined according to the ischemic impact: cardiac operation with cardiopulmonary bypass under beating heart conditions (CPB+B) or regional ischemia of the heart (RGI), n = 10; operations with cardiopulmonary bypass and aortic clamping (CPB+B+Ac), n = 10; regional ischemia of the heart and lung, n = 20; and cardiac operations with deep hypothermic circulatory arrest (DHCA), n = 10.

Results: Syndecan-1 and hyaluronan were detected in all infants, providing an indication for the presence of a glycocalyx. During the operations, no significant difference in syndecan-1 concentration was observed in the CPB+B group, but levels increased significantly in both other groups. Maximum increases were observed in the CPB+B+Ac group (105 ± 24, p < 0.01 vs RGI; p < 0.01 vs DHCA), and the highest values were found in the DHCA group (129 ± 20, p < 0.05 vs RGI; p < 0.05 vs CPB+B+Ac). In the RGI group, hyaluronan levels increased by 118 ± 39, p < 0.05, and the highest values were found in the DHCA group (138 ± 34, p < 0.05 vs RGI; p < 0.05 vs CPB+B+Ac).

Conclusions: The present data provide the first evidence for local turnover of vascular EG in infants. Similarly to the process in adults, the shedding of this structure increases with ischemia-reperfusion, the extent being dependent on the degree of ischemic challenge.


Cardiopulmonary bypass and the endothelial glycocalyx: Shedding new light

Sanjay Kaushal, MD, PhD, and Brody Welman, MD

From the Division of Cardio Surgery, University of Maryland School of Medicine, Baltimore, MD.

Heparin: Effects upon the Glycocalyx and Endothelial Cells

Bruce D. Speirs, MD, FAHA

Heparin: Effects upon the Glycocalyx and Endothelial Cells

Bruce D. Speirs, MD, FAHA

Department of Anesthesiology, University of Florida College of Medicine, Gainesville, Florida

Presented at the Perfusion Downday Meeting, The Barossa Valley, South Australia, Australia, August 6-8, 2015.

Abstract: Unfractionated heparin (UFH) is the most widely used anticoagulant in the United States. UFH is only weakly, relatively, or not at all, a direct thrombin inhibitor but instead acts by activating antithrombin III, which in turn inhibits thrombin and factor Xa. UFH is used in the treatment of deep venous thrombosis, pulmonary embolism, and many other conditions. UFH is also used as a bridge to oral anticoagulants, where UFH is used for the first 48 hours to prevent embolization of the heart due to the higher levels of UFH. UFH is also used in cardiac surgery to prevent thrombosis of the heart. UFH is a useful tool for heparin sulfate. Based on the surface of endothelial cells, heparin sulfate protides endothelial surfaces from inflammatory attack and serves as a mechanostressor for vascular shear. UFH and all glycosaminoglycans here for ending to restore. This is a new line on some of fascinating single biology of these polyglycans. Perhaps a number of the complex combination attributed to UFH are effective in the field of medicine.

Keywords: Heparin, anticoagulation, endogenous receptor, platelets, endothelial, J Transl Med 2010;8:109

Fluid resuscitation and markers of glycocalyx degradation in severe sepsis

Xinhui Wu, Zhenjie Hu, Hufang Yuan, Lei Chen, Yong Li, Congcong Zhao

Fluid resuscitation and markers of glycocalyx degradation in severe sepsis

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7281039/

Abstract: Background: The aim of this study was to determine...
Endothelial Glycocalyx and Cardiopulmonary Bypass
Gerard J. Myers, RT, CCP Emeritus* Julie Wegner, PhD, CPIT
*Eastern Perfusion International, Dorchester, New Scotia KOWPA, Canada and Tucson, Arizona

Abstract: On the outer surface of a human cell there is a thin layer of complex carbohydrates called glycocalyx, which is referred to in angiography. This layer can be visualized and analyzed in different ways. The composition of glycocalyx is an important area of research.

What is Glycocalyx?

- The glycocalyx is a thin (500-2000nm) hydrated gel-like layer on the luminal surface of the vascular endothelium.
- Given that the vascular endothelium covers a total surface of around 4000-7000m², in spite of its microscopic thinness this layer actually occupies about 25% of the total intravascular volume.
- The name means “sweet husk”, referring to the high polysaccharide content.
- It is in fact composed of a vast variety of macromolecules, including:
  - Glycoproteins
  - Polysaccharides
  - Proteoglycans
  - Glycosaminoglycans, such as heparin sulfate, chondroitin sulfate and hyaluronic acid.
- These molecules are characterised by a polyanionic charge; this helps repel circulating platelets.
- The exact composition varies greatly according to the local microenvironment.

Components of Endothelial Glycocalyx

- Given that the vascular endothelium covers a total surface of around 4000-7000m², in spite of its microscopic thinness this layer actually occupies about 25% of the total intravascular volume.
Components of Endothelial Glycocalyx

- At any given time, it also contains constituents of the routine molecular traffic which passes through it or lodges within it, such as:
  - Plasma proteins
  - Enzymes and enzyme inhibitors
  - Growth factors
  - Cytokines
  - Amino acids
  - Cations
  - Water
- The glycocalyx is fragile but self-repairing
  - Additionally, it must be mentioned that certain tissues possess capillaries which are intentionally denuded of glycocalyx
    - choroid plexus
    - secretory areas of endocrine glands
    - hepatic sinusoids and the reticuloendothelial system of the spleen
    - Functionally, glomerular capillaries also act as if they have no glycocalyx (they actually do have it, but the endothelium there is full of massive fenestrations)

Functions of Endothelial Glycocalyx

- Protection: Cushions the plasma membrane and protects it from chemical injury
- Immunity to infection: Enables the immune system to recognize and selectively attack foreign organisms
- Defense against cancer: Changes in the glycocalyx of cancerous cells enable the immune system to recognize and destroy them
- Transplant compatibility: Forms the basis for compatibility of blood transfusions, tissue grafts, and organ transplants
- Cell adhesion: Binds cells together so that tissues do not fall apart
- Inflammation regulation: Glycocalyx coating on endothelial walls in blood vessels prevents leukocytes from rolling/binding in healthy states
- Fertilization: Enables sperm to recognize and bind to eggs
- Embryonic development: Guides embryonic cells to their destinations in the body

Dysfunction of Endothelial Glycocalyx

- Thinning of the glycocalyx layer is caused by generally any pathological process that is known to cause atheroma formation:
  - Hyperglycaemia
  - Hyperlipidaemia
  - Fluid Overload
  - Smoking
- Shedding of the glycocalyx layer is caused by:
  - Inflammation, mediated by TNFα
  - Ischaemia-reperfusion injury
  - Hypervolaemia
  - Hydroxyethyl starch
  - Major vascular surgery (seems like a consequence of bypass and tissue necrosis)
  - Major abdominal surgery (even without much abdominal sepsis)
  - Septis

Consequences of the Dysfunction of Endothelial Glycocalyx

- Local hypercoagulability
- Global autoheparinisation (especially during trauma)
- Increased capillary permeability
  - Tissue and organ oedema
  - Impaired microcirculatory oxygen distribution
  - Loss of vascular responsiveness
- Increased platelet aggregation, leading to microvascular thrombosis and DIC
- Increased leucocyte-endothelium interaction, leading to inflammation
Literature Citations- 2019

- 16724 publications on "cardioplegia"
- 14515 publications on "myocardial protection"
- 60 publications on "Del Nido Cardioplegia" (2011)
- 124 publications on "HTK Cardioplegia" (1984)

Del Nido vs HTK

<table>
<thead>
<tr>
<th>Del Nido</th>
<th>HTK</th>
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<td>Pediatric formula</td>
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<td>Immature heart</td>
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<td>Lower-temp</td>
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<td>Hemodilution/Transfusion</td>
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<td>Lidocaine Dosing Dilemma</td>
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<tr>
<td>Conflicting data on limited population</td>
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<td>Limited clinical parameters studied</td>
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<td>No data on long-term outcome</td>
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Background

- The present study aims to compare
  ✓ Plasma levels of syndecan-1, a biomarker of EG integrity, in patients undergoing primary aortic valve replacement with CABG with either Del Nido or HTK versus crystalloid cardioplegia
  ✓ Verified by cell culture

Patient & Methods

- This prospective study included patients undergoing combined aortic valve replacement who received different cardioplegic solutions between January 2015 and November 2018
  ✓ Group 1: St. Thomas (control) N=98
  ✓ Group 2: Del Nido N=92
  ✓ Group 3: HTK N=106
- Serum Syndecan-1 levels were measured by ELISA via coronary sinus sample
  ✓ Before CPB (T1)
  ✓ At the end of CPB (T2) with a solid-phase monoclonal BB4 antibody (higher levels implicate worse protection)
- A left ventricular specimen is collected at the end of CPB and processed
- Cells were incubated with LPS in culture medium until 24 h
- EG shedding (Syndecan-1, SC-12765) until 24 h was documented in microscopy
There wasn’t a significant difference among the groups with respect to demographic data, type of surgery and BMI. Early perioperative data demonstrated that all three types of cardioplegic techniques provided effective clinical outcome with similar effects on blood biochemical parameters.

<table>
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<th>Serum Syndecan-1 T1 (ng/mL)</th>
<th>Serum Syndecan-1 T2 (ng/mL)</th>
</tr>
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<tbody>
<tr>
<td><strong>St Thomas</strong></td>
<td>29.3± 4.0</td>
<td>122.6± 8</td>
</tr>
<tr>
<td><strong>Del Nido</strong></td>
<td>34.1± 4.1</td>
<td>99.5± 6.2</td>
</tr>
<tr>
<td><strong>HTK</strong></td>
<td>35.2± 4</td>
<td>59.4± 5.2*</td>
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*: p<0.05 vs control (St Thomas)
**Future**

- Strategies for repairing of injured EG Wall via nanotechnology
- Creation of novel EG layer via decellularization/recellularization techniques by tissue engineering
- Building biosensors/biomarkers to detect early injury of EG
- Simulation techniques to mimic EG for treatment in 3D cell culture

**Take Home Messages**

- Cardiac surgery and the use of CPB alters the EG and microcirculation
- These findings contribute to our understanding of the pathologic changes induced on the microcirculation by surgery and CPB
- What remains unclear, however, is the clinical relevance of the transient changes observed in the EG and microvasculature after surgery and CPB
- Because of the EG’s known role in maintaining vascular permeability, shedding of the EG associated with CPB likely contributes to postoperative morbidity at some level, although such a contribution was not clearly captured in many studies
- Additional studies are needed to define better the clinical utility of EG measurement in patients undergoing cardiac surgery with CPB
- Current studies however offer important preliminary evidence that CPB is associated with alterations in the EG and microcirculation and protection of EG layer may contribute better postoperative outcomes

Thanks!!

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Blood Conservation During Cardiac Surgery

Erick McNair, PhD, CCP, FICA
Departments of Pathology and Laboratory Medicine and Surgery, Division of Cardiac Surgery

Disclosure Statement

- No financial disclosures
- Hemobag® provided by Global Blood Resources

Why do we care about Blood Transfusions

- Transfusions are associated with an increased morbidity and mortality in cardiac surgery.¹
- The higher the transfusion rate, the higher the complication rate²
- Cardiac surgery has the largest consumption of blood products of any field in medicine³

Evidence Based Guidelines

Class Of Recommendation and Level of Evidence

- 2011 Update on Blood Conservation Practice Guidelines STS and Cardiovascular Anesthesiologists⁴
- Cell Washing IIa (A): --- (moderate; benefit >> risk)
  ---- Recommendation: procedure is reasonable
  ---- Considered useful, effective, and beneficial
- MUF I(A): --- (strong; benefit >>> risk)
  ---- Recommendation: procedure should be performed.
  ---- Procedure is useful, effective, and beneficial.
**Purpose of the Study**

- Goal: to provide evidence based data regarding which technique is best at increasing serum Hgb, while reducing blood transfusions in cardiac postoperative patients
- 3 different interventions were compared for impact of removal of crystalloid

**Hypothesis**

- That patients who underwent the Online-MUF technique would demonstrate a higher serum Hgb and a lower RBC transfusion volume at the 18-hour postoperative interval, as compared to the Offline-MUF and Control (cell washing) methods.
- Primary outcome variable: serum Hgb level at the 18-hour interval
- Secondary outcome variable: units of RBC’s transfused

**Methods**

- n=99; 35-Online-MUF, 30-Offline-MUF, 34-Cell-Washing
  - consecutive males and females
    - 40 to 80 yrs.
    - elective or urgent
    - 75kg or less

**Online-Modified Ultrafiltration (MUF)**

- Patient (TBV = 5L)
- 10-15min
- ~1000 mL
Offline-MUF

16.4 g/dL

10-12 min

Hemofilter

~1000 mL

Crystalloid

Residual Pump Volume

Cell Washing Technique

5 min ~500 mL

20 g/dL

~1000 mL

Statistical Analysis

- Descriptive statistics (means, frequencies) for group characteristics, with comparison by ANOVA, Kruskal-Wallis or Chi-square testing
- Outcomes were initially assessed across groups at the individual time points and compared using ANOVA/Wilcoxon rank-sum test
- Hemoglobin (main outcome) was further assessed by linear mixed effects model to account for repeated measurements within patients over multiple time points

Results

**Table 1 Demographic Data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group I (n = 36)</th>
<th>Group II (n = 30)</th>
<th>Group III (n = 34)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender M/F</td>
<td>23M/13F</td>
<td>21M/9F</td>
<td>21M/13F</td>
<td>0.42</td>
</tr>
<tr>
<td>Age (years)</td>
<td>66 ± 10.8</td>
<td>68.1 ± 11.4</td>
<td>68 ± 9.3</td>
<td>0.55</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.5 ± 8.8</td>
<td>167.83 ± 9.3</td>
<td>167.9 ± 9.0</td>
<td>0.48</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>72.8 ± 8.3</td>
<td>74.9 ± 10.3</td>
<td>73.8 ± 8.8</td>
<td>0.69</td>
</tr>
<tr>
<td>BMI</td>
<td>26.7 ± 4.2</td>
<td>26.7 ± 4.3</td>
<td>26.2 ± 2.8</td>
<td>0.33</td>
</tr>
<tr>
<td>Prime Vol (mL)</td>
<td>952 ± 256.9</td>
<td>834 ± 215.3</td>
<td>898.6 ± 214.4</td>
<td>0.36</td>
</tr>
<tr>
<td>X Clamp (min)</td>
<td>90.03 ± 27.0</td>
<td>89.5 ± 22.5</td>
<td>99.9 ± 23.5</td>
<td>0.46</td>
</tr>
<tr>
<td>CPB Time (min)</td>
<td>120 ± 32.9</td>
<td>109.7 ± 23.9</td>
<td>123.4 ± 32.5</td>
<td>0.90</td>
</tr>
<tr>
<td>EF (%)</td>
<td>54.9 ± 9.7</td>
<td>56.4 ± 9.9</td>
<td>57.6 ± 8.6</td>
<td>0.48</td>
</tr>
<tr>
<td>CrCl (mL/min/m²)</td>
<td>83.6 ± 27.3</td>
<td>92.3 ± 32.5</td>
<td>88.8 ± 25.1</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Primary and Secondary Outcomes

ANOVA p= 0.002
Online vs Offline p= 0.045
Offline vs Centrifugation p= 0.001
Online vs Centrifugation p= 0.07

ANOVA p= <0.0001
Online vs Offline p= 0.006
Offline vs Centrifugation p< 0.0001
Online vs Centrifugation p= 0.02

Discussion
Online MUF
Pros
- highest Hgb @ arrival
- 2nd highest @ 18 hrs.
Cons
- highest in transfusion of vol.
- highest fluid balance
- time consuming
- highest weight change

Offline MUF
Pros
- highest Albumin @ arrival
- lowest fluid balance
- lowest transfusion vol.
- lowest weight change
Cons
- lowest Hgb @ 18 hrs.
- inadequate clearance of heparin

Centrifugation
Pros
- highest Hgb @ 18 hrs.
- fastest turn around
Cons
- lowest Albumin
- 2nd highest fluid balance
- 2nd highest transfusion vol.

Conclusion
- Online MUF did not provide the highest Hgb @ 18 hrs and did not decrease blood transfusion requirements and clinical outcomes as anticipated.
- There is no evidence in the data to suggest that online MUF is associated with a higher Hgb at the 18 hour interval as compared to offline MUF and Cell Washing, although differences in crystalloid and blood product administration may influence our result.
We have to modelling to complete that would take out the influence of differences in fluid and blood product administration between the groups (potential confounders).

References


Why are Patients Prone to a Blood Transfusion during Cardiac Surgery?

- Cardiac surgery: requires CPB
- 2L prime pump; 2-5L anesthesia = Hemodilution
- Hemodilution = Dilutional Anemia
- Blood transfusions can save lives
- Numerous complications can arise from blood transfusions.1,2
- Acute transfusion reactions, transfusion-related lung injury, incorrect component transfusion, hemolysis, infections, storage errors, and anti-D administration errors.3
Evidence Based Guidelines

- Association of Anesthesiologist’s Guidelines: cell salvage for peri-operative blood conservation 2018
- 2011 Update STS and Cardiovascular Anesthesiologists Blood Conservation Practice Guidelines
- Cell Washing IIa (A): (moderate; benefit >> risk): procedure can be useful, effective, and beneficial. Recommendation: procedure is reasonable
- MUF I(A): (strong; benefit >>> risk): procedure is useful, effective, and beneficial. Recommendation: procedure should be performed.

Methods

- N=99; 35-Online, 30-Offline, 34-Cell Washing
- consecutive males and females
- 40 to 80 yrs.
- elective or urgent
- 75kg or less
- Exclusion criteria: 1) emergent (2) h/o liver or kidney dysfunction (3) anemic (baseline Hgb <100 g/L; (4) cardiomyopathy; (5) redo-cardiac procedures; (6) h/o stroke; (7) h/o TIA; (8) preop coagulopathies

Results

- ANOVA = 0.024
- Group 1 vs. 2 = 0.003

RESULTS

- ANOVA = 0.002
- Group 1 vs. 2 = 0.04
- Group 2 vs. 3 = 0.001
- Group 3 vs. 1= 0.070
RESULTS

Table 4 Clinical Outcome Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Overall p</th>
<th>1 vs. 2</th>
<th>2 vs. 3</th>
<th>1 vs. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU Balance (mL)</td>
<td>1880 ± 500</td>
<td>1022 ± 344</td>
<td>1286 ± 24</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight Δ (kg)</td>
<td>4.33 ± 1.3</td>
<td>0.94 ± 0.22</td>
<td>3.3 ± 1.6</td>
<td>0.001*</td>
<td>0.001*</td>
<td>0.001*</td>
<td>0.01*</td>
</tr>
<tr>
<td>Weight Δ (%)</td>
<td>5.7 ± 1.9</td>
<td>1.3 ± 0.27</td>
<td>4.6 ± 2.4</td>
<td>0.001*</td>
<td>0.001*</td>
<td>0.001*</td>
<td>0.02*</td>
</tr>
<tr>
<td>Chest Tube Loss (mL)</td>
<td>881 ± 392</td>
<td>786 ± 308</td>
<td>878 ± 411</td>
<td>0.70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventilation time (hrs.)</td>
<td>7.5 ± 6.4</td>
<td>7.4 ± 4.3</td>
<td>7.3 ± 2.6</td>
<td>0.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Products, units</td>
<td>0</td>
<td>4.0 (11.4)</td>
<td>3.4 (10.7)</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platelets, units</td>
<td>0</td>
<td>4.0 (11.4)</td>
<td>2.7 (6.7)</td>
<td>0.57</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frozen plasma, units</td>
<td>0</td>
<td>3.8 (8.6)</td>
<td>3.2 (6.1)</td>
<td>0.23</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Inflammatory Mediators

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Overall p</th>
<th>1 vs. 2</th>
<th>2 vs. 3</th>
<th>1 vs. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>IL-6 (pg/mL)</td>
<td>43.1 ± 14</td>
<td>64.6 ± 16.3</td>
<td>58.5 ± 19</td>
<td>0.04</td>
<td>0.73</td>
<td>0.001*</td>
<td>0.001*</td>
</tr>
<tr>
<td>TNF-α (pg/mL)</td>
<td>5.2 ± 2.5</td>
<td>4.0 ± 2.1</td>
<td>3.9 ± 1.8</td>
<td>0.001*</td>
<td>0.001*</td>
<td>0.001*</td>
<td>0.001*</td>
</tr>
<tr>
<td>MDA (µM)</td>
<td>0.32 ± 0.09</td>
<td>1.5 ± 0.86</td>
<td>1.3 ± 0.5</td>
<td>0.36</td>
<td>0.28</td>
<td>0.002*</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Linear Mixed Effects Model

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Estimate (Standard Error)</th>
<th>P-value</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept (Offline)</td>
<td>103.2 (1.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept (Online)</td>
<td>106.2 (1.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept (Centrifugation)</td>
<td>106.0 (1.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time* Offline</td>
<td>0.12 (0.16)</td>
<td>0.45</td>
<td>0.001*</td>
</tr>
<tr>
<td>Time* Online</td>
<td>0.16 (0.15)</td>
<td>0.29</td>
<td>0.03*</td>
</tr>
<tr>
<td>Time* Centrifugation</td>
<td>0.61 (0.15)</td>
<td>0.0001</td>
<td></td>
</tr>
</tbody>
</table>

- Mean ICU arrival hemoglobin levels estimated to be 103, 106, and 106 g/L for the respective groups
- On average, no significant change in hemoglobin over time for offline group (p = 0.45)
- On average, no significant change in hemoglobin over time for online group (p = 0.29)
- On average, statistically significant rise if centrifuged (p=0.0001)
  - Greater than that of offline and online groups
### Mean High with Standard Error Bars by Group

#### Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albumin (mmol/L)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrival: 30.2 ± 3.5</td>
<td>(29.7 ± 3.2)</td>
<td>(28.7 ± 3.3)</td>
<td></td>
</tr>
<tr>
<td>8 hrs: 29.7 ± 3.2</td>
<td>(29.7 ± 3.2)</td>
<td>(28.7 ± 3.3)</td>
<td></td>
</tr>
<tr>
<td>18 hrs: 28.7 ± 3.3</td>
<td>(28.7 ± 3.3)</td>
<td>(28.7 ± 3.3)</td>
<td></td>
</tr>
<tr>
<td>HS Troponin T</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrival: 631.3 ± 420</td>
<td>(997.4 ± 592)</td>
<td>(648.4 ± 327)</td>
<td></td>
</tr>
<tr>
<td>8 hrs: 997.4 ± 592</td>
<td>(31 ± 2.7)</td>
<td>(31 ± 2.7)</td>
<td></td>
</tr>
<tr>
<td>18 hrs: 648.4 ± 327</td>
<td>(31 ± 2.7)</td>
<td>(31 ± 2.7)</td>
<td></td>
</tr>
<tr>
<td>CrCL mL/min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrival: 89.5 ± 30.2</td>
<td>(81.5 ± 26)</td>
<td>(80 ± 27)</td>
<td></td>
</tr>
<tr>
<td>8 hrs: 81.5 ± 26</td>
<td>(85.5 ± 29.2)</td>
<td>(89.1 ± 36.4)</td>
<td></td>
</tr>
<tr>
<td>18 hrs: 80 ± 27</td>
<td>(85.5 ± 29.2)</td>
<td>(89.1 ± 36.4)</td>
<td></td>
</tr>
<tr>
<td>GGT (U/L)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrival: 31 ± 13.3</td>
<td>(34 ± 15.6)</td>
<td>(31 ± 19.4)</td>
<td></td>
</tr>
<tr>
<td>8 hrs: 34 ± 15.6</td>
<td>(30.4 ± 15.1)</td>
<td>(25.4 ± 12.5)</td>
<td></td>
</tr>
<tr>
<td>18 hrs: 31 ± 19.4</td>
<td>(40 ± 24)</td>
<td>(37.5 ± 12.2)</td>
<td></td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrival: 1.95 ± 0.8</td>
<td>(1.8 ± 0.84)</td>
<td>(2.0 ± 0.75)</td>
<td></td>
</tr>
<tr>
<td>8 hrs: 1.8 ± 0.84</td>
<td>(1.5 ± 0.6)</td>
<td>(1.8 ± 0.76)</td>
<td></td>
</tr>
<tr>
<td>18 hrs: 2.0 ± 0.75</td>
<td>(1.8 ± 0.76)</td>
<td>(2.0 ± 1.2)</td>
<td></td>
</tr>
<tr>
<td>aPTT (sec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrival: 33.1 ± 3.3</td>
<td>(32.5 ± 4.6)</td>
<td>(33.5 ± 3.4)</td>
<td></td>
</tr>
<tr>
<td>8 hrs: 32.5 ± 4.6</td>
<td>(29.7 ± 4.1)</td>
<td>(32.6 ± 4.0)</td>
<td></td>
</tr>
<tr>
<td>18 hrs: 33.5 ± 3.4</td>
<td>(32.6 ± 4.0)</td>
<td>(33 ± 4.1)</td>
<td></td>
</tr>
</tbody>
</table>

#### Overall p (1 vs. 2) (2 vs. 3) (1 vs. 3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>(1 vs. 2)</th>
<th>(2 vs. 3)</th>
<th>(1 vs. 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albumin</td>
<td>0.02*</td>
<td>0.02*</td>
<td>0.004*</td>
</tr>
<tr>
<td>HS Troponin T</td>
<td>0.260</td>
<td>0.47</td>
<td>0.070</td>
</tr>
<tr>
<td>CrCL mL/min</td>
<td>0.97</td>
<td>0.412</td>
<td>0.46</td>
</tr>
<tr>
<td>GGT (U/L)</td>
<td>0.06</td>
<td>0.04*</td>
<td>0.35</td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
<td>0.017*</td>
<td>0.21</td>
<td>0.003*</td>
</tr>
<tr>
<td>aPTT (sec)</td>
<td>0.013*</td>
<td>0.017*</td>
<td>0.78</td>
</tr>
</tbody>
</table>

* Denotes statistical significance at p < 0.05
**The Evolution of Patient Blood Management Programs in Cardiac Surgery: What is the Ultimate Frontier?**

Prof Serdar Gunaydin, MD, PhD
Department of Cardiovascular Surgery
Numune Training & Research Hospital,
University of Health Sciences,
Ankara-Turkey

Kevin McCusker, CCP, PhD
Assistant Professor of Surgery
New York Medical College, NY
2017 EACTS/EACTA Guidelines on patient blood management for adult cardiac surgery

The Task Force on Patient Blood Management for Adult Cardiac Surgery of the European Association for Cardio-Thoracic Surgery (EACTS) and the European Association of Cardiothoracic Anaesthesiology (EACTA)

Authors: Task Force Members: Damiano Pagano* (EACTA Chairperson) (UK), Milan Milicicic (Netherlands), Michael I. Meester* (Netherlands), Umberto Benedetto (UK), Daniel Boillier* (Switzerland), Christian von Heimann* (Germany), Anders Jepsen (Sweden), Andreas Koch* (Germany), Ruben L. Oeser (Augsburg, Germany), Marco Ranzini* (Italy), Harald Berg Rave* (Denmark), Alexander B.A. Verh (Holland), Alexander Wabu (Norway), Christi Boer** (EACTA Chairperson) (Netherlands)

- 1,061 institutions returned with a 32% response rate
- 78% of anesthesiologists and 67% of perfusionists reporting having read all, part, or a summary of the Guidelines
- 20% of institutions that an institutional discussion had taken place as a result of the Guidelines
- 14% reported that an institutional monitoring group had been formed
- 26% reported one or more practice changes in response to the Guidelines
- The changes made were reported to be highly (6%) or somewhat effective (31%) in reducing overall transfusion rates
- Only 4 of 38 Guideline recommendations were reported by more than 5% of respondents to have been changed in response to the Guidelines

- a perceived lack of evidence
- a lack of awareness of the guidelines
- logistic issues related to the blood supply
- institutional dogma/policies that are based on economic considerations

Serdar Gunaydin MD, PhD has been granted a PBM course certificate by Eurasian Heart Foundation, 2008
Serdar Gunaydin, MD, PhD has been granted a certificate of Instructor for PBM courses by Eurasian Heart Foundation, 2011
The implementation of a multidisciplinary patient blood management (PBM) program may contribute to a reduction in transfusion requirements, a decrease in health costs and an improvement in patient outcomes.

We compared two different time intervals under different strategies of blood management in a tertiary cardiac unit.

**Background**

- **FOUNDATION**
  - 1881 BEDS
  - 1140 DISCIPLINES
  - 38 STAFF
  - 4215 OUTPATIENT/YEAR
  - 1,768,649 OPERATION/YEAR
  - 55,469 TOTAL RBC UNIT/YEAR

**CARDIOVASCULAR SURGERY**

<table>
<thead>
<tr>
<th></th>
<th>A-C GROUP OP (n)</th>
<th>D-E GROUP OP (n)</th>
<th>OUTPATIENTS (n)</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>857</td>
<td>461</td>
<td>34,445</td>
<td>1318</td>
</tr>
</tbody>
</table>

**Methods**

- This retrospective cohort study included high-risk patients (Euroscore II >5) undergoing cardiac surgery with cardiopulmonary bypass under different PBM strategies during the period from January 2012 until December 2018.
- Patients were matched for age, gender, BMI and STS score:
Building a PBM Program

**Numune Training & Research Hospital - Ankara**

**Team**
- Cardiovascular Surgeon
- Anesthesiologist
- Perfusionist
- Nurse (ICU/Ward)
- Hematologist
- Blood Bank
- Hemovigilance Team
- Hospital Technologies Assessment Team

**2016**
- Education
- Transfusion Log
- IV Limitation
- Revision & Adaptation of Current Guidelines
- Treatment of Anemia
  - Iron carboxymaltose

**Minimally Invasive Surgery**
- Tranexamic Acid
- DDAVP
- Cerebral/Somatic Oximetry
- Design of ECC Circuitry (Integrated Filter)
- Customized Minimally Invasive ECC
- Cardioplegia
- RAP
- VAVD
- Ultrafiltration
- HemoStep
BUILDING A PBM PROGRAM
NUMUNE TRAINING & RESEARCH HOSPITAL-
ANKARA
POSTOPERATIVE

- Transfusion Log
- IV Limitation
- Fibrinogen Concentrate

Preoperative Iron Supplementation for
High-Risk Cardiac Surgery

- 495 patients
- IV Iron- Two subsequent doses in 5-7 days
- IV Iron- Characteristics
- Administration

IMPACT OF FIBRINOGEN CONCENTRATE IN
AN ESTABLISHED PBM PROTOCOL FOR
CARDIOVASCULAR SURGERY

- Ethics approval (2018-March)
- Haemocomplettan FL
- Perioperative follow-up by ROTEM
  and serum fibrinogen levels
- Comparison of a well established
  PBM program versus PBM +
  Fibrinogen Concentrate
- N=198 patients (December 2018)
Cerebral + Somatic Oximetry As Part Of A PBM Program In Cardiovascular Surgery

Impact of Minimally Invasive Surgery vs Conventional for Blood Conservation

RESULTS

<table>
<thead>
<tr>
<th>CARDIOVASCULAR SURGERY CASELOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-C GROUP (n)</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>2015</td>
</tr>
<tr>
<td>2016</td>
</tr>
<tr>
<td>2017</td>
</tr>
<tr>
<td>2018</td>
</tr>
</tbody>
</table>
PBM PROGRAM STARTED IN 2016

CARDIOVASCULAR SURGERY
Decrease in Tx (vs 2015)

<table>
<thead>
<tr>
<th></th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENERAL (%)</td>
<td>2.80</td>
<td>55</td>
</tr>
<tr>
<td>/A-C GROUP OP (%)</td>
<td>31</td>
<td>65</td>
</tr>
</tbody>
</table>

COST-EFFICIENCY (TL)

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENDORSEMENT (TL)</td>
<td>8,168,714</td>
<td>8,576,899</td>
<td>11,245,248</td>
</tr>
<tr>
<td>INVOICE (TL)</td>
<td>9,002,283</td>
<td>9,570,028</td>
<td>13,588,902</td>
</tr>
<tr>
<td>DISPOSABLES</td>
<td>5,202,018</td>
<td>4,697,240</td>
<td>4,355,299</td>
</tr>
</tbody>
</table>

-219,734 TL
5.06%
42 CABGX3
Total RBC: 34881 Units
**BLOOD BANK**

<table>
<thead>
<tr>
<th></th>
<th>2017 USED</th>
<th>2017 DESTROYED</th>
<th>2018 (6 MONTHS) USED</th>
<th>2018 (6 MONTHS) DESTROYED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RBC</strong></td>
<td>13805</td>
<td>329</td>
<td>9527</td>
<td>188</td>
</tr>
<tr>
<td><strong>PLT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RANDOM</td>
<td>2476</td>
<td>99</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>POOLED</td>
<td>1901</td>
<td>43</td>
<td>1720</td>
<td>99</td>
</tr>
<tr>
<td><strong>FFP</strong></td>
<td>12964</td>
<td>330</td>
<td>7768</td>
<td>192</td>
</tr>
<tr>
<td>PLT APHERESIS</td>
<td>816</td>
<td>21</td>
<td>316</td>
<td>7</td>
</tr>
<tr>
<td>WHOLE BLOOD</td>
<td>17</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CRYOPRECIPITATE</td>
<td>233</td>
<td>-</td>
<td>425</td>
<td>5</td>
</tr>
</tbody>
</table>

**Preservation:**
- RBC: 42 days
- PLT: 5 days
- FFP: 2 years
- Apheresis PLT: 5 days

DESTROYED RBC: 71,393 TL
DESTROYED FFP: 22,770 TL
TOTAL: 94,163 TL (16 CABGX3)

**BLOOD BANK - DESTRUCTION REASONS**

<table>
<thead>
<tr>
<th></th>
<th>RBC</th>
<th>PLT</th>
<th>FFP</th>
<th>Apheresis PLT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expiration (%)</td>
<td>94.15</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Return after melting (%)</td>
<td>32.29</td>
<td>5.85</td>
<td>67.71</td>
<td>0</td>
</tr>
<tr>
<td>Destruction of the package (%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**THE EVOLUTION OF PATIENT BLOOD MANAGEMENT PROGRAMS IN AORTIC VALVE SURGERY: WHAT IS THE ULTIMATE FRONTIER?**

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV Fluid Restriction</td>
<td>+</td>
</tr>
<tr>
<td>Transfused Blood</td>
<td>+</td>
</tr>
<tr>
<td>Revision &amp; Adaptation of PBM Guidelines</td>
<td>+</td>
</tr>
<tr>
<td>Extracorporeal Circulation</td>
<td>-</td>
</tr>
<tr>
<td>Utilization of Salvaged Blood</td>
<td>-</td>
</tr>
<tr>
<td>Single Dose Cardioplegia</td>
<td>-</td>
</tr>
<tr>
<td>Minimally Invasive Surgery</td>
<td>-</td>
</tr>
<tr>
<td>Transfusion IV Iron Supplementation</td>
<td>-</td>
</tr>
<tr>
<td>Autologous Transfusion</td>
<td>+</td>
</tr>
</tbody>
</table>

**NEXT TARGET FOR PBM**

Ankara City Hospital Campus

3804 hospital beds, 735 outpatient units, 128 OR
**Results**

- Stepwise multiple logistic regression analysis demonstrated
  - minimally invasive surgery (OR: 4.1)
  - minimally invasive extracorporeal circuitry (OR: 3.8)
  - utilization of salvaged blood (OR: 2.8)
    - pharmacologic interventions (iron, fibrinogen) (OR: 2.1)

  as leading independent predictors of the reduction in transfusion
- Cost analysis demonstrated 15.7% decrease in Group 2 with respect to Group 1 (p=0.022)

**EPILOGUE**

- The creation of the term patient blood management reflects a paradigm shift from blood transfusion to blood management policies that incorporate multimodal blood conservation strategies
- Surgeon should absolutely be the most motivated figure in the team
- RBC/FFP?
- Cardiovascular Surgery/Other Disciplines?
- Researchers, professional societies, funding agencies, and industrial partners should focus their attention on verification of these techniques
- With the support of a more solid evidence base, future management guidelines can not only be adapted to reflect new insights into optimal patient management but also universally adopted into clinical practice

**Thanks!!**

S Gunaydin, MD, PhD
gunaydin@isnet.net.tr
Protamine

- Gold standard for heparin reversal following CPB.
- An electrostatic bond between the positively charged protamine molecules and the negatively charged heparin molecules.
- This heparin-protamine interaction can be associated with a substantial decrease in patient systemic blood pressure, increased pulmonary artery pressure, and an overall decrease in systemic vascular resistance.
- May result in decreased cardiac output and risk of post-cardiotomy decompensation.
- Therefore, a “test dose” is routinely administered to examine a patient’s hemodynamic response to protamine prior to full heparin reversal.

Protamine

- Can be a perfusionists enemy!
- Surgeons insist to keep pump suction on until the last minute to “save blood”.
  - As a “safety” back up
  - Despite cell saver availability

When do you turn off your CPB suckers?

a) Before protamine test dose (PTD)
b) After PTD
c) ¼ protamine in
d) ½ protamine in
Background

<table>
<thead>
<tr>
<th>Procedure</th>
<th>CPB Time</th>
<th>Heparin LD</th>
<th>Additional Heparin</th>
<th>Last ACT on CPB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redo Sternotomy, AVR, TV Repair, MV Repair, PFO Closure (May 3/18)</td>
<td>3h, 12m</td>
<td>30,000u</td>
<td>10,000u</td>
<td>953s</td>
</tr>
<tr>
<td>MVR (June 20/18)</td>
<td>(1) 1h, 42m (2) 44m</td>
<td>80,000u</td>
<td>35,000u</td>
<td>498s</td>
</tr>
<tr>
<td>AVR (July 5/18)</td>
<td>2h, 16m</td>
<td>35,000u</td>
<td>15,000u</td>
<td>542s</td>
</tr>
</tbody>
</table>

Additional Info:
- Clot visualized, transfusion to patient stopped.
- Pump suckers still in use.
- Pump volume transfused to patient.

Clot Location:
- Reservoir Sock
- Oxygenator Outlet
- Reservoir Sock

Emergency pump brought in – patient very unstable.
- Surgeon and anesthetist able to gain control (generalized surgical bleeding).
- Once stable, clotted circuit flushed to cell saver.

Study Purpose

- Evaluate patient ACT following a “test dose” of protamine
- Determine feasibility of reinitiating CPB after PTD administration
Study Design

- Prospective study – 120 CPB patients at TGH
- Data collection July to Nov 2018

Study Design

- Wide variety of medical staff participation

<table>
<thead>
<tr>
<th>Medical Personnel</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeons</td>
<td>13</td>
</tr>
<tr>
<td>Anesthetists</td>
<td>34</td>
</tr>
<tr>
<td>Perfusionists</td>
<td>20</td>
</tr>
</tbody>
</table>

**Case Type**

<table>
<thead>
<tr>
<th>Case Type</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ACB</td>
<td>48</td>
</tr>
<tr>
<td>Aortic Dissection</td>
<td>1</td>
</tr>
<tr>
<td>AVR</td>
<td>17</td>
</tr>
<tr>
<td>Valve + ACB</td>
<td>10</td>
</tr>
<tr>
<td>Bentall</td>
<td>5</td>
</tr>
<tr>
<td>Heart Transplant</td>
<td>2</td>
</tr>
<tr>
<td>Hemarch/Valve Sparing Root</td>
<td>4</td>
</tr>
<tr>
<td>MVR</td>
<td>9</td>
</tr>
<tr>
<td>Myectomy</td>
<td>3</td>
</tr>
<tr>
<td>&gt;1 Valve</td>
<td>8</td>
</tr>
<tr>
<td>PTE</td>
<td>5</td>
</tr>
<tr>
<td>Redo Congenital</td>
<td>7</td>
</tr>
<tr>
<td>Redo Valve(s)</td>
<td>1</td>
</tr>
</tbody>
</table>

**Heparin Management on CPB**

- Standard heparin dosage 4 mg/kg (400IU/kg)
- ACT maintained > 480 seconds
- 75% of cases re-dosed heparin on CPB
Last ACT on CPB

- 650±155 sec
- 6 cases reported ACT < 480s before termination

Percentage of Full Protamine Dose

- Mean protamine test dose = 36±21 mg (4-200 mg)
- Mean percentage of full dose = 11±7%

What would you predict the ACT would decrease by following a 10% protamine test dose?

ACT Drop Post Protamine Test Dose

- Mean: 40±25%

6 positive differentials (3-31% increase)
- May be due to inappropriately timed ACT samples
ACT Post Protamine Test Dose

- Last ACT on CPB (650±155 s)
- ACT post PTD (376±153 s) p<0.05
- 81% ACTs < 480 s
- 54% ACT< 400 s and unsuitable for CPB re-initiation (104-392s)

ACT Decrease vs. % Protamine Test Dose

- Majority of protamine test doses fall between 4-18% of full dosage
- Drop in ACT was unpredictable regardless of the dose

Limitations/Considerations

- Varying time between last ACT on CPB
  - Some patients required additional heparin dosing after last recorded ACT
- Varying time between giving PTD and drawing ACT
- Varying PTD (anesthesia discretion)

Conclusions

- Despite institutional standardization for PTD there is a large variation amongst Anesthetists
- No reliable way to predict how patient ACTs will respond to PTD
- Circuit integrity at risk if using pump suckers during and post PTD
  - Despite circulating post CPB volume, flushing circuit to patient
Actions

- Recommended that the pump suckers to be discontinued before any amount of protamine is administered to the patient.
  - Raised awareness amongst cardiac team members regarding CPB circuit integrity
  - No further incidences of CPB clotting
Does Standardizing Extracorporeal Circuit Design for Cardiopulmonary Bypass Affect Outcomes?
Results from a National Perfusion Registry
Al Stammers, Linda Mongero
Eric Tesdahl, Tom Coley

Variability Reduction in Healthcare

- Pricing pressures influence most (all) healthcare decisions
- Providers achieve better efficiencies through standardization
- Variation reduction results in a streamlined approach to delivery

AmSECT Standards and Guidelines

Extracorporeal Circuitry
Extracorporeal Circuitry

- Numerous iterations of ECC configs.
- Complexity increases with new designs
- Little standardization exists
- Challenging for perfusion coverage
- Difficult supply chain management
- Custom tubing packs are expensive

Objectives

Hypothesis
Standardization of extracorporeal circuitry across multiple hospitals will result in improved outcomes.

Process
- Established work-group to review pack use across national hospitals
- 31 circuit factors were analyzed (pump type, coatings, safety,…)
- Survey sent to end-users as a needs assessment
- Circuit schematics created and shared with manufacturers
- Non-sterile circuits created and reviewed by end-users

Pack Enhancement Project

Methods

- Switch to oxygenators with integrated arterial filter
- Observational study using prospectively collected data
- Non-randomized
- Analysis of data from a national registry (SCOPE)
- Adult patients (>18-years) non-reoperative CABG
- 91 hospitals from January 2017 –December 2018
- IRB approved

Disclosure: None

Methods

Groups
- Pre-standardization change (Pre-CH) v. Post-standardization change (Pst-CH)
  - Study inclusion - minimum of 50 CPB procedures post-change
  - Data collection - buffer period of 2-weeks on either side of change

Primary End-Point
- Circuit prime volume

Secondary End-Points
- RBC transfusion, Hemodilution, HCT drift

Reversion group – initially made the pack change but reverted back
Statistics

Group Differences
- Chi-squared tests, Welch's anova
- Mixed effect binary logistic regression

Regression Analysis – Mixed Effects
- Individual level patient factors (age, gender, CBV, diabetes, HCT, …)
- Procedure based factors (procedure acuity, surgeon, hospital)
- Intraoperative management (AP, CPB volume, crystalloid cardioplegia volume, total urine output, anesthesia volume, ultrafiltration volume, CPB time)
- Hospital level actors (procedure volume, transfusion triggers)

Results

Initial review: 91 hospitals with 47 unique packs
Study size: 74 hospitals
Final pack number: 8 for a 83% reduction in circuits
Hospitals > 50 procedures: n=34
Procedure Count: Pre-CH n=5,746 Pst-CH n=5,702

Concurrent Analysis
Hospitals: 101 Procedures: 50,135
Pre-CH n=24,045 Pst-CH n=26,090

Results

Demographic Data for all Patients

<table>
<thead>
<tr>
<th></th>
<th>Pre-CH 5,746</th>
<th>Pst-CH 5,702</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender = Male (%)</td>
<td>4,034 (70.2)</td>
<td>4,132 (72.5)</td>
<td>0.008</td>
</tr>
<tr>
<td>Age (mean (sd))</td>
<td>65.1 (11.4)</td>
<td>64.8 (11.8)</td>
<td>0.155</td>
</tr>
<tr>
<td>Height cm (mean (sd))</td>
<td>172.0 (10.3)</td>
<td>172.3 (11.1)</td>
<td>0.100</td>
</tr>
<tr>
<td>Weight kg (mean (sd))</td>
<td>89.6 (20.1)</td>
<td>90.3 (21.0)</td>
<td>0.065</td>
</tr>
<tr>
<td>BSA (mean (sd))</td>
<td>2.02 (0.24)</td>
<td>2.03 (0.25)</td>
<td>0.049</td>
</tr>
<tr>
<td>Nadler TBV (mean (sd))</td>
<td>5.26 (0.95)</td>
<td>5.30 (0.98)</td>
<td>0.013</td>
</tr>
</tbody>
</table>

Results

Procedure Types

<table>
<thead>
<tr>
<th>Procedure Type (%)</th>
<th>Pre-CH 5,746</th>
<th>Pst-CH 5,702</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic Surgery</td>
<td>122 (2.1)</td>
<td>146 (2.6)</td>
<td>0.007</td>
</tr>
<tr>
<td>AV Surgery + CABG</td>
<td>373 (6.5)</td>
<td>420 (7.4)</td>
<td></td>
</tr>
<tr>
<td>CABG Reoperation</td>
<td>59 (1.0)</td>
<td>58 (1.0)</td>
<td></td>
</tr>
<tr>
<td>Combined AV/MV</td>
<td>74 (1.3)</td>
<td>57 (1.0)</td>
<td></td>
</tr>
<tr>
<td>Combined AV + MV</td>
<td>541 (9.4)</td>
<td>523 (9.2)</td>
<td></td>
</tr>
<tr>
<td>Combined CABG</td>
<td>2,097 (45.1)</td>
<td>3,578 (65.8)</td>
<td></td>
</tr>
<tr>
<td>Combined CABG + MV</td>
<td>301 (5.2)</td>
<td>227 (4.0)</td>
<td></td>
</tr>
<tr>
<td>MV Surgery + CABG</td>
<td>129 (2.2)</td>
<td>112 (2.0)</td>
<td></td>
</tr>
<tr>
<td>Other (count %)</td>
<td>405 (7.1)</td>
<td>425 (7.3)</td>
<td></td>
</tr>
</tbody>
</table>
**Results**

**Mean Change in Net Prime Volume**

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-CH</th>
<th>CH</th>
<th>Post-CH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reversion Group</td>
<td>2.100</td>
<td>1.951</td>
<td>1.422</td>
</tr>
</tbody>
</table>

**Results**

**Mean Change in Hematocrit Drift (1st OR – Low CPB)**

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-CH</th>
<th>CH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reversion Group</td>
<td>0.59</td>
<td>0.05</td>
</tr>
</tbody>
</table>

**Results**

**Mean Change in Intraoperative RBC U**

<table>
<thead>
<tr>
<th>Group</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reversion Group</td>
<td>0.001</td>
</tr>
</tbody>
</table>

**Results**

**Mean Change in Net Prime Volume**

<table>
<thead>
<tr>
<th>Group</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reversion Group</td>
<td>0.001</td>
</tr>
</tbody>
</table>
Results

Mean Change in Hematocrit Drift (1st OR – Low CPB)

Reversion Group
N=6

<table>
<thead>
<tr>
<th>Group</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-CH</td>
<td>2,100</td>
</tr>
<tr>
<td>CH</td>
<td>1,951</td>
</tr>
<tr>
<td>Post-CH</td>
<td>1,422</td>
</tr>
</tbody>
</table>

P=0.299

Results

Mean Change in Intraoperative RBC Utilization

Reversion Group
N=6

<table>
<thead>
<tr>
<th>Group</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-CH</td>
<td>2,100</td>
</tr>
<tr>
<td>CH</td>
<td>1,951</td>
</tr>
<tr>
<td>Post-CH</td>
<td>1,422</td>
</tr>
</tbody>
</table>

P=0.037

Limitations

- Analysis of data from an national registry with prospective data without randomization
- Techniques for blood conservation measures were not standardized across centers
- Not a longitudinal study so lacks clinical outcomes
- Transfusion protocols non-standardized

Conclusions

The differences seen in net prime volume and hematocrit drift occurred across the time period of the study in concurrent group

There was a significant reduction intraoperative red blood cell transfusion

The pack enhancement project results in a reduction in the number of packs by over 80%, which improves supply chain processes, and results in minor benefits in patient care.
Thank You

On behalf of all the authors we extend a special thanks to all the perfusion associates at SpecialtyCare who contribute daily to SCOPE and improving outcomes for our patients.
Identifying Occupational Hazards in Clinical Perfusion Practice

A Mixed Methods Study

Joy McLemore Stewart MS CCP, Joseph J. Sistino PhD CCP FPP
Gary Grist RN CCP Emeritus, Brad A. Winn CCT CCP LP,
Nicky L. Pipkin MD FACS FCCP

No Disclosures

Introduction

Occupational Hazards
- risks that are recognized as a consequence of a certain vocation
  - OSHA sites hospitals as one of the most hazardous places to work
  - This ranking was derived from the number of injuries and illnesses requiring days off

Disability
- inability to perform a "substantial amount of work" due to mental or physical impairment
  - Work is “substantial” if it involves doing significant physical or mental activities or a combination of both.

Purpose

• Define the scope of occupational hazards specific to perfusion practice
• Describe working conditions for perfusionists working with disabilities
• Propose solutions to reduce the occurrence of perfusion-related hazards
Methods

- Following IRB approval
- Qualitative structured questionnaire was sent to five perfusionists of various demographic backgrounds to aid in the development of the final occupational hazards survey.
- 23-question survey was developed and disseminated to perfusionists to provide feedback on perfusion-related occupational hazards in the profession.
- Demographics, practice size and area, caseload, prior perfusion-related injuries sustained, and level of stress using a Likert scale.
- Open-ended questions to provide participants with opportunities to share their thoughts, suggestions, and experiences.

Number of Respondents

N= 254
ABCP 4,234 (2017 annual report)

Low response rate of approximately 6% may bias the results.
Still important to note the survey raises many areas of concern.

Female (103, 43.5%)  Male (134, 56.5%)
Have you sustained an injury or illness because of an occupational hazard in the hospital environment in the past 5 years (Needle sticks, flu exposure, etc.)?

Yes 26.5%

Have you had or will have any surgical repairs for physical injuries caused by your work as a perfusionist?

Yes 12.2%
Do you believe you have experienced back pain resulting from your perfusion duties?

- Neck pain 28.7%
- Lower back pain 52.5%
- Mid-back pain 16.0%
- Upper back pain 13.1%
- Hip injury 4.5%

81.5% of perfusionists experienced back pain

Have you ever had to work while you felt physically impaired (due to injury or pregnancy)?

- Yes 51.6%

Comments:

Pregnancy:
- I've worked through two pregnancies, which is where the back pain really shines through.
- I am often put in situations with no coverage, and work through the pain or exhaustion. I was once diagnosed with pneumonia while pregnant and admitted to the hospital while I was pumping a case.
- I had to work during my pregnancy till the day I was admitted to the hospital.
- On call at almost full term, difficult case, only perfusionist available in the weekend.
- Worked until 39 weeks in two pregnancies. Currently employed as the only fulltime CCP at a center doing 300 hearts and 100 TAVRs/year.

Comments

Pregnancy:
- Being a pregnant perfusionist brings up a number of hazards - increased by working alone and being on call. I’m appalled by management reactions to simple needs such as bathroom breaks. Unless you have great coworkers it’s near impossible.
- Pumped pregnant with twins - avg 54 hours/wk w minimum breaks. Nursed one year with inadequate breaks to pump
- Have vomited in trash can when sick. When pregnant had to work even with threatening premature labor prior to being out on 3 months bedrest
- I worked right up until I delivered both my children... it was difficult bc no bathroom breaks
Comments

Pregnancy:
- Pumped 2 cases while in labor!
- While pregnant it was difficult to not use the restroom during long cases.
- I had to work alone during both pregnancies, and was a solo perfusionist at a 280 a year program while my partner was out of town.
- I worked during pregnancy and had premature contractions due to not eating/drinking because when on call you can’t get a break.
- Severe menstrual cramps, heavy menstrual bleeding. In all these instances, I had no other recourse but to finish out the case, then deal with the discomfort, pain, or menstrual bloodstained pants and chair after my duties.

Working while sick:
- We have no relief to call off. Must work sick or cancel cases.
- We work sick all the time as we don’t have anyone to cover unless you hospitalized you work.
- Had to pump several cases while sick with the flu and throwing up. Anesthesia placed an IV in my arm for fluids so I could finish the case.
- Severe lower back pain which limited my flexibility and ability to focus mentally.
- Cancer, short staffed.
- I had cancer and was undergoing chemo therapy but I wanted to work when I could. It was my choice.

Working after surgery:
- Worked day after knee surgery, passed kidney stone during surgery because no relief was available.
- There are no sick days. After my knee surgery for ACL repair I came back too soon and suffered a longer recovery.
- Post surgery, could have had 6 weeks off, back in 2 days.
- I was actually fired from a small contact group because I took time off for surgery.

Hazards
- Broke my foot during an emergency aortic root repair because someone put a stretcher outside the operating room door that I opened to get something from outside the room.
- Hit head on monitor. Knocked out cold for a few minutes. Worked with concussion.
- Concussion from hitting head on monitor.
Comments

- Part of being a perfusionist sometimes involves long hours, sometimes not sleeping due to overnight emergencies. It all comes with the responsibility of being a perfusionist and part of an open heart team
- There are none. Get over it and do your job or get out!

How often have you experienced burnout from your responsibilities as a perfusionist?

Burnout was defined as emotional exhaustion, depersonalization, and reduced feelings of work-related personal accomplishment

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than once in week</td>
<td>5.1%</td>
</tr>
<tr>
<td>More than once in month</td>
<td>10.6%</td>
</tr>
<tr>
<td>More than once in six months</td>
<td>13.0%</td>
</tr>
<tr>
<td>More than once in a year</td>
<td>8.3%</td>
</tr>
<tr>
<td>Once a week</td>
<td>4.3%</td>
</tr>
<tr>
<td>Once a month</td>
<td>5.9%</td>
</tr>
<tr>
<td>Once in six months</td>
<td>9.1%</td>
</tr>
<tr>
<td>Once a year</td>
<td>19.3%</td>
</tr>
</tbody>
</table>

Nearly 75% reported experiencing burnout

Have you experienced any of the following impairments in the past year?

<table>
<thead>
<tr>
<th>Impairment</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>physical illness</td>
<td>13.0%</td>
</tr>
<tr>
<td>mental illness</td>
<td>1.6%</td>
</tr>
<tr>
<td>emotional stress</td>
<td>39.1%</td>
</tr>
<tr>
<td>loss of motor skills</td>
<td>0.4%</td>
</tr>
<tr>
<td>loss of cognitive functioning</td>
<td>2.0%</td>
</tr>
<tr>
<td>drug abuse</td>
<td>0.0%</td>
</tr>
<tr>
<td>alcohol abuse</td>
<td>1.2%</td>
</tr>
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Have you experienced post-traumatic stress disorder at some point in your perfusion career?

(PTSD is a mental health condition that's triggered by a terrifying event - either experiencing it or witnessing it. Symptoms may include flashbacks, nightmares and severe anxiety, as well as uncontrollable thoughts about the event)

Yes 27.2%

Due to the level of stress, I have considered leaving the perfusion profession.

Agree 21.3%, Strongly agree 10.2%

Total = 30.5%

Compared to other medical professions, do you consider the risk of psychological occupational hazards in perfusion to be:

Psychological Stress

When I went for counseling to a psychiatrist, she revealed to me that most of her patient population is because of this one surgeon. She has had nurses travel 90 minutes to work at another hospital to avoid this surgeon. She told me that HE'S the one who needs medication, not the rest of her patients who are on antidepressants because of what we go through.
Suggestions – increase staffing

- AmSECT and ABCP should address more issues like this.
- Maintain staffing levels such that no one needs to do more than 150 cases per year, and especially no more than 16 hours on duty without 12 hours off.
- Adequate staffing to provide relief to perfusionist. Too often we are negligently understaffed and are expected to work indefinitely with no breaks or time off of call duties.
- If hospitals legally had to have an N +1 (number of cases plus 1 perfusionist available) it would give perfusionist a chance to get a break if needed. Sometimes you just need a bathroom break but if something else was to happen you would have another perfusionist available. I believe we should have it even when on call as that is some of the most difficult cases.
- Working with more than one perfusionist on each case always!

Suggestions

- Perhaps a new Dr. Friday with AmSECT.
- Have ergonomics specialists that can evaluate our specific jobs and make suggestions to reduce these hazards.
- Scavenge gases!
- If you encounter an issue with your job concerning a difficult case or poor outcome with resulting stress and/or anxiety, please seek help. Search out another professional to aide you in your recovery.

Thank you to all the participants in this survey

You have enlightened and empowered all of us to make improvements in our profession!
Reducing the Impact of Perfusion Medical Waste on the Environment

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Background…

• The US healthcare system generates over 5 billion pounds of waste each year, and that number is growing (1)
  • 13.7 million pounds per day
• The operating room is the second largest source of hospital waste
• A typical adult perfusion circuit produces approximately 15 pounds of waste per case (2)
  • 15 lbs x 350,000 surgeries = 5.25 million pounds of waste from circuits alone (3)
• No current standards exist for reuse or recycling

No Disclosures
Background and Current Practices:

- Medical Waste in the United States (1):
  - 49-60% incinerated
  - 20-37% autoclaved
  - 4-5% other treatments
  - Not applicable to CPB circuit
- Medical Waste is defined by individual state law
- Controlled-air incineration is the most common form of waste removal (2)
- “Incomplete” incineration releases pollutants including:
  - Acid gases
  - Oxides of nitrogen
  - HCl
  - Other harmful organic compounds
- “Complete” incineration is not financially feasible on a commercial scale

Public Health Impact:

- EPA standards: biohazardous waste must be either incinerated or sterilized before disposal in municipal waste (1)
- Health concerns of incineration:
  - Residual chloride released into atmosphere
  - Majority of chlorine released into the environment is from waste PVC (1)
  - Causes acid rain (2)
  - Release of dioxins
  - Class I carcinogen (3)
  - One of the “deadliest poisons of all”: potassium cyanide has a higher LD50
  - Skin diseases, hepatic damage, hormonal disruption
  - Vinyl Chloride (monomer made of chlorinated hydrocarbons) releases CO2, CO, hydrogen chloride, and phosgene (4)
  - Raynaud’s, joint pain

- Perfusion specific:
  - 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)
  - Released with synthesis and combustion of PVC (incomplete combustion of fossil fuels) (1)
  - Studies have shown:
    - Changes in kidney, heart, aorta endothelium
    - Cell dysfunction
    - Hypertension, stroke, coronary artery disease (2)
Well, that’s depressing…

So, what can we do?

- Cleaner Incineration
- Landfilling
- Reuse
- Recycling

Cleaner Incineration:
- How do we eliminate the release of dioxins?
- Dechlorination of PVC before incineration
  - Lessens health risks of dioxins in the atmosphere
  - Does not solve ultimate waste problem, but does reduce impact on the planet
- New incineration methods:
  - Addition of NaOH (1)
  - Addition of lignocellulose (2)
**Not yet commercially feasible, but currently being researched in other industries

Landfilling:
- Medical waste can be decontaminated and buried (1)
  - Diminishing land availability
  - Increased number of landfills is a temporary fix
  - Slow decomposition
- Process:
  - Waste decontaminated
  - Crushed down and heated (further decontamination)
  - Sent to landfill
  - Up to 80% reduction in volume (2)

Reusing:
- Not often discussed in the USA perfusion community
  - Could have significant role in reduction of environmental impact of single use items
- International influence
  - Korea: prevention and minimization first (1)
  - Countries with limited resources: full circuit is rinsed and reused (2)
  - Exception: oxygenator and filters
- Hard for perfusion
  - Minimization is not necessarily possible
  - Government agencies
  - Public perception

Reusing:

- Can we reuse?
  - **REMEDY** 2006-2019
    - Recovered Medical Equipment for the Developing World
    - Cannulas, cautery pens, pacing wires, aortic punches
    - Guidelines for training and handling

- Sustainability is not intended outcome, but shows an alternative to "single use"

- Further research needed

Recycling:

- Desired end-of-life outcome for plastics
  - Difficult with high chlorine content, hazardous additives

- Most PVC products (other industries) have useful lifespan of 30-50 years
  - Gained mainstream usage in 1970’s
  - Volume of waste expected to increase greatly in near future

Recycling:

- Two practices:
  - Mechanical recycling
    - Ground into granules
    - Heated to liquid form, remolded into new product
    - No chemical reaction
    - Used with large quantities of similar post-industrial waste
  - Feedstock recycling
    - Heated past melting point
    - Virgin chemical components extracted
    - Raw materials can be used for any new PVC product
    - High costs, low investment return, limited incentive

Future of Recycling:

- New dechlorination and additives scavenging methods
  - China (2018)
    - Near-critical methanol
      - Dechlorinates and recovers additives simultaneously
      - Plasticizer, stabilizer, lubricant
      - Production of new PVC

- Ideal world? Or just the future?
  - CPB circuit taken from OR post operation
  - Sent to facility for sanitation, dechlorination, scavenging
  - Molecular parts used to create new products
  - Medical, cable, construction, flooring industries

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Conclusions:

- PVC in CPB circuits contributes to negative environmental impact
- Responsibility to find new methods of disposal
- Right now:
  - Properly sort waste
  - Other considerations for “single use” equipment
- Long term:
  - Be aware of new research and opportunities
  - Follow lead of other PVC industries
  - Be a part of the conversation