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EDITORIAL COMMENTARY

Should we be doing the Norwood procedure sooner?

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See related article on pages 2181-8.

The article by Lynch and colleagues from the University of Pennsylvania and Children's Hospital of Philadelphia in

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this issue of the *Journal* draws the provocative conclusion that the Norwood procedure should not be delayed beyond the first few days after birth. They suggest that there is a greater risk of brain injury when surgery is undertaken at 5 days of age relative to 3 days of age. There are some important limitations to the study, however, that cast doubt on the advisability of applying this recommendation to all patients with hypoplastic left heart syndrome (HLHS) irrespective of clinical status.

The report describes a comprehensive study of 37 neonates who had a Norwood procedure and who underwent preoperative and early postoperative brain magnetic resonance imaging scans. The patients also underwent preoperative and postoperative monitoring of cerebral oxygen saturation and cerebral blood flow with custom-designed optical techniques analogous to near-infrared

spectroscopy. The study confirms previous reports from the University of Pennsylvania, as well as other centers, that there is a high incidence of new white matter injury detectable by magnetic resonance imaging after cardiac surgery, as well as an important incidence of preoperative brain injury. In addition to greater age at surgery, Lynch and colleagues identified another surprising predictor of postoperative brain injury, namely higher preoperative brain blood flow.

The finding that age at surgery is a strong predictor of the probability of postoperative periventricular leukomalacia is difficult to explain. Lynch and colleagues have not speculated in any detail as to why this might be the case. For example, perhaps the subset of patients with HLHS who have a rapidly decreasing pulmonary resistance and unrestrictive atrial septum might have reduced cerebral blood flow preoperatively, and this could increase the risk of postoperative white matter injury. This hypothesis, however, would not fit with the paradoxical *increase* in cerebral blood flow index found in this study. Furthermore, another subset of neonates with HLHS has a highly restrictive atrial septum and is profoundly blue from the time of birth until the atrial septum is opened, usually by interventional catheter methods. These patients are likely to have an increasing oxygen saturation and decreasing cerebral blood flow during the days after their atrial septal procedure. Commonly, there is also an improvement in indices of renal and hepatic function during this period of recovery from the early hypoxic insult. Presumably the preoperative cerebral oxygen saturation and blood flow indices are quite different in this subset relative to the patients at the opposite end of the spectrum with very low pulmonary resistance from the time of birth. Other complicating factors in suggesting a uniform approach to the timing of Norwood surgery (the earlier the better for all) include the presence of antegrade cerebral blood flow in the subset of patients with aortic stenosis versus the subset who have reduced cerebral blood flow secondary to the presence of aortic atresia and a highly obstructive aortic isthmus. Without question, measures of cerebral oxygen saturation and cerebral blood flow will be quite different in these 2 anatomic subsets of patients.

The University of Pennsylvania has been a leader in developing sophisticated methods for optical imaging of the brain, as well as deriving measures of cerebral oxygenation and cerebral blood flow through near-infrared spectroscopy. It is important to understand that the instrument used in this study for assessment of cerebral oxygenation and cerebral blood flow is a custom-built device rather than one of the commercially available near-infrared spectroscopy machines that are currently in clinical use. Clearly the finding that the “blood flow index” derived from this

equipment suggests increased preoperative brain blood flow in patients who subsequently had worse postoperative periventricular leukomalacia must raise doubts regarding the validity of this monitoring technique for cerebral blood flow in the setting of HLHS. Perhaps the cerebral hemodynamics specific to HLHS somehow invalidate the technique.

The most likely unifying hypothesis to explain Lynch and colleagues’ counterintuitive findings (more preoperative cerebral blood flow results in more injury and 2 extra preoperative days result in more injury) is the fact that they were using spot measurements of cerebral oxygen saturation and brain blood flow index, with only a single preoperative optical measurement immediately before surgery and limited measurements (every 2 hours for the first 12 postoperative hours). Previous reports that have explored the predictive value of perioperative cerebral oxygenation have used continuous measures of cerebral oxygenation by near-infrared spectroscopy for 24 hours or longer and have looked at indices such as the average cerebral oxygen saturation or the duration below a cutoff saturation.

In summary, Lynch and colleagues have treated infants with HLHS as a uniform patient population while the reality is that this term covers a very wide spectrum of both anatomy and physiology. The conclusion that age at surgery will always be an important predictor of postoperative brain injury defies logic for certain subcategories of patients. Furthermore other indices of organ function apart from the brain are clearly still in a recovery phase in many patients at 3 days after birth. It is generally accepted that patients with preoperative renal or hepatic dysfunction do less well if early surgery is undertaken before there has been full metabolic recovery. Although cerebral injury must be avoided if at all possible, other organ systems and indeed the whole patient must be optimized when it comes to timing decisions. Furthermore, others have documented that most of the early postoperative changes seen on brain magnetic resonance imaging at 1 or 2 postoperative weeks have recovered by 6 months.¹ In the current study, Lynch and colleagues have not documented that the changes they are seeing are of long-term functional significance by undertaking developmental outcome studies. It will be valuable to extend this work in future studies with collection of more comprehensive chronology of the optical changes noted and validation of the blood flow index in patients with HLHS, including more detailed subgroup analyses.

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