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TECHNIQUE OF CIRCULATORY ARREST MAKES A DIFFERENCE

To the Editor:

I enjoyed the recent article by Damberg and colleagues¹ and the accompanying editorial commentary by Kouchoukos² regarding the ongoing differences of opinion regarding the application of deep hypothermic circulatory arrest during aortic surgery in adults. The same controversy continues among congenital surgeons. However, I was surprised to see both in the article by Damberg and colleagues¹ as well as the editorial commentary by Kouchoukos that the only technical detail of circulatory arrest that was discussed was its duration. I was also surprised to see that the Yale group continues to use the alpha-stat pH strategy despite good evidence that this provides less neuroprotection than the alternative pH stat strategy (ie, CO₂ addition) and in fact is likely to shorten the safe maximal duration of circulatory arrest.

The alpha-stat strategy is appropriate for normal flow cardiopulmonary bypass in adults because it reduces the microembolic load to the brain by more closely linking cerebral blood flow with cerebral oxygen requirement.³ However, cerebral blood flow has 2 functions for the patient undergoing deep hypothermic circulatory arrest. In addition to supplying oxygen and other substrates, cerebral blood flow also cools the brain to deep hypothermia. Cerebral blood flow is reduced by use of the more-alkaline alpha-stat strategy so that the total duration of cooling must increase to compensate. In fact, the total volume of blood (ie, CBF in mL/min × time) needed to cool the brain to the desired deep hypothermic temperature will be the same with either alpha-stat or pH-stat.

There are additional reasons why pH-stat should be preferred.

1. pH-stat is known to suppress cerebral metabolism.⁴ Studies in our laboratory⁵ confirmed that pH-stat lengthens the safe duration of deep hypothermic circulatory arrest for a given temperature and hematocrit.
2. pH-stat improves oxygen availability by counteracting the leftward shift of oxyhemoglobin induced by hypothermia. This is particularly important in the early cooling phase, when the brain is warm but the blood is cold.
3. The only prospective, randomized clinical trial of pH strategy during deep hypothermic bypass that included patients undergoing deep hypothermic circulatory arrest demonstrated an improved perioperative clinical outcome with pH-stat.⁶ Although this trial was in infants, in view of the aforementioned points, we believe the conclusions can be extrapolated to adults undergoing deep hypothermic circulatory arrest.

In addition to the importance of pH strategy, our laboratory studies over many years as well as 2 randomized prospective clinical trials in infants demonstrated that hematocrit is also critical in determining the safe maximum duration of circulatory arrest. Interestingly the Yale article fails to mention the level of hematocrit that was applied. There is no question that the outdated dogma that hemodilution improves the safety of circulatory arrest is unsupported by any current data. In fact, our clinical trials demonstrated that a hematocrit greater than 23.5% was required to avoid neurodevelopmental impairment in infants undergoing deep hypothermic bypass with or without circulatory arrest. Furthermore, our laboratory studies demonstrated an additive impact of low hematocrit, alkaline pH strategy (alpha-stat), greater temperature, and longer duration of circulatory arrest. At a minimum, adult centers undertaking deep hypothermic circulatory arrest in addition to those proposing alternative methods of neuroprotection should undertake a prospective randomized study with careful cognitive assessment before and after surgery to investigate optimal pH strategy and hematocrit during deep hypothermic circulatory arrest. We need to move beyond a simple debate of safe maximal duration.

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ALPHA-STAT VERSUS pH-STAT: WE DO NOT PAY IT MUCH MIND

Video clip is available online.

Reply to the Editor:

We thank Dr Jonas for his letter to the Editor¹ in response to our recent publication regarding our favorable long-term experience with deep hypothermic circulatory arrest (DHCA) in aortic arch surgery.² Dr Jonas is an absolute world leader in the physiology of DHCA in pediatric cardiac surgery.

There are 2 general approaches to pH management in DHCA intended to address the increased solubility of carbon dioxide (CO₂) at subphysiologic temperatures; each approach has proponents and detractors. In the alpha-stat approach, pH is managed in a “temperature-corrected” format, keeping the carbon dioxide partial pressure (pCO₂) in the normal range at 37°C, recognizing that the true pCO₂ in the patient will be lower, given the lower body temperature. In the pH-stat approach, CO₂ is added to maintain a pCO₂ of 40 at the patient’s true (low) temperature. The addition of CO₂ has well-known cerebral vasodilatory effects and results in increased brain perfusion.

Dr Jonas has unequivocally demonstrated improved brain blood flow in infants undergoing operations under DHCA when their anesthetic management takes a pH-stat approach.³

However, the following reasons motivate us to continue as we have been doing successfully for more than 3 decades.

FIGURE 1. Clean, uncluttered field offered by DHCA for aortic arch replacement.

1. Excellent clinical results. Our mortality (overall, 2.9%; elective, 1.5%) and stroke (overall, 2.0%; elective, 1.2%) rates are among the lowest reported in large series of aortic arch operations conducted under DHCA^{2,4} and supported by clinical⁵ and quantitative neuropsychologic testing.⁶
2. Strokes in adult aortic surgery are generally embolic, not ischemic.^{4,7} A pH-stat approach would not be protective against particulate embolization.
3. No randomized trials in adults. We are not aware of randomized trials of the 2 pH management strategies in adults undergoing DHCA.
4. Potential for deleterious “brain steal” with the alpha-stat approach. The resultant global cerebral vasodilation of pH-stat can reduce cerebral perfusion pressure and result in “brain steal,” in which blood flow is shunted away from poststenotic regions in adult humans.⁸
5. Theoretical beneficial shift in the oxygen dissociation curve. We have come across no evidence to show that this theoretical benefit of higher CO₂ has clinical impact.

VIDEO 1. Total aortic arch replacement under DHCA. Video available at: [https://www.jtcvs.org/article/S0022-5223\(18\)30869-9/fulltext](https://www.jtcvs.org/article/S0022-5223(18)30869-9/fulltext)