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Commentary: How cold should we go?

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The cardinal experiments of the great Dr Bigelow in the 1950s demonstrated the exponential decrease in brain metabolic rate as temperature falls (Figure 1).¹ This basic science permitted Meshalkin and colleagues' application of circulatory arrest^{2,3} in infants with congenital heart disease and then Griep and colleagues'⁴ dramatic introduction of straight deep hypothermic arrest (DHCA) into clinical practice for aortic arch surgery.

In mathematics and physics, it is often instructive to examine boundary conditions, where extreme circumstances can be probed. In this regard, as concerns optimal temperatures for brain preservation, the senior author's experience may be helpful by documenting the complete adequacy of brain preservation at low temperatures in the extreme condition of no flow whatsoever, that is, straight DHCA.

In thousands of cases, the senior author has used antegrade perfusion only once, and never used retrograde cerebral perfusion. All operations have been done under straight DHCA, with no adjunct perfusion of any kind.⁵⁻⁷

We have cooled to 20°C for hemiarch procedures and to 18°C for total arch procedures, without any antegrade or retrograde perfusion whatsoever. Circulatory arrest times ranged up to 50 minutes or more in cases of extreme complexity.⁶

CENTRAL MESSAGE

Seese et al report more favorable outcomes in elective aortic hemiarch replacements under moderate rather than deep hypothermia. However, questions remain regarding the interpretation of these data.

We have examined outcomes rigorously by multiple quantitative modalities. Mortality was very low, 1.4% for elective procedures. Stroke rate was very low, 1.2% for elective procedures.^{6,7} We compared preoperative with postoperative quantitative assessment of cognitive abilities, with no differences noted.^{8,9} We even tested a large group of individuals with high cognitive needs for their work, wanting to make sure that subtle deficits in people with ordinary jobs did not escape detection.⁸ The "high-cognitive" group included doctors, lawyers, professors, administrators, scientists, artists, musicians, and writers. No change from preoperative occupational performance was noted.

Perhaps most compelling is recent data we have compiled on long-term survival after operations performed under straight DHCA.⁷ Remarkably, we found that long-term survival of these patients having undergone such major aortic surgery was no different from that of an age- and sex-matched population: 74.4% at 8 years (Figure 2).⁷

So, it seems that at the boundary condition of no flow, patients are quite safe at these temperatures: 20°C for hemiarch procedures and to 18°C for total arch procedures. Unlike the authors of the study¹⁰ discussed in this Commentary, we noted no adverse sequelae from the hypothermia in any of our multiple published reviews.¹¹⁻¹⁴

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FIGURE 1. Dramatic decrease in cerebral oxygen consumption as temperature falls. Note near-nil oxygen consumption at 18°C. Reprinted with permission from Kirklin and colleagues.¹

Now, the authors of the present study¹⁰ are providing brain perfusion—by the antegrade route. So, why do they need hypothermia at all? They must not have confidence in their antegrade brain perfusion. They must have feared inadequate or uneven antegrade perfusion. We are provided no specific details as to which arteries were perfused or at what flow rates or at what rewarming rates. This would be very important information, perhaps lacking in the Society of Thoracic Surgeons database. Few surgeons cannulate and

perfuse all 3 vessels: innominate, left carotid, and left subclavian. Few surgeons occlude the left subclavian to prevent retrograde steal. So, even with antegrade perfusion, it must be feared that regions of the brain may remain unperfused or underperfused due to failure to supply all 3 branches, potential incomplete circle of Willis, or unknown optimal perfusion rate. A sobering recent report finds ubiquitous brain emboli in patients undergoing antegrade cerebral perfusion.¹⁵

FIGURE 2. Long-term survival of patients with interventions under deep hypothermic arrest is no different from the general population. Reprinted with permission from Damberg and colleagues.⁷

CHICKEN AND THE EGG

An obvious question that comes to mind is the following: Could the poorer outcomes in the patients cooled to lower temperatures be reflective of more severe pathology or more difficult operations? The authors do not provide any information on this point. It seems logical that experienced surgeons might cool lower if they were expecting a longer or more difficult procedure or if they encountered intraoperative technical difficulties. Details regarding the extent of operation, and statistical analysis with this factor included, could help us to put the findings of the study by Seese and colleagues¹⁰ into perspective. In this regard, the much greater rates of previous cardiac surgery in the lower temperature groups (Table 2 in their paper¹⁰) argues strongly for greater surgical complexity in the low-temperature patients, leading to a “chicken and the egg” problem.

Another question that arises is why there were essentially no valve-sparing aortic root replacements in this large number of cases reported. Another question for the authors concerns the finding that there were only minimal differences in permanent stroke among the temperature groups (Table 3 in their paper¹⁰); in fact, these minimal differences favored a lower temperature range than the 27°C that was optimal for survival. This warrants some comment.

The authors are to be commended for bringing so much data from hundreds of sites into analysis in this paper.¹⁰ Their suggestion—mid-range cooling to 27°C—seems a reasonable one for those who use antegrade perfusion.

We emphasize that straight DHCA is another excellent option, avoiding embolic strokes and protecting the brain well. This was the most common form of brain protection for the earlier generation of surgeons, and it still works very well.

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