The effects of postoperative hematocrit on shunt occlusion for neonates undergoing single ventricle palliation

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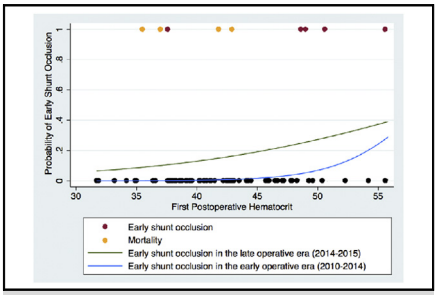
ABSTRACT

Objectives: Our primary objective was to test the effects of first postoperative hematocrit on early shunt occlusion for children undergoing systemic to pulmonary artery shunt placement. Because any intervention to reduce shunt occlusion is only beneficial if it reduces mortality or is, at least, mortality neutral, we also tested the effects of first postoperative hematocrit on in-hospital mortality.

Methods: We conducted a retrospective study on all neonates who underwent primary systemic to pulmonary artery shunt placement, with or without a Norwood/Damus–Kaye–Stansel procedure, at Columbia University Medical Center between January 2010 and July 2015. Univariable regression was used to test the effects of first postoperative hematocrit on early shunt occlusion and 30-day mortality, clustering standard errors by surgeon. In secondary analyses, we also tested associations between red blood cell transfusion volumes in the first 24 postoperative hours and first postoperative hematocrit, shunt occlusion, and mortality.

Results: Eighty infants met inclusion criteria. Median initial postoperative hematocrit was 41.7% (interquartile range, 37.9-46.0). Six infants (7.5%) died. Four infants (5.0%) died within the first 30 days. Five infants (6.3%) experienced early shunt occlusion. No children with early shunt occlusion died. In univariable models, for every 5 additional percentage points of hematocrit, an infant's odds of early shunt occlusion more than doubled (odds ratio, 2.70; $P = .009$). The odds of all-cause 30-day mortality remained unchanged.

Conclusions: Higher postoperative hematocrit levels are associated with early shunt occlusions in infants undergoing primary systemic to pulmonary artery shunt placement. Multicenter investigations are warranted to validate these findings and to determine ideal postoperative hematocrit targets for this population. (J Thorac Cardiovasc Surg 2016;■:1-9)



First postoperative hematocrit and early postoperative shunt occlusion.

Central Message

For neonates undergoing systemic to pulmonary artery shunts, higher hematocrit levels are associated with early shunt occlusion.

Perspective

A significant cause of systemic to pulmonary artery shunt failure in neonates is shunt occlusion. In a retrospective study of 80 infants, we found increased first postoperative hematocrit to be associated with early occlusion. Studies are needed to validate these results and determine ideal target hematocrits for this vulnerable population.

CONG

A significant cause of shunt failure in neonates after systemic to pulmonary artery shunt placement is shunt occlusion, yet little is known about why shunts occlude in some infants and not in others.[1-7] It has been hypothesized that, in addition to shunt anatomy,[7] fluid shifts and hemoconcentration might predispose children to shunt occlusion, especially after gastrointestinal surgeries,[8] but the majority of shunt occlusions occur in the early postoperative period, without associated surgeries.[5,6]

Beginning in the latter half of 2014, we noticed an increase in the incidence of early shunt occlusions in our neonatal cardiac intensive care unit. We conducted a

Scanning this QR code will take you to a video for the article.

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Abbreviations and Acronyms
FFP = fresh-frozen plasma
IQR = interquartile range
OR = odds ratio
PRBC = packed red blood cell

retrospective chart review to investigate the causes of this increase. Given that platelet adhesion in pulsatile shear flow is known to be significantly influenced by the concentration and characteristics of neighboring red blood cells,[9,10] we hypothesized that increased hematocrit in the early postoperative period might be a cause of early shunt occlusion. Therefore, we set out to test the associations between first postoperative hematocrit and early shunt occlusion for children undergoing systemic to pulmonary artery shunt placement at our center. Because any intervention to reduce shunt occlusion is only beneficial if it reduces mortality or is, at least, mortality neutral, we also set out to test the associations between first postoperative hematocrit and in-hospital mortality.

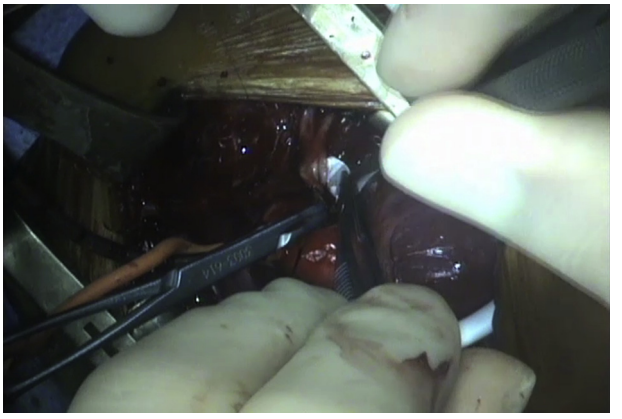
MATERIALS AND METHODS

Patients

We performed a retrospective study, including all neonates who underwent systemic to pulmonary artery shunt placement at Columbia University Medical Center, with or without a Norwood/Damus–Kaye–Stansel procedure, between January 2010 and July 2015. These dates were chosen to include all data available in our clinical database at the onset of this study. Infants undergoing right ventricle to pulmonary artery shunt placement were not included. One child who underwent systemic to pulmonary artery shunt placement but who had an initial postoperative hematocrit of 66.8 and who consequently rapidly underwent partial exchange transfusion was excluded from the analysis. This study was approved by the Columbia University Medical Center Institutional Review Board, with waiver of informed consent.

Operative and Perioperative Management

At our institution, systemic to pulmonary artery shunts are placed by lateral thoracotomy or median sternotomy on the basis of patient cardiac anatomy and surgeon preference (see Video 1). Intraoperative fluid management includes continuation of maintenance fluids or addition of normal saline or Ringer's lactate as determined by the anesthesia team. All shunted infants leave the operating room intubated and are recovered in the neonatal cardiac intensive care unit. Choice of initial inotropic support is based on patient condition and anesthesiologist and surgeon preferences. In the perioperative period, all shunted patients receive intravenous maintenance fluids (of 100 mL/kg·d) with dextrose and standard electrolytes. Our current anticoagulation practice is to initiate oral aspirin approximately 12 hours after shunt placement (at a dose of 20 mg/d), assuming the platelet count is greater than 100 K and surgical site bleeding is minimal. Until mid-2010, shunted infants at our center received aspirin, at the same dose, only after full enteral feeds were established. There was a brief time in early 2010 when shunted infants operated on by a single surgeon were given heparin after hemostasis was achieved, but none was started on heparin within the first 24 postoperative hours. Packed red blood cell (PRBC) transfusion thresholds are determined on an individual basis by patient condition and intensive care team discretion.



VIDEO 1. Blalock–Taussig shunt placement. The video details the placement of a Blalock–Taussig shunt as part of a single ventricle palliation. Video available at: http://www.jtcvs.org.

Risk Factors

The primary variable of interest was the first postoperative hematocrit on returning to the intensive care unit. All hematocrit levels were measured in our clinical laboratory using a Sysmex XN-9000 analyzer (Sysmex, Kobe, Japan), which calculates percent hematocrit using cumulative pulse height detection. Data also were collected on sex, weight, intracardiac anatomy, shunt type and size (first in millimeters and then indexed to birth weight), use of cardiopulmonary bypass, performance of a pulmonary artery plasty, intraoperative PRBC transfusion volume, fluid balance on pulmonary bypass, cell saver transfusion volume coming off bypass, arterial oxygen tension leaving the operating room, first postoperative platelet count, presence and volume of postoperative PRBC, platelets, and fresh-frozen plasma (FFP)/cryoprecipitate transfusion administrations in the first 24 postoperative hours (or until shunt occlusion), type and timing of anticoagulation, peak vasoactive-inotropic score within the first 24 postoperative hours, surgeon, and operative era. Earlier operative era was defined as all patients undergoing operation before July 1, 2014; later operative era was defined as all patients operated on or after that date. Vasoactive-inotropic score was calculated using the formula previously described by Gaies and colleagues.[11]

Outcomes

The primary outcome of interest was early shunt occlusion within the first 24 postoperative hours requiring surgical intervention, including shunt revision, catheter intervention, or manual shunt manipulation. Infants with shunt occlusion determined on autopsy also were included. Shunt occlusion was presumed on the basis of the loss of a shunt murmur and inability to visualize shunt flow on echocardiogram in the presence of systemic desaturations and an acute decrease in end-title carbon dioxide without an identifiable pulmonary cause and with amelioration of symptoms after manual manipulation of the shunt or shunt revision. No patients with early shunt occlusion died before intervention. All patients had heparin boluses given, their chests opened, and shunts manually manipulated to relieve obstruction. Patients who did not recover after this manipulation were taken back to the operating room for immediate shunt exploration and revision and potential placement on extracorporeal membrane oxygenation. No shunts were observed to be kinked on visual inspection, and in no patients did the mere act of opening the chest relieve symptoms. Consideration also was given to diagnostic or therapeutic catheterization; 2 patients who had partial but not complete recovery after manual shunt manipulation were taken to the catheterization laboratory, where angiography was performed, demonstrating shunt narrowing without kinking, and shunts were stented. All patients recovered after shunt