Tricuspid valve replacement with cardiopulmonary bypass in a patient with sickle cell disease and protein C deficiency

Palatnik md Y, Sarwar md M
Suny Upstate Medical Univeristy, Syracuse, NY, USA

Case Presentation
We present a case of a 35 year old female with severe tricuspid valve regurgitation, sickle cell disease and protein C deficiency undergoing tricuspid valve replacement using cardiopulmonary bypass (CPB). Patient was maintained on heparin infusion up to the morning of the case. After induction of general anesthesia, 2 units of packed RBCs (pRBC) were given to minimize the concentration of HbS. The CPB pump was primed with 6 units of pRBC and 4 units of FFP to replace anticoagulant factor C. Upon initiation of CPB, an exchange transfusion was performed. Cardioplegia was initiated with a warm (37 C) solution and CPB was carried out at normothermia. The venous saturation was maintained at 70% throughout the case. Arterial blood pressure was maintained above 60 mm Hg. The tricuspid valve was found to be rheumatic and was replaced with a bioprosthetic tissue valve. Two more units of FFP were administered during closure to replete coagulation factors lost during CPB as well as protein C. The patient was extubated on postoperative day #1 and started on warfarin and heparin infusion on postoperative day #2.

Discussion
Sickle cell disease is an inherited disorder of hemoglobin caused by a substitution of valine for glutamic acid in the beta hemoglobin chain. The vaso-occlusive crises in sickle cell disease are initiated by hypoperfusion, hypoxia, hypothermia, acidosis, stress, inflammation, which can all occur with CPB. Management of CPB includes avoidance of hypovolemia, hypothermia, acidosis and hypoxemia, reduction of blood viscosity, optimization of total hemoglobin, and minimization of Hb S levels. To increase our patient’s Hct, 2 units of pRBCs were transfused at the start of the case, and 6 units were added to CPB circuit prime. She also received additional 3 units of pRBCs during CPB. To limit the risk of hypothermia, which increases blood viscosity, cardioplegia was initiated with a warm solution and CPB was performed at normothermia. FiO2 was maintained at 100% and pO2 > 250 mmHg to avoid hypoxia. Protein C is a vitamin K-dependent protein synthesized in the liver, which acts as an anticoagulant via inhibition of procoagulant factors V and VIII. With protein C deficiency, the patient is at increased risk of thrombosis and pulmonary embolism. Therapy of protein C deficiency involves transfusion of FFP, factor IX concentrate (rich in protein C) and administration of heparin and warfarin.

References
Introduction:
Percutaneous Aortic Bioprosthesis Implantation is performed in patients with severe cardiovascular dysfunction and co-morbidity with high risk of Central Nervous System (CNS) isquemic events. A 12 patients pool underwent this procedure. CNIO monitorization and processed EEG were performed in all of them and showed to be relevant and useful tools, in order to identify cerebral tissue hypoxia, guide/access anesthetic and complications management.

Clinical Presentation:
A 12 patients pool underwent PABI, under general intravenous anesthesia, curarization and invasive mechanical ventilation. All were monitored by ASA Standards, Invasive arterial pressure, CNIO and Processed EEG data. Vasopressure support was administered according to clinical needs.

CNIO measurement by placing Cerebral Oximeters, INVOS® in 7 patients and FORESIGHT® in the remaining 5 was performed; BIS® in 9 patients (6 INVOS®/3 FORESIGHT®) and Bilateral BIS® in 3 patients (1 INVOS®/2 FORESIGHT®) were used to obtain and process raw EEG data.

These parameters were used for neuromonitoring and anaesthetic management; their readings/obtained data showed marked variations in the two cerebral hemispheres. This correlated well with clinical/radiological findings, procedure technical steps and complications, as well as patient outcome. Corrective and therapeutic actions were taken according to this guidance, manipulating anaesthetic and hemodynamic parameters aiming to prevent and reduce neurological injuries.

Conclusions:
Given clinical evidence, StcO2/raw EEG processed monitorization, were relevant and useful, reflecting the balance of local cerebral oxygen supply and demand; allowed monitoring changes in cortical blood oxygen saturation and guiding anaesthetic management according to patients needs; taking corrective actions on peri-op in order to minimize secondary damage to isquemic and hypoxic events. Recent research and clinical experience indicates such action can prevent and reduce neurological injuries associated with surgery and critical care situations, reducing the cost of care.
Introduction:
Many institutions require nurses to prepare intravenous lines with in-line filters. Many manufactures of In-line intravenous filters exist but by enlarge all fall into two groups: 0.22 micron and 1.22 micron semi-permeable membrane filters. These devices are designed to filter out and hold particulates, such as rubber stoppers, glass from ampoules and large bacterial colonies. In addition most companies claim that an air venting function exist with these filters. A Cochran analysis suggested that the evidence for use of such devices is minimally positive and cost is significant. They suggest little evidence exist in children for the use of these filter, however still endorse considering their use. Several studies have shown when obstructed, replacement of the filter is necessary, which increases the infection risk significantly by breaking of the sterile line. Other studies also have found no statistically significant evidence of decreased bacterial infection when using these filters. Many intravenously administered compounds including, propofol, mannitol, and blood products are known to clog these filters and therefore most institutions donât use them in the operating room areas.

Cardiopulmonary bypass represents a unique environment in which extreme flow rates and volumes are often necessary for resuscitation of the patient during the case. Most manufactures also suggest a maximum pressure of 30 cm of water be applied to these filter, above which the integrity of filter is not guaranteed. In addition, a relatively new technique, vacuum assisted venous drainage, places extreme negative pressure on the venous canulas which is transmitted to these filters. Pressure as low as 60cm negative pressure can be place on the venous reservoir. No manufacture data exist regarding the viability of these filters when exposed to such extremely low pressures. The purpose of this study is to examine the effect of low pressures, vacuum, on the viability of these filters.

The usage of filters remains controversial as to their effectiveness in removing bacteria, viruses and other infectious material. The manufacturer recommends these devices primarily to remove particulate matter, and does not warrant nor guarantee their ability to remove air. With the advent of mass produced and prefiltered intravenous fluids, admixtures and additives, and with the standardization of needleless systems which eliminates coring of septum few if any particulate events occur. The use of vacuum assisted venous drainage in cardiopulmonary bypass additional concerns of air trapping was raised. Our study while simple showed some air is produced when existing lines are exposed to vacuum. While these bubbles probably were present but too small to visualize prior to vacuum application they do present a risk to the patient. If filters are used in the system additional potential breaks or leaks in the line can occur with the additional connections as observed in our study. Also, while initially air is probably taken to the cardiotomy reservoir any air created or entrained during vacuum assist that remains in the line will be flushed into the patient after infusions are resumed when off bypass.
Management of a trauma patient with anomalous venous return

Klima R, Klimova A
1 Veterans Hospital, Little Rock, AR, USA; 2 Uams, Little Rock, AR, USA

Introduction: Partial anomalous pulmonary venous connection (PAPVC) is a congenital cardiac defect that is caused by the anomalous return of one or more of the pulmonary veins to the right atrium, inferior (IVC) or superior vena cava (SVC). The overall incidence is estimated to be 0.7 percent with equal frequency in men and women.

Case description: A 58 year old man was admitted to the university hospital with traumatic left femoral neck fracture, left proximal humeral fracture, and right acute fronto-temporal subdural hemorrhage on Saturday morning. His medical history revealed PAPVC with one pulmonary vein returning to superior vena cava combined with atrial septal defect, severe pulmonary hypertension, and mild chronic obstructive pulmonary disease. Other significant clinical findings were COPD and severe chronic lower back pain treated with intrathecal pain pump. On advice of on call anesthesiologist and orthopedic surgeon femoral fracture fixation with an intramedullary nail was postponed till Monday due to requested cardiology and pulmonary consultation. The surgery was further delayed due to lack of coordination among services involved in this case. Anesthesiologist who was assigned to this case on Tuesday found patient with rapidly deteriorating pulmonary function requiring noninvasive ventilation with bilevel positive airway pressure (BiPAP). After all necessary preoperative consultations and exams were performed, right intertrochanteric fracture repair with intramedullary nail was performed uneventfully under general anesthesia on Wednesday, four days after patient’s admission to the hospital. Swan-Ganz catheter and arterial line were used for hemodynamic monitoring.

Discussion: This case illustrates that in trauma patient with PAPVC and ASD surgery can safely be done under general anesthesia with appropriate ventilation management and hemodynamic monitoring. Anesthesiologist should play a key role in coordinating the pre-operative evaluation in trauma patients in order to avoid delay in surgical intervention.

References:
Retrograde autologous prime (RAP) of the cardiopulmonary bypass (CPB) circuit is used to decrease transfusion requirements, although its efficacy has been questioned. We describe a cause of decreased venous return due to a large volume of blood being inadvertently pumped into the RAP bag at the initiation of CPB and the therapy employed.

A 48 year old, 90kg man with cardiomyopathy presented for placement of left ventricular assist device. He was admitted for heart failure and managed with milrinone and intra-aortic balloon pump.

In the OR standard monitors and an arterial line were placed and general endotracheal anesthesia was induced. Initial hematocrit (Hct) was 34%. The CPB machine was primed per institutional protocol. A 7mm arterial cannula was inserted into the ascending aorta and tested. A 29 Fr venous cannula was placed into the right atrial appendage. The patient then exhibited decreases in systemic blood pressure (BP) from 110/60 to 79/40. CPB was initiated, foregoing RAP. Full flow of 4 L/min was obtained, although there was poor venous return, with only 300mL in the bypass reservoir. Initial mean systemic BP was 47 mmHg. Several phenylephrine boluses were given and the systemic BP increased as did the bypass reservoir volume. The decreased venous return was attributed to vasodilation, as it was resolving with vasoconstrictors and adjustment to non-pulsatile flow.

After 10 minutes on CPB, the perfusionist noted the bag used to collect prime during the RAP to be full of blood, which suddenly ruptured. The perfusionist closed the stopcock on the line connecting the collection bag to the oxygenator, ceasing the flow of blood. 1 L of crystalloid was added to the reservoir. Four units of packed red blood cells and 2 units of fresh frozen plasma were administered into the CPB machine. Hct increased from 20% to 26% post transfusion. The patient remained on bypass with a mean systemic BP in the 50âs. The rest of the case was uneventful. No additional blood products were required. The patient did well, and was discharged from the hospital on POD# 18.

Low venous return to the CPB circuit may have many etiologies, such as low blood volume, air in the venous line, inappropriate cannula placement, or obstruction. To our knowledge, this is the first report of a lack of venous return due to an overly filled RAP bag.

One contributing factor was the patient’s hypotension, causing us to forgo the usual RAP and proceed directly onto CPB. This deviation from routine resulted in the loss of a large volume of the patientâs blood.

Another contributing factor was the presence of trainees. This stresses the importance of simulator training in perfusion education. This case highlights the importance of vigilance in the operating room during CPB as well as clear communication between all members of the intraoperative team.

Background: Tranexamic acid (TXA) reduces blood loss and transfusion requirements in children undergoing cardiac surgery requiring cardiopulmonary bypass (CPB) (1). However, there are no pharmacokinetic (PK) studies of TXA in this group of patients. Current dosing recommendations are based on an efficacy study of high dose TXA in pediatric patients undergoing repeat cardiac surgery (1). We are performing a PK study in children who receive high dose TXA for surgery requiring CPB.

Methods: Blood is being collected from 55 children who receive TXA during surgery requiring CPB. The patients were divided into 3 groups: neonates (0-2 months), infants (2 months-1 year), and older children (up to 20 kg). A TXA bolus of 100 mg/kg is given prior to incision followed by an infusion of 10 mg/kg/hour during the surgery. An additional bolus of 100 mg/kg is placed in the CPB prime. TXA levels are measured at 18 time points.

TXA levels were measured using an Agilent 1200 HPLC system. TXA concentration data were analyzed by nonlinear mixed-effects methods using NONMEM 7.2 and Monolix3.2. A two compartment structural model was used.

Results: Currently the TXA levels from 27 patients have been collected and analyzed (12 neonates, 9 infants, 6 older children). The minimal therapeutic level which must be maintained in high risk patients has previously been established as 126 mcg/mL (2). In all 3 groups, the high dose regimen described above resulted in some patients having extremely high peaks or sub therapeutic troughs. See Figure 1. Decreasing the bolus doses and increasing the infusion rate will reduce the peak levels and decrease the likelihood of sub therapeutic troughs. In the neonatal group, when the boluses are reduced by 45% and the infusion rate is doubled, the peaks are minimized and the steady state is maintained in the therapeutic range. See figure 2.

Conclusion: TXA dosing changes including lowering the bolus doses and increasing the infusion rate will increase the number of patients having therapeutic levels. However, dosing based solely on weight maybe suboptimal for this group of patients. Additional variables including the pump prime volume will also need to be analyzed before specific recommendations can be made.

References:
Figure 1: TXA concentration versus time: cumulative data for each group. The time under the break in the x-axis represents the average time from initial bolus of TXA to initiation of CPB. Dotted Line represents the minimal therapeutic concentration of 126 mcg/mL.
Figure 2: Simulated TXA levels in a 3.2 kg neonate who received bolus doses of 55 mg/kg and an infusion dose of 20 mg/kg/hour. CPB was initiated 78 minutes after initial bolus of TXA.
Background
Hemodynamic transesophageal echocardiography (hTEE) with a miniaturized, disposable monoplane probe approved for 72 hours of use allows for serial, direct cardiac assessments in postoperative cardiac ICU patients. A prior hTEE study at our institution established criteria for use and demonstrated management changes in 47% of patients. We hypothesized that hTEE would help guide the clinical management of patients undergoing left ventricular device (LVAD) implantation.

Methods
From 6/2009 to 11/2011, 6 patients underwent implantation of a long-term LVAD with postoperative hTEE monitoring. The mean patient age was 55 (range 47-64). Ischemic etiologies accounted for 50% of the patients and 5 patients (83%) were on intravenous ionotropes. Three patients (50%) had preoperative intraaortic balloon pumps and 1 patient (17%) was supported with a short-term percutaneous device. One patient (17%) presented in cardiogenic shock while 5 patients (83%) underwent elective operations. hTEE assessments were made when the clinicians deemed it appropriate.

Results
Four (67%) patients had clinical decisions guided by hTEE, of which LVAD rpm changes and fluid management were most common. One patient was promptly re-explored for tamponade and later underwent guided resuscitation and RV monitoring for sepsis. Another patient was managed for new onset right ventricular (RV) failure. The figure below shows management changes in a patient guided by hTEE post LVAD.

Conclusions
TEE is the intraoperative standard of care for patients undergoing LVAD implantation. Postoperative assessment with hTEE in this case series provided valuable information in this challenging population to effectively treat conditions that were not fully appreciated with standard hemodynamic monitoring.
The near-infrared spectroscopy has gained momentum and its utility has increased. Studies have shown better outcomes, shorter ICU stay and ultimately cost containment when these devices were used. We simultaneously compared two cerebral oximeters: FORE-SIGHT (CASMED, Branford, CT) and INVOS 5100 (Covidien, Boulder, CO) during cardiac surgery. After IRB approval, we enrolled fifteen consented patients. Inclusion criteria were patients 65 and older, presenting for non-emergent CABG, and open chamber surgery. One sensor from each manufacturer was placed on the left side of the forehead (upper and lower) and in the reverse order on the right side. Continuous rSO2 (INVOS) and ScO2 (FORE-SIGHT) data was recorded. Intervention was based on a standard treatment protocol for patient management at our institution, triggered when the rSO2 was less than 55% or decreased more than 20% from baseline. The data was cleaned for interference between devices by removing all zero values and using a two minute moving average. The event markers were analyzed with 1 minute averages: pre-induction, induction, initiation of CPB, separation from CPB, and chest closure. The length of time a monitor displayed value below 55% was represented as TUT (time under threshold) in minutes. A paired student t-test was used to establish if the two devices had similar readings and Pearson correlation coefficient was used to examine the devices for agreement which was represented in our scatter plot. From the fifteen patients, 11(7 CABG, 4 open chamber) finished the study. Two patients dropped out due to interruption of data collection and two due to significant sensor interference. Analyzing the data from the event markers (n=102) shown in Figure 1, we found that there is a correlation (R2 = 0.386) between the two devices' measurements, but their absolute values differ significantly (p < .00001) with INVOS showing lower readings, average bias of 7.45 and 95% confidence interval of between 6.0135 and 8.880. Using the continuous data (n=48115), INVOS measured lower than the 55% threshold (Table 1) more often than FORE-SIGHT did, on average 47 minutes more on the left and 110 minutes more on the right side, consistently prompting treatment often without expected result. Based on these findings, the devices tested showed significant discrepancy. Given the treatment protocol used we can assume that treating of false positive values can lead to possible injury, neurological deficit and an increase in morbidity and mortality. False negative results may have the same effect. A careful evaluation of other clinical parameters should be considered before a decision to treat is made.
<table>
<thead>
<tr>
<th>Patient</th>
<th>( \text{SctO}_2 \text{ L} )</th>
<th>( \text{SctO}_2 \text{ R} )</th>
<th>( \text{rSO}_2 \text{ L} )</th>
<th>( \text{rSO}_2 \text{ R} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.2</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>15.9</td>
<td>32.7</td>
<td>172.0</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.9</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>48.2</td>
<td>284.4</td>
</tr>
<tr>
<td>5</td>
<td>9.6</td>
<td>23.0</td>
<td>14.7</td>
<td>75.9</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>0.0</td>
<td>24.1</td>
<td>6.2</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
<td>46.4</td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>306.4</td>
<td>115.0</td>
</tr>
<tr>
<td>9</td>
<td>0.0</td>
<td>0.0</td>
<td>0.3</td>
<td>213.9</td>
</tr>
<tr>
<td>10</td>
<td>0.0</td>
<td>0.0</td>
<td>66.2</td>
<td>105.9</td>
</tr>
<tr>
<td>11</td>
<td>0.0</td>
<td>0.0</td>
<td>27.1</td>
<td>220.5</td>
</tr>
<tr>
<td>average</td>
<td>0.9</td>
<td>3.5</td>
<td>47.3</td>
<td>113.0</td>
</tr>
<tr>
<td>maximum</td>
<td>9.6</td>
<td>23.0</td>
<td>306.4</td>
<td>284.4</td>
</tr>
</tbody>
</table>
INVOS v FORE-SIGHT during Cardiac Surgery

\[
y = 1.0847x - 13.37
\]

\[
R^2 = 0.3861
\]
Introduction:
Systemic air embolism has been a recognized intraoperative complication. It occurs as a complication of positive pressure ventilation in the face of penetrating chest trauma and also has been described in relation to the radiofrequency ablation of bronchial tumors. Today, with the advent of new technologies and sophisticated operative techniques requiring high pressure insufflation, the potential for intraoperative catastrophe remains high.

Case presentation:
We present a 62-year-old man who, during an iatrogenic left-sided pneumothorax for a robot-assisted coronary bypass procedure, developed a systemic CO2 embolism as documented by perioperative transesophageal echocardiography (TEE). This robotic assisted procedure was applied to graft the left internal thoracic artery (ITA) to the left anterior descending coronary artery (LAD) without opening the chest. After single one-lung ventilation was initiated, the camera port and insufflation needle were placed and intrathoracic CO2 insufflation was initiated for surgical visualization. A sudden hemodynamic compromise ensued and TEE showed echogenic microcavitations ("air") in the left atrium and aorta as seen via the midesophageal short axis aortic view. CO2 was immediately discontinued and the insufflation needle removed. Further hemodynamic collapse required chest compressions and increasing inotropic and vasopressor support. The plan to graft the ITA to the LAD via Off Pump Coronary Artery Bypass Grafting (CABG) was changed to Cardiopulmonary Bypass (CPB)-assisted CABG with full heparinization. A puncture site in the left lung was detected during exploration following median sternotomy and a 2-vessel-CABG was accomplished; the patient was weaned off CPB utilizing multiple vasopressors and transported to the CVICU. Vasopressor and inotropic support were weaned over several hours and the patient was extubated on post-operative day 1. However, the patient’s neurological status was compromised (left-side neglect and lethargy) and MRI showed several small thalamic and frontal infarctions on the right side. Neurologic status was continuously improved and on postoperative day 7 patient was discharged home. Subsequent clinical visits indicated no neurologic sequelae with the patient reporting to be at his baseline.

Discussion:
Our case demonstrates the potentially devastating effects of circulatory air as the result of need to insufflate the thorax in cardiac procedures, and the utility of TEE to detect and aid in the treatment of air embolism. The different clinical syndromes associated with air embolism in the systemic venous (right heart) and the systemic arterial (left heart) circulation need to be understood in order to diagnose and appropriately treat these condition in clinical settings.

References:
Introduction: Continuing our work with high resolution measurements of rapidly changing flow rates and associated pressures during CPB with automated data collection from a CPB system, we captured arterial pump outlet pressures (APOP) through use of a conventional pressure transducer connected to our physiologic monitoring system (Intellivue à Philips). This technique permitted direct export of the pump outlet pressure into our AIMS database. During collection of this data we noticed beat frequencies in APOP. Our measured APOP waveform in CPB patients was similar in shape to the Moscato group in vitro experiment (1). At flow rates of 5L/min and higher our APOP reaches a plateau of 370 mmHg. This may be artifactual- a limitation of the Edwards pressure transducer or the Philips IntelliVue electronics. As Pump flow increases the oxygenator outlet pressure continues to increase while APOP develops a broader plateau clipped at ~ 370 mm Hg. With decreasing flows the plateau durations decrease to zero and peak APOP decreases to values below 370. Supplemental flow rate and temperature data from the pump were also obtained by an RS-232 Communication Module (CM) obtained from our Terumo- Sarns rep. Methods: IntelliVue pressure transducers were connected to pressure ports upstream and downstream of the OX. These two pressure signals were directly entered into our AIMS every 15 sec. In addition, these pressure waveforms were also recorded by our IntelliVue Information Center (IIC) which can capture and store four waveforms during a case. Typically, EKG, A-line, CO2, and Pulse Oximeter waveforms are selected for capture and storage. These stored waveforms may be viewed at typical EKG scanning rates (6.25, 12.5, 25 and 50 mm/sec. Data were still recorded from the Pump via the RS-232 CM port and the Asus Eee PC. The Pump flows and temperatures are only updated every 66 sec at the CM port. Results: See Figure Below Summary: APOP waveforms observed here demonstrate detailed structures similar to those obtained in laboratory pump tests. Beat frequencies observed in our studies are most likely related to oxygenator compliance effects. Reference 1: Moscato, F.; Colcacino F.; Arabia M.; Danieli G.; Pressure Pulsation in roller pumps: A validated lumped parameter model. Medical Engineering & Physics 30 (2008) 1149-1158
Beat Frequency Signal in CPB Arterial Pump Outlet Pressure
Introduction: In the context of rising health care costs, all physicians bear the responsibility of minimizing cost while providing care that meets or exceeds national quality benchmarks. For patients undergoing surgery, intraoperative anesthetic drug costs constitute a small but significant fraction of the total cost in the perioperative period. Previous studies have revealed that anesthesiologists are generally unaware of drug costs (1), and this provides an avenue for education and the implementation of cost minimizing strategies. Anesthesiology residencies provide a good opportunity to develop cost awareness among physicians in training. Ideally, anesthetic drug cost containment will improve with experience. As mandated by the Anesthesiology residency program requirements, residents at our institution complete a minimum of two separate months in cardiac anesthesia, typically one month during the CA-1 year, and one or two additional months in the subsequent years of training. In order to determine if experience improves anesthetic drug cost containment, we compared the total anesthetic drug cost per case, as residents progressed through their rotations in cardiac anesthesia.

Study: We considered the total anesthetic drug cost for 204 separate adult cardiac cases, including coronary artery bypass grafting, aortic valve replacement, mitral valve replacement/repair, and ventricular assist device placement. 72 of the cases analyzed were done by residents in their first month of cardiac anesthesia, and 127 of the cases were done by residents in their subsequent months of cardiac anesthesia. The total drug cost for all medications used by the anesthesiologist in the OR (excluding inhalational agents) was calculated. We compared the average total cost per case between the two groups using the Student's T-test. The average total cost per case for residents in their first month ($192.60; SD= $81.80) was significantly less than the average total cost per case for residents in their subsequent months ($223.70; SD=$95.40) (p=0.018)

Discussion: The results revealed that more experienced residents had a higher average total cost per case. One possible explanation for this finding is that complex cases may have been assigned to more experienced residents, and that these patients may have required greater pharmacologic support (2). Another reason for the finding of no decrease in cost over the training sequence may be that experienced residents attempted to anticipate the pharmacologic needs for their patients. The departmental guidelines for adult cardiac anesthesia contain specific medications that should be prepared for particular cardiac cases. In anticipation of individual patient needs, more experienced residents may have strayed outside the guidelines in preparation. This anticipatory dispensing of additional medications may have resulted in higher wastage in cases performed by upper level residents. Drug wastage has already been shown to play a significant role in intraoperative drug costs (3).

References:
Low Peak Diastolic Filling Velocity Measured by 3D Echocardiography May Predict Diastolic Dysfunction

Wolff G, Ahlgren B, Seres T
University of Colorado Denver, Aurora, CO, USA

Background: Doppler analysis of transmitral and pulmonary venous flow, the mainstay of evaluating left ventricular (LV) diastolic dysfunction (DD), is subject to error from loading conditions. Tissue Doppler (TD) imaging reduces this error, but accuracy may suffer from two-dimensional (2D), single-plane analysis. Real-time three-dimensional (3D) echocardiography eliminates the errors from geometric assumptions of LV volumes required by 2D analysis and allows quantitative assessment of volume changes during diastole. The volume-time curve (VTC) produced by 3D echo has been shown to correlate with more detailed imaging modalities, such as MRI and angiography, and identifies LV performance changes associated with DD. In this study, we utilized 3D echo to analyze peak diastolic filling velocity from the first derivative of the diastolic VTC and hypothesized that peak filling velocity can predict DD in our patient population.

Methods: In this retrospective cohort study, we identified 47 patients who underwent preoperative transthoracic echocardiography prior to liver transplantation between May 2007 and September 2011. Left ventricular diastolic performance was assessed by mitral annular TD and transmitral and pulmonary venous doppler flow analysis. Peak filling of the ventricle was determined by taking the first derivative of the 3D VTC. Data for normal patients were compared to those with DD using Student’s t-test. Associations between the different parameters were analyzed by using Spearman’s correlation.

Results: Of the 47 patients, 12 demonstrated abnormal age-corrected TD and Doppler flow values. Ten patients had grade 2 (pseudonormal) and 2 patients had grade 3 (restrictive) DD. No patients demonstrated LV systolic dysfunction. Mean peak filling velocity for normal patients (279.5 ± 116.7 mL/sec) and for patients with DD (187.4 ± 85.6 mL/sec) were significantly different (p = 0.007). In addition, the peak filling velocity showed significant correlation with LV end diastolic volume (EDV), stroke volume (SV), ejection fraction (EF), cardiac output (CO), cardiac index (CI), mitral inflow E velocity (MVE), pulmonary vein S (PVS) and D (PVD) velocities, left atrial volume (LAV), and left atrial volume index (LAVI). The peak filling velocity did not correlate significantly with TD E measured at the septal or lateral walls.

Conclusion: 3D echocardiographic measurement of peak diastolic filling velocity predicted grade 2 and 3 DD. The peak diastolic filling velocity correlated with volume dependent systolic and diastolic parameters.

Peak Filling Rate (mL/sec)

Normal: 279.5
Diastolic Dysfunction: 187.5
<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation with Peak Filling Rate (VTC First Derivative)</th>
<th>Significance (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDV</td>
<td>-0.632</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>SV</td>
<td>-0.755</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>EF</td>
<td>0.362</td>
<td>0.012</td>
</tr>
<tr>
<td>CO</td>
<td>-0.822</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>CI</td>
<td>-0.752</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>MVE</td>
<td>-0.422</td>
<td>0.003</td>
</tr>
<tr>
<td>PVS</td>
<td>-0.443</td>
<td>0.002</td>
</tr>
<tr>
<td>PVD</td>
<td>-0.319</td>
<td>0.029</td>
</tr>
<tr>
<td>TD E’ Lateral Wall</td>
<td>-0.248</td>
<td>0.093</td>
</tr>
<tr>
<td>TD E’ Septal Wall</td>
<td>-0.243</td>
<td>0.1</td>
</tr>
<tr>
<td>LAV</td>
<td>-0.648</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>LAVI</td>
<td>-0.602</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>
Protamine-induced pulmonary vasoconstriction (PIPV) is induced by heparin-protamine complexes activating the complement cascade and stimulating the arachidonic acid (AA) pathway resulting in the release of thromboxane A2 (TxA2), a potent pulmonary vasoconstrictor. Blocking the AA pathway with aspirin preoperatively may prevent PIPV. In a prospective study of 1497 patients, 10 developed PIPV. None of the patients taking 325mg aspirin within 7 days of their operation developed PIPV. Blocking the thromboxane A2 receptor has also prevented PIPV induced by heparin-protamine complexes. In a porcine model of PIPV, pretreatment with indomethacin prevented PIPV seen in all control animals.

Ketorolac is a potent nonsteroidal anti-inflammatory drug that competitively inhibits both cyclooxygenase enzymes, preventing the conversion of AA to prostaglandin G2 and thromboxanes including TxA2. In this case report, a 53 year old male underwent coronary artery bypass grafting using cardiopulmonary bypass and anti-coagulated with 400u/kg of heparin. After an uneventful revascularization and termination of cardiopulmonary bypass, protamine 3mg/kg was initiated by slow infusion. After approximately 3 minutes of the infusion, the pulmonary arterial pressure had increased from 29/16 to 79/31. The protamine infusion was stopped and supportive care with small doses of epinephrine to a total of 50 mcg was initiated. Pulmonary pressures continued to rise and Ketorolac, 30mg IV, was administered. The pulmonary arterial pressures decreased to the patient’s baseline within 7 minutes of ketorolac administration (Chart). The protamine infusion was restarted without a further increase in pulmonary arterial pressure, and the activated clotting time returned to baseline. Estimated blood loss for the case was 500cc. The patient required intra-operative transfusion of one unit of cell saver and one unit of packed red blood cells to a hemoglobin of 7.9 g/dL. The postoperative bleeding was moderate, with losses of 250, 120, 45, 90, 190cc in the first 5 hours and 1800cc total for postop day 0. He received 4 units of packed red blood cells postop day 0 to maintain his hemoglobin greater than 9g/dL and was extubated the evening after surgery.

The use of the intravenous non-steroidal anti-inflammatory, ketorolac, to interrupt the AA cascade and production of thromboxane A2 and resolve PIPV has not been previously published. The use of ketorolac as a rescue treatment for PIPH should be balanced with possible increased bleeding and how severe the pulmonary hypertension is in the clinical setting. This case report suggests the potential for future investigation of ketorolac as an agent to treat PIPV in the acute setting.

References:
3 Hobbhahn et al, Anesthesia and Analgesi, Vol. 67, 1988; pp253-60
Hemodynamic Trend

Pressure (mm Hg)

- Red: Systemic Systolic Pressure
- Blue: Systemic Diastolic Pressure
- Yellow: Pulmonary Systolic Pressure
- Green: Pulmonary Diastolic Pressure
- Blue dashed: Central Venous Pressure

Protamine started at 11:45 am
Ketorolac administered at 11:51 am
Selective Antegrade Cerebral Perfusion is Protective Against Cerebral Desaturation with Near Infrared Spectroscopy

Stevens Q, Justison G, Weitzel N, Ahlgren B, Reece T, Seres T
University of Colorado, Aurora, CO, USA

Introduction:
Near infrared spectroscopy (NIRS) provides continuous noninvasive transcutaneous analysis of regional brain oxygen saturation. It has been suggested that declines of cerebral oxygen saturation may indicate cerebral ischemia (1). Recent evidence suggests that poor postoperative outcomes may be predicted by increased degree of cerebral desaturation during aortic arch surgery, possibly due to the necessity of using circulatory arrest (3). Performing selective antegrade cerebral perfusion (SACP) during circulatory arrest may be protective against neurologic morbidity (4, 5). We hypothesized that SACP reduces cerebral hypoxic events. A retrospective study was carried out to compare the patterns of cerebral oximetry desaturation during right-sided SACP and circulatory arrest without SACP (CA).

Methods:
Patients presenting over a 2-year period undergoing aortic surgery using circulatory arrest and NIRS monitoring were included. Twenty-five patients met inclusion criteria; 4 underwent circulatory arrest only and 21 received SACP. Cerebral oxygen desaturation was defined as levels below 40% using NIRS. The cerebral oxygen desaturation below 40% was calculated as a cumulative area of the oxygen saturation curve below the 40% threshold. This parameter represents the severity and the length of desaturation in time. The desaturation patterns during SACP and CA were compared to the desaturation patterns at all time points outside of SACP or CA. The occurrence of in hospital stroke was also evaluated.

Results:
Analysis of NIRS values revealed significantly less area of desaturation below 40% during SACP, versus CA. When desaturation events did occur during SACP, they were more likely to occur on the patient’s left side (Table 1). Patients receiving SACP had significantly less area of desaturation below 40% during SACP (-179Â±809) than time points outside SACP (-8734Â±16840, p <0.03). Patients receiving CA only trended towards a greater area of desaturation below 40% during CA (-39970Â±35625) than time points outside CA (-17333Â±17317, p 0.44). One patient suffered from stroke in the SACP group versus no patients in the CA group (Chi Square=0.19).

Conclusions:
Significant cerebral desaturation events, values less than 40% measured by NIRS, in patients undergoing aortic surgery occurred with significantly less severity and duration during SACP than circulatory arrest alone. When cerebral desaturation events do occur during right-sided SACP they preferentially occur on the left side. Cerebral desaturations are more likely to occur in the SACP group at time points outside of SACP, and more likely to occur during CA in the absence of SACP. There was no significant difference in stroke risk between the SACP and CA groups.

References:
3. J Thorac Cardiovasc Surg. 2011; 141; 815-21
<table>
<thead>
<tr>
<th>Variable</th>
<th>SACP (n=21)</th>
<th>CA (n=4)</th>
<th>p values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>57±11</td>
<td>45±15</td>
<td>0.078</td>
</tr>
<tr>
<td>Case Duration (min)</td>
<td>445±97</td>
<td>420±108</td>
<td>0.654</td>
</tr>
<tr>
<td>Bypass Duration (min)</td>
<td>196±54</td>
<td>183±68</td>
<td>0.671</td>
</tr>
<tr>
<td>Cross Clamp duration (min)</td>
<td>99±57</td>
<td>133±54</td>
<td>0.356</td>
</tr>
<tr>
<td>Circ Arrest Temperature (°C)</td>
<td>23.7±2.3</td>
<td>20.8±1.7</td>
<td>0.023</td>
</tr>
<tr>
<td>Hospital LOS (days)</td>
<td>12±9</td>
<td>8.3±3.2</td>
<td>0.503</td>
</tr>
<tr>
<td>NIRS Sampling Time during Circ Arrest (sec)</td>
<td>3380±1888</td>
<td>3262±1181</td>
<td>0.906</td>
</tr>
<tr>
<td>Total NIRS Sampling Time (sec)</td>
<td>47218±16716</td>
<td>35671±20682</td>
<td>0.412</td>
</tr>
<tr>
<td>Total Area of Desat (&lt;40%) During Circ Arrest</td>
<td>-179±809</td>
<td>-39970±35625</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Area of Desat (&lt;40%) Left Side During Circulatory Arrest</td>
<td>-179±809</td>
<td>-33010±36573</td>
<td>&lt;0.0002</td>
</tr>
<tr>
<td>Area of Desat (&lt;40%) Right Side During Circulatory Arrest</td>
<td>0</td>
<td>-27840(n=1)</td>
<td></td>
</tr>
<tr>
<td>Total Area of Desat (&lt;40%) at time points outside Circulatory Arrest</td>
<td>-8734±16840</td>
<td>-17333±17317</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Values are mean±SD, p values are calculated by unpaired Student’s t test

Significant difference is determined at p<0.05

LOS: length of stay, NIS: near infrared spectroscopy