Blood and Blood Product Conservation: Results of Strategies to improve clinical outcomes in Open Heart Surgery Patients at a Tertiary Hospital

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Financial Disclosure

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Junaid Khan MD

- Director of CV Service Alta Bates Summit Medical Center
- Managing Partner of East Bay Cardiac Surgery
- Assistant Professor of Surgery, UCSF
- President California Society of Thoracic Surgeons

Alta bates Summit Medical Center

- Tertiary Center
- 3 Cardiothoracic Surgeons
- Average 400 Hearts per year
- Performing Open, MICS, and TAVR
- Average 2800 Heart Catheterizations
- Diverse patient populations
Why is focusing blood conservation important

- Currently a CMS Quality Measure for Cardiac Programs
- Blood transfusions are linked with increased morbidity and mortality of patients 1,2,3
- Deleterious effects of blood transfusions increase on a per unit basis 3,4
- It is only a matter of time until blood product usage at programs are publicly reportable
- Reimbursement will eventually be tied to quality measures

STS Guidelines 2011 - Multimodal approach

- **Heparin Management.** For patients requiring longer CPB times (> 2 to 3 hours), it is not unreasonable to consider maintenance of higher or patient-specific heparin concentrations during CPB to reduce hemostatic system activation, reduce consumption of platelets and coagulation proteins, and reduce blood transfusion. (Level of evidence B)

- **Protamine Dosing.** It is not unreasonable to use either protamine titration or empiric low-dose regimens (eg, 50% of total heparin dose) to lower the total protamine dose and lower the protamine-to-heparin ratio at the end of CPB to reduce bleeding and blood transfusion requirements. (Level of evidence B)

- **Bypass circuits.** Heparin-coated bypass circuits (either the oxygenator alone or the entire circuit) are not unreasonable for blood conservation in cardiac operations. (Level of evidence B)

- **Prime Volume.** It is not unreasonable to use low prime and minimized extracorporeal bypass circuits to reduce the fall in hematocrit during CPB as part of a multimodality blood conservation program. (Level of evidence B)

*Can ABSMC implement a multimodal strategy to reduce and track the impact on blood utilization?*

Study Design

- Retrospective chart review of 718 patients over 27 months
- 10 month reference period
- Stepped implementation of two technology upgrades over 17 months
- Comparison made using STS database and electronic medical record for demographics, labs, and blood product usage.
- Analysis of pre/post implementation of both technology upgrades directly on blood product usage and indirectly on ICU time and LOS
- Endpoints: Determine if optimization of CPB circuit and implementation of HMS impact intraoperative PRBC, platelet, cryo, FFP, ICU, LOS
Changes Made to Intraoperative Equipment at Alta Bates Summit Medical Center in Oakland, CA

- No transfusion triggers were changed
- No surgical staff changes
- No new perfusion techniques such as RAP were implemented
- Cortiva® (formerly Carmeda®) coating was maintained
- Oxygenator upgrade to the Integrated Affinity Fusion™ Oxygenation System
- Centrifugal pump head upgraded to Affinity CP™
- Hemostasis Management System (HMS™) implemented for all heparin and protamine dosing
Implementation Timeline

Reference Period


Oxygenator Implementation

Phase in

Complete Conversion

HMS Implementation
Blood Utilization: Intraoperative Changes

- Reduction in Prime Volume (362ml)
  - ½ to 3/8 venous line conversion (100 ml savings)
  - Integration of arterial filter (222 ml savings filter and oxy)

- New smaller centrifugal pump head (40ml savings)
Blood Utilization: Intraoperative Changes

- Reduction in Contact activation and blood trauma
  - Cortiva (formerly Carmeda) coated circuit
  - Blood flow path through oxygenator 3cm
- Less traumatic centrifugal pump head
Illustration of innovations with new CBP upgrades

Curved Venous Inlet

Radial Flow Path (3cm)

Image captured using contrast under fluoroscopy
Blood Utilization: Intraoperative Changes

- HMS for heparin/Protamine dosing in addition to real time heparin monitoring
## Demographics

<table>
<thead>
<tr>
<th></th>
<th>White</th>
<th>Black</th>
<th>Asian</th>
<th>Hawaiian / Pac Islanders</th>
<th>Ave Age</th>
<th>% Female</th>
<th>BMI</th>
<th>% On Dialysis</th>
<th>Ave Pre-Op Hb</th>
<th>Ave Pre-Op HCT</th>
<th>% Pre-Op INR &gt; 1.2</th>
<th>Ave Pre-Op Creatinine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
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<tr>
<td>(1/1/14 – 7/31/15)</td>
<td>41.98%</td>
<td>18.27%</td>
<td>18.77%</td>
<td>2.22%</td>
<td>64</td>
<td>32.4%</td>
<td>28.2</td>
<td>4.2%</td>
<td>12.9</td>
<td>37.9</td>
<td>10.4%</td>
<td>1.27</td>
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<tr>
<td><strong>Oxygenator Upgrade</strong></td>
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<tr>
<td>(8/1/15 – 1/31/16)</td>
<td>44.33%</td>
<td>18.56%</td>
<td>19.59%</td>
<td>1.03%</td>
<td>65</td>
<td>29.9%</td>
<td>28.2</td>
<td>11.4%</td>
<td>12.5</td>
<td>37.2</td>
<td>15.5%</td>
<td>1.72*</td>
</tr>
<tr>
<td><strong>Oxy and HMS Upgrade</strong></td>
<td></td>
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<tr>
<td>(2/1/16 – 12/31/16)</td>
<td>39.35%</td>
<td>16.20%</td>
<td>22.69%</td>
<td>1.39%</td>
<td>65</td>
<td>31.9%</td>
<td>27.5</td>
<td>4.6%</td>
<td>12.8</td>
<td>37.5</td>
<td>13.4%</td>
<td>1.42</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
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<tr>
<td>(1/1/14 – 12/31/16)</td>
<td>41.50%</td>
<td>17.69%</td>
<td>20.06%</td>
<td>1.81%</td>
<td>65</td>
<td>31.9%</td>
<td>28.0</td>
<td>5.3%</td>
<td>12.8</td>
<td>37.7</td>
<td>12.0%</td>
<td>1.38</td>
</tr>
</tbody>
</table>

*p=0.0096, elevated creatinine as to be expected with higher percentage of patients on Dialysis.
## Comorbidities – End Stage Renal Disease

<table>
<thead>
<tr>
<th></th>
<th>Patient Not on Dialysis</th>
<th>Patient on Dialysis</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave preop Hb</td>
<td>12.9 ± 2.2</td>
<td>10.7 ± 1.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Ave preop HCT</td>
<td>38.3 ± 5.4</td>
<td>32.6 ± 5.1</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Ave preop Creatinine</td>
<td>1.0 ± 0.6</td>
<td>7.1 ± 3.2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>% INR&gt;1.2</td>
<td>10.58%</td>
<td>21.05%</td>
<td></td>
</tr>
<tr>
<td>Ave IntraOp PRBC Units</td>
<td>0.37 ± 1.25</td>
<td>0.89 ± 0.99</td>
<td>0.001</td>
</tr>
<tr>
<td>Ave Total PRBC Units</td>
<td>1.91 ± 2.55</td>
<td>3.82 ± 2.62</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Ave IntraOp Platelets</td>
<td>0.74 ± 1.15</td>
<td>1.63 ± 1.51</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Ave OHS Hrs</td>
<td>3.5 ± 1.5</td>
<td>4.0 ± 1.8</td>
<td>0.029</td>
</tr>
<tr>
<td>Ave ICU Hrs</td>
<td>60.7 ± 50.6</td>
<td>89.6 ± 71.6</td>
<td>0.001</td>
</tr>
<tr>
<td>Ave Cost Ratio</td>
<td>1.0 ± 0.3</td>
<td>1.46 ± 0.7</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

% of OHS Patients on Dialysis

![Graph showing % of OHS Patients on Dialysis](image)
# Comorbidities – Overweight and Obese

<table>
<thead>
<tr>
<th>BMI</th>
<th>Normal BMI</th>
<th>Overweight</th>
<th>Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Count</td>
<td>258</td>
<td>228</td>
<td>232</td>
</tr>
<tr>
<td>Ave BMI</td>
<td>22.3 ± 1.9</td>
<td>27.2 ± 1.5</td>
<td>35.0 ± 4.7</td>
</tr>
<tr>
<td>Ave pre-op Hb</td>
<td>12.5 ± 2.0</td>
<td>12.8 ± 1.9</td>
<td>13.0 ± 2.6</td>
</tr>
<tr>
<td>Ave pre-op HCT</td>
<td>37.1 ± 5.5</td>
<td>37.7 ± 5.6</td>
<td>38.3 ± 6.0</td>
</tr>
<tr>
<td>% pre-op INR &gt; 1.2</td>
<td>11.6%</td>
<td>9.2%</td>
<td>15.1%</td>
</tr>
<tr>
<td>Ave pre-op Creatinine</td>
<td>1.32 ± 1.6</td>
<td>1.53 ± 2.0</td>
<td>1.29 ± 1.6</td>
</tr>
<tr>
<td>% Intra-Op RBC</td>
<td>29.8%</td>
<td>21.1%</td>
<td>23.3%</td>
</tr>
<tr>
<td>Ave intra-op RBC</td>
<td>0.64 ± 1.1</td>
<td>0.48 ± 1.1</td>
<td>0.50 ± 1.1</td>
</tr>
<tr>
<td>Ave total RBC</td>
<td>2.48 ± 2.8</td>
<td>2.00 ± 2.3 *</td>
<td>2.13 ± 2.8</td>
</tr>
<tr>
<td>Ave intra-op platelets</td>
<td>0.56 ± 0.8</td>
<td>0.52 ± 0.8</td>
<td>0.48 ± 0.8</td>
</tr>
<tr>
<td>Ave total platelets</td>
<td>0.96 ± 1.3</td>
<td>0.86 ± 1.1</td>
<td>0.84 ± 1.3</td>
</tr>
<tr>
<td>Ave intra-op cryo</td>
<td>0.48 ± 1.0</td>
<td>0.50 ± 1.0</td>
<td>0.47 ± 0.9</td>
</tr>
<tr>
<td>Ave total cryo</td>
<td>1.20 ± 1.8</td>
<td>1.19 ± 1.8</td>
<td>1.20 ± 1.9</td>
</tr>
<tr>
<td>Ave intra-op FFP</td>
<td>0.42 ± 1.0</td>
<td>0.38 ± 0.9</td>
<td>0.40 ± 1.1</td>
</tr>
<tr>
<td>Ave total FFP</td>
<td>0.74 ± 1.4</td>
<td>0.61 ± 1.2</td>
<td>0.71 ± 1.7</td>
</tr>
<tr>
<td>Ave Surgery Time</td>
<td>3.4 ± 1.4</td>
<td>3.6 ± 1.7</td>
<td>3.7 ± 1.5</td>
</tr>
<tr>
<td>Ave ICU Hours</td>
<td>70.0 ± 85.2</td>
<td>60.6 ± 48.4</td>
<td>64.4 ± 46.3</td>
</tr>
<tr>
<td>Ave Normalized Cost</td>
<td>1.06 ± 0.49</td>
<td>1.00 ± 0.38</td>
<td>1.04 ± 0.40</td>
</tr>
</tbody>
</table>

* * p = 0.0203 compared to normal BMI values
Case length/complexity

Quarterly Average Cross Clamp and Bypass Time

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</tr>
</thead>
<tbody>
<tr>
<td>Oxy</td>
<td>1.8</td>
<td>1.6</td>
<td>1.4</td>
<td>1.2</td>
<td>1.5</td>
<td>1.3</td>
<td>1.1</td>
<td>1.0</td>
<td>1.5</td>
<td>1.3</td>
<td>1.1</td>
<td>1.0</td>
</tr>
<tr>
<td>HMS</td>
<td>1.8</td>
<td>1.6</td>
<td>1.4</td>
<td>1.2</td>
<td>1.5</td>
<td>1.3</td>
<td>1.1</td>
<td>1.0</td>
<td>1.5</td>
<td>1.3</td>
<td>1.1</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Heparin and Protamine Usage

Quarterly Average Heparin Usage

- Ave 56,903 units (7/2014 – 1/2016)
- Ave 43,796 units (2/2016 – 12/2016)

Quarterly Average Protamine Usage

- Ave 340.3 mg (7/2014 – 1/2016)
- Ave 183.2 mg (2/2016 – 12/2016)

p < 0.0001
Prime Volume Reduction

Ave Total Prime Volume

OXY Transition began

OXY Transition complete
Intra-Operative PRBC Transfusion Rate

Quarterly Average % Cases Intra-Op PRBC Transfused

- **Baseline**
  - Ave 26.7% cases transfused intra-op

- **Oxygenator Upgrade Only**
  - Aug 2015 to Jan 2016
  - Ave 22.7% (p=0.0211 compared to baseline)

- **HMS Mgt & Oxygenator Upgrades**
  - Feb 2016 – Dec 2016
  - Ave 8.8% (p=0.0017 compared to oxy upgrade)
Platelet Usage

Quarterly Average % Cases Total Platelets Transfused

Average # Units Intra-Op and Total Platelets Transfused

HMS
Cryoprecipitate and Fresh Frozen Plasma Usage

Quarterly Average % Cases
Intra-Op and Total Cryo Transfused

y = -0.0005x + 20.296
R² = 0.8603

y = -0.0004x + 17.295
R² = 0.7916

Intra-Op and Total FFP Transfused

y = -0.0004x + 15.924
R² = 0.8699

y = -0.0003x + 14.847
R² = 0.8931
Changes made to intraoperative CBP circuit and HMS monitoring led to improvements
## Average Cost savings per patient

<table>
<thead>
<tr>
<th></th>
<th>% Savings Blood Product Cost*</th>
<th>% Savings Total Hospitalization*</th>
<th>Average Blood Product $ Savings</th>
<th>Average Total Hospitalization Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Based on internal hospital blood acquisition costs (2)</td>
</tr>
<tr>
<td>Fusion CPB Upgrade</td>
<td>21%</td>
<td>7%</td>
<td>$2,000</td>
<td>$10,464-13,314</td>
</tr>
<tr>
<td>Fusion Plus HMS</td>
<td>61%</td>
<td>8%</td>
<td>$5,500</td>
<td>$11,958-15,216</td>
</tr>
</tbody>
</table>

*% reduction based on data collected from Epic electronic medical record accounting pages

**TRENDING DOLLAR VALUE OF COST SAVINGS**

- $12,000-15,000 per patient total Hospitalization Cost
- $5,500 Blood Product Cost

2. Data on File with pathology department ABSMC Oakland, Ca 2016

Note: This data is representative of ABSMC only, and is not necessarily representative others experience or what they could be.
Summary

Intraoperative implementation of CPB circuit upgrades and the Hemostasis management system led to an intraoperative blood product usage reduction and overall trends toward lower ICU time and LOS.

- 67% total reduction in intraoperative PRBC; 15% oxy, 61% HMS
- 56% perioperative 80% intraoperative reduction in Platelets
- 23% reduction in Heparin
- 46% reduction in protamine
- Average hospitalization cost per patient down $12,000-15,000, blood product cost $5,500
Clinical Benefits Observed

- Benefits to patients, clinicians, and the hospital
- Engagement across surgery, anesthesia, perfusion, pathology, point of care
- Patients are “dry” when they hit the ICU
- Impact of delivery of less protamine, less bleeding
- Ability to use known heparin concentration to initiate bypass
- Less hemodilution as seen in reduction in intraoperative transfusions in all products
- Benefit seen using HMS in CPB cases under 2 hours as seen by transfusion level reduction for PRBC, platelets, cryo and FFP
- Anticipation of decreased morbidity and mortality
- Average total hospitalization cost and blood product cost per patient down
Summary

- Blood Conservation is not easy, requires a multidisciplinary longitudinal approach
- Hemodilution and Blood trauma is real
- Protamine is an anticoagulant
- Fusion + HMS reduced blood and blood product usage at a tertiary hospital
- Benefits for the patient, surgeon and hospital
Additional Resources that support these findings

- **Reduction in Blood Trauma**

- **Reductions in Protamine reversal dosing**

- **Reduction in Transfusion rates**