SURVEY REPORT

Results from the Perfusion.com Cardiac Surgery Hematocrit Trend Survey: Observations and Evidence-Based Recommendations

AUTHORS / SPONSORING INSTITUTIONS

Jeffrey B. Riley, MHPE, CCT, Circulation Technology Division, http://amp.osu.edu/ct, The Ohio State University, Columbus, OH


By Invitation:

David Moskowitz, MD, Chief of Cardiothoracic Anesthesia Department of Anesthesiology and Critical Care Medicine, Englewood Hospital and Medical Center, http://www.englewoodhospital.com/, Englewood, NJ

Aryeh Shander, M.D. Chief of Department of Anesthesiology, Critical Care Medicine Englewood Hospital and Medical Center in Englewood, NJ. Clinical Professor of Anesthesiology & Medicine Mt. Sinai School of Medicine in NY http://www.bloodlessmed.com/Pages/about_us.htm

BACKGROUND

In the face of a national shortage and increasing demand for blood products, it is imperative that those who care for patients undergoing cardiothoracic and vascular surgical procedures optimize the patient’s red blood cell mass and coagulation prior to surgery. (1) Clinicians and supporting staff need to employ a multi-modality approach to conserve plasma proteins, clotting factors and red blood cells from being wasted perioperatively. (2,3)

Today’s perfusionist is an integral member of a multidiscipline perioperative team (anesthesia, nursing, surgery, blood bank, pathology laboratory) approach with improved team communications for conservation of autologous blood and avoidance of allogeneic
transfusions. (4,5,6) JCAHO, AABB, perfusion professional organizations and others alike recognize the need for increased diligence in perioperative blood management. (7)

Perfusion.com solicited various perfusionists to respond to an on-line survey regarding collecting hematocrit (Hct) measurements at certain time points during cardiac surgery. The goal of the survey was to describe the average change in hematocrit at six time points during adult cardiac surgical procedures to characterize hematocrit levels throughout the surgery. The second goal of the study was to provide perfusionists the ability to apply the results of the survey to benchmark their local clinical experiences.

**METHOD**

During October and November in 2005, perfusionists were solicited at [http://www.perfusion.com](http://www.perfusion.com) and volunteered to participate in the survey to collect hematocrit levels from each of five adult patients undergoing cardiopulmonary bypass (CPB). The perfusionists retrospectively reviewed the charts for hematocrit levels at six time points throughout the procedure. All data was kept confidential and abided by current 1996 Health Insurance Portability and Accountability Act (HIPAA) regulations.

<table>
<thead>
<tr>
<th>Sample Point</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Baseline from the chart, morning of surgery, pre-anesthesia or day before surgery</td>
</tr>
<tr>
<td>Post-Intubation</td>
<td>If your service draws an ABG sample after the ET tube is inserted</td>
</tr>
<tr>
<td>Pre-CPB</td>
<td>Immediately prior to initiating CPB usually during ACT sampling post-heparinization</td>
</tr>
<tr>
<td>On-CPB</td>
<td>Three to ten minutes into the initiation of CPB, post-ECC dilution (first gas on CPB)</td>
</tr>
<tr>
<td>End-Surg</td>
<td>Last hematocrit measurement prior to leaving the OR, post protamine or chest closed</td>
</tr>
<tr>
<td>Nadir (Lowest)</td>
<td>Record the lowest hematocrit value measured any time during the surgical procedure, at any time point</td>
</tr>
</tbody>
</table>

**Note:** Hct is hematocrit; ABG is arterial blood gas; ET is endotrachial tube; Surg is surgery; CPB is cardiopulmonary bypass.
Data points were entered in an on-line form at Perfusion.com. Descriptive statistics were calculated employing SPSS 13.0 for Windows® (http://www.spss.com/). Hematocrit results from the six time events were statistically compared by analysis of variance. Trend information was plotted and differences calculated.

RESULTS

Forty-nine perfusionists responded to the survey. Table two is a summary of the data for the Hct observations reported at the six time periods.

Table 2:
Hematocrit levels at various time points during cardiac surgery

<table>
<thead>
<tr>
<th>Measurement Point</th>
<th>Obs (n)</th>
<th>Hct (mean)</th>
<th>Hct (% BL)</th>
<th>Hct (Median)</th>
<th>Hct (Std Dev)</th>
<th>Hct (Min / Max)</th>
<th>Hct (95% CI LB)</th>
<th>Hct (95% CI UB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>245</td>
<td>38.7</td>
<td>100.0</td>
<td>39.0</td>
<td>5.7</td>
<td>14.3/55.0</td>
<td>38.1</td>
<td>39.5</td>
</tr>
<tr>
<td>Post-Intubation</td>
<td>215</td>
<td>35.7</td>
<td>91.5</td>
<td>36.0</td>
<td>5.0</td>
<td>22.0/47.0</td>
<td>35.0</td>
<td>36.3</td>
</tr>
<tr>
<td>Pre-CPB</td>
<td>206</td>
<td>33.6</td>
<td>87.9</td>
<td>33.0</td>
<td>5.2</td>
<td>20.0/48.0</td>
<td>32.8</td>
<td>34.3</td>
</tr>
<tr>
<td>On-CPB</td>
<td>245</td>
<td>24.8</td>
<td>64.9</td>
<td>25.0</td>
<td>4.2</td>
<td>14.0/36.0</td>
<td>24.3</td>
<td>25.4</td>
</tr>
<tr>
<td>End-Surg</td>
<td>240</td>
<td>27.8</td>
<td>73.0</td>
<td>27.0</td>
<td>4.8</td>
<td>14.0/41.0</td>
<td>27.2</td>
<td>29.4</td>
</tr>
<tr>
<td>Nadir (Lowest)</td>
<td>244</td>
<td>23.5</td>
<td>61.5</td>
<td>23.6</td>
<td>4.0</td>
<td>14.0/36.0</td>
<td>23.0</td>
<td>24.0</td>
</tr>
</tbody>
</table>

Note: BL is baseline; Std dev is one standard deviation; Min is minimum; Max is maximum; CI is confidence interval; LB is lower bounds; UB is upper bounds

All mean Hcts from each time period were significantly different from the others (p < 0.004) including nadir compared to On-CPB. Figure one is a boxplot that illustrates the drop in Hct and the deviation of the reported Hct values as the cardiac surgery proceeds.

The mean drop in hematocrit percent from baseline to Pre-CPB was −5.3 +/- 0.5 (1 SD) which was 12.1% of the Baseline Hct value. The mean drop from Pre-CPB to On-CPB was −8.7 +/- 0.5 Hct % which was 23.0% of the baseline Hct value. The drop in Hct with anesthesia control was significantly less than the drop in Hct with the initiation of CPB (p < 0.001). Figure Two compares the drop in Hct with anesthesia compared to the drop in Hct with the initiation of CPB.
Figure 1:
Boxplot of reported hematocrits by measurement point

Note: Black bars are the median; Boxes are the 25th percentile to the 75th percentile; Whiskers are +/- 1.5 interquartile range values; Observations represented as circles are outliers which more than 1.5 interquartile range units from the median.

DISCUSSION

It is exceedingly useful to describe the hematocrit levels at various time points from numerous institutions from across the United States during cardiac surgery. An interesting finding during this study was that the drop in Hct with introduction of CPB is significantly greater than the drop in Hct during the Pre-CPB anesthesia periods.
Figure Two

Mean Hematocrit Values by Event
206 - 245 patient values per event reported by 49 perfusionists
surveyed at Perfusion.com; October, 2005

<table>
<thead>
<tr>
<th>Surgery Event</th>
<th>Hematocrit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>38.8</td>
</tr>
<tr>
<td>Post-Intubation</td>
<td>35.7</td>
</tr>
<tr>
<td>Pre-CPB</td>
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</tr>
<tr>
<td>On-CPB</td>
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</tr>
<tr>
<td>Nadir</td>
<td>23.5</td>
</tr>
<tr>
<td>End-Surgery</td>
<td>24.8</td>
</tr>
</tbody>
</table>

Δ -5.2 ± 0.5; η² = 0.97; p<0.001
Δ -8.7 ± 0.5; η² = 0.97; p<0.001

The drop with CPB is significantly greater than the drop with anesthesia (p<0.001)

Note: Δ is difference; η² is effect size; The drop in Hct with anesthesia was exceeded by the drop in Hct with initiation of CPB

While a survey such as this has limitations, absolute hematocrit values and trends can be easily established with this type of study. Perfusionists, anesthesiologists and cardiac surgeons will be able to draw information from this descriptive study to benchmark their own practice hematocrit levels.

Open-heart team members treat every patient with universal precautions because that is the standard for accepted care. Yet when it comes to blood conservation and avoidance we treat some patients and patient populations differently than others. We need to treat every patient as if they were of the Jehovah's Witness faith and not waste a drop of blood in order to maximally preserve the patient’s native cell fractions and mass. (8) Clinical equations, garnered from the literature review, to minimize hemodilution and predict post-dilution Hct and protein levels are presented in Appendix One for use by the reader.
This model survey should be reproduced at a much greater level in the US. Perhaps more information could be collected to help interpret and understand the trends in Hct during cardiac surgery with CPB.

**OBSERVATIONS**

The following observations are supported by the results of this descriptive survey:

- Perfusion.com perfusionist members are willing to submit clinical data on-line for survey purposes
- The Nadir Hct observed during cardiac surgery is significantly lower than the initial On-CPB Hct
- The End-surgery Hct is significantly greater than the observed On-CPB Hct and the Nadir Hct
- The drop in Hct associated with CPB is significantly greater than the drop in Hct associated with anesthetic induction

**RECOMMENDATIONS**

There appears to be room for improvement in preventing drops in hematocrit during the Pre-CPB period and On-CPB period. Like other authors (9), upon completion of this analysis, we offer the following recommendations and evidence. *However, these recommendations do not supersede the informed sound judgment of the clinicians caring for a particular patient.*

**Recommendation One:** Anesthesia, surgery and perfusion specialties should continue to work to improve on the multi-modality approach to preserve hematocrit. There is room for process improvement in both anesthesia and perfusion specialties, but of course, every team member is responsible to help preserve Hct.

**Evidence to Read:**

• Dial S, Delabays E, Albert M, Gonzalez A, Camarda J, Law A, Menzies D. 
Hemodilution and surgical hemostasis contribute significantly to transfusion requirements in 

• Belway D, Rubens FD, Wozny D, Henley B, Nathan HJ. Are we doing everything we can to 

• Shander A, Moskowitz D, Rijhwani TS. The safety and efficacy of "bloodless" cardiac 

• Richard Merritt. US heart patients receive more transfusions than international patients 

• Habib RH, Zacharias A, Schwann TA, Riordan CJ, et al. Adverse effects of low hematocrit 
during cardiopulmonary bypass in the adult: Should current practice be changed? *J Thorac 

• Van der Linden P, De Hert S, Daper A, Trenchant A, Jacobs D, De Boelpaepe C, 
Kimbimbi P, Defrance P, Simoens G. A standardized multidisciplinary approach 
reduces the use of allogeneic blood products in patients undergoing cardiac surgery. 

• Helm RE, Rosengart TK, Gomez M, Klemperer JD, DeBois WJ, Velasco F, Gold JP, Altorki 
NK, Lang S, Thomas S, Isom OW, Krieger KH. Comprehensive multimodality blood 
conservation: 100 consecutive CABG operations without transfusion. *Ann Thorac Surg.* 

**Recommendation Two:** It is important to adopt a team approach to blood management with 
attainable goals to make red cell conservation a viable practice.

**Evidence to Read:**

• Hardy JF, Van der Linden P. Blood conservation and the management of perioperative blood 
transfusions in a patient undergoing major vascular surgery: a Self-Assessment Program. *Can 

• Shander A, Moskowitz D, Rijhwani TS. The safety and efficacy of "bloodless" cardiac 

• Paiva P, Ferreira E, Antunes M. Bloodless open heart surgery: simple and safe. *Rev 
Port Cardiol.* 2005;24(5):647-54.

**Recommendation Three:** Cardiac surgery patients should be screened for blood indices, protein concentration, and treated preoperatively to maximize conservation of their red blood cell mass and blood fractions. Perfusionists should calculate post-dilution Hct, protein concentration and expected colloidal osmotic pressure (COP) to treat the patient accordingly. See the [Clinical Equations Appendix](#) for the clinical algorithms to estimate post dilution Hct, total protein concentration and COP.

**Evidence to Read:**


**Recommendation Four:** CPB circuits should be safely condensed to primes of 1500 mls or less for adults to decrease the effects of obligatory hemodilution and hypoproteinemia from the ECC. See the clinical equations in the **Clinical Equations Appendix** to assess the impact of circuit prime volume.

**Evidence to Read:**


**Recommendation Five:** Retrograde Autologous Priming is an excellent technique to minimize the effects of hemodilution from the ECC and should be considered for use with all CPB cases with the help of Anesthesia and the surgical team.

**Evidence to Read:**


**Recommendation Six:** Anesthesia should reduce the amount of crystalloid volume given as much as possible, and increase the patient’s systemic vascular resistance as tolerated by afterload.

**Evidence to Read:**


**Recommendation Seven:** Colloid solution is an acceptable alternative to avoid excessive hemodilution from overload crystalloid infusion during surgery. See the equations in the [Clinical Equations Appendix](#) to estimate colloidal osmotic pressure during CPB.
Evidence to Read:


**Recommendation Eight:** Acute normovolemic hemodilution (ANH), either prior to heparinization or during the onset of CPB may help preserve autologous whole blood. ANH should be performed as tolerated through the use of calculations and nomograms. See the [Clinical Equations Appendix](#) for clinical algorithms to estimate safe ANH sequester volume.
Evidence to Read:


**Recommendation Nine:** Meticulous surgical technique should be employed throughout the surgical procedure. When ever there is obvious surgical bleeding the surgeon should stop to tie down or cauterize the area to reduce waste.

Evidence to Read:

Recommendation Ten: Cell washing should be kept to a minimum and limited to the pre- and post-heparinization period. Coronary suckers are a safe alternative to use during the heparinization period to preserve frank autologous whole blood and return it back to circulation. A waste sucker should be kept in the field for undesirable shed blood and irrigant solutions.

Evidence to Read:

**Recommendation Eleven:** Hemoconcentration should be considered for use to reverse excess fluid administration, eliminate undesirable byproducts including antiplatelet medications and concentrate the patient’s red cell mass and plasma proteins.

**Evidence to Read:**

**Recommendation Twelve:** On-site coagulation monitoring (i.e., thromboelastography and heparin concentration determination) along with targeted pharmacotherapy (antifibrinolytics and desmopressin acetate) are an integral part to prevent empiric transfusions of allogenic blood and blood products.

**Evidence to Read:**


**Recommendation Thirteen:** Remember that transfusion of any allogeneic blood product is an "organ transplant" and not just a medication that is without side-effects. Everyone (surgeons, anesthesiologists, perfusionists and nurses) needs to think of a blood product infusion for what it actually is an "organ transplant" and not another medication that they can order from a menu.

**Evidence to Read:**


**Appendix One: Clinical Equations**

**Acute Normovolemic Hemodilution**

Ovrum (1), Moskowitz, Vinas (2) and others employ the following three equations to estimate the safe ANH volume to remove prior to CPB. The first step is to estimate the patients circulating blood volume (Eq. 1). Find the necessary pre-CPB Hct with Eq. 2 given a desired on-CPB Hct; then calculate the safe ANH volume with Eq. 3.

\[
EBV = f_{BV} \times Kg \quad \text{Eq. 1}
\]

\[
Hct_{preCPB} = \frac{Hct_{onCPB} \times (EBV + \text{Prime Volume})}{EBV} \quad \text{Eq. 2}
\]

\[
\text{ANH Volume} = \frac{EBV \times (Hct_{initial} - Hct_{preCPB})}{Hct_{initial}} \quad \text{Eq. 3}
\]

Where:

- EBV is the patient’s estimated blood volume in cc
- \( f_{BV} \) is the blood volume factor in cc blood per kilogram: typically 70-90 cc/kg
- Kg is body weight in kilograms
- Hct_{preCPB} is the percent estimated patient Hct required before CPB to achieve the desired Hct_{onCPB}
- Hct_{onCPB} is the desired percent Hct after initiating CPB
- Prime Volume is the extracorporeal circuit prime volume in cc
- Hct_{initial} is the patient percent Hct after hemodilution after anesthetic induction
- ANH Volume is the whole blood volume in cc to be sequestered prior to CPB.


**Post-Dilutional Hematocrit (Hct\(_{onCPB}\))**

Once the ANH volume has been sequested; the post-dilutional, on-CPB Hct may be more accurately estimated. Using the same estimated blood volume (Eq. 1), the patient red blood cell mass (RCM\(_{pt}\) in cc) is estimated with Eq. 4 The on-CPB Hct is then estimated from the RCM\(_{pt}\), EBV and extracorporeal circuit prime volume (cc). DeFoe, et al. recommend that the on-CPB Hct be predicted for all CPB patients and action taken to avoid the patient experiencing low Hct on CPB which leads to undesirable post operative outcomes. (2,3)

\[
EBV = f_{BV} \times Kg \quad \text{Eq. 1}
\]

\[
RCM_{pt} = EBV \times Hct_{initial} \quad \text{Eq. 4}
\]

\[
Hct_{onCPB} = \frac{RCM_{pt}}{(EBV + PrimeVolume)} \quad \text{Eq. 5}
\]

---


Post-Dilutional Total Protein and Colloidal Osmotic Pressure (COP)

Blackwell, et al. and Beshere, et al. provide guidance to predict, measure and estimate on-CPB total protein concentration ([TP] in gm/dL) and the resulting colloidal osmotic pressure (COP in mmHg). (1,2) Normal COP is 18 to 22 mmHg, during CPB the COP falls to 8-15 mmHg.

\[
[TP]_{onCPB} = \frac{[TP]_{preCPB} \times EBV}{EBV + PrimeVolume} \quad \text{Eq. 6}
\]

\[
COP_{mmHg} = \left(3.32 \times [TP_{onCPB}]\right) - 2.0 \quad \text{Eq. 7}
\]


REFERENCE


__________________________________________________________

Last updated: January 14, 2006