

Neurologic Recovery after Prolonged Circulatory Arrest in Surgery for Aortic Dissection

I. Knezevic,¹ S. Sesok,² J. Bergsland,³ G. Poglajen,⁴ Igor D. Gregoric⁵

¹Department of Cardiovascular Surgery, ²Department of Neurology, and ⁴Department of Cardiology, University Medical Center, Ljubljana, Slovenia; ³Interventional Center, National Hospital, Oslo, Norway;

⁵The Texas Heart Institute at St. Luke's Episcopal Hospital, Houston, Texas, USA

ABSTRACT

Background: Brain injury manifested by subtle, transient neurologic and neuropsychologic dysfunctions occurs in about a quarter of patients who are subjected to periods of deep hypothermia and circulatory arrest (DHCA). We describe a patient who sustained minimal neurologic damage despite prolonged DHCA.

Methods: The patient was a previously healthy 62-year-old woman with acute type A aortic dissection that involved the ascending aorta. During surgery we established retrograde cerebral perfusion and DHCA to provide cerebral protection, and during the procedure the patient underwent 3 separate DHCA periods with a total circulatory arrest time of 91 minutes. Because of tubing damage, retrograde cerebral perfusion was not used during the final period (59 minutes). The patient's head was packed in ice to facilitate maintenance of brain hypothermia. Her average systemic temperature during the third period of circulatory arrest was 22.5°C.

Results: Extensive neuropsychologic testing, which was performed to assess the patient's cognitive functions and abilities at 4-month follow-up, showed an absence of global cognitive decline and only a moderate impairment of attentional capacity. Overall cognitive functioning was within the normal range and did not interfere with everyday activities or quality of life.

Conclusion: Although the total arrest time vastly exceeded the recommended safe period, our patient survived and sustained minimal neurologic damage. The combination of neuroprotective measures used may have contributed to this beneficial outcome.

INTRODUCTION

Acute type A aortic dissection remains a challenging surgical problem. In the 1960s, mortality was high [Safi 1998], but it has subsequently been reduced because of

advances in surgical techniques and neurologic protective measures. Today, we have reached a stage at which mere survival and the absence of gross neurologic deficits cannot be regarded as acceptable results. Subtle, transient neurologic and neuropsychologic dysfunctions occur as functional manifestations of brain injury in about a quarter of patients after periods of deep hypothermia and circulatory arrest (DHCA). The duration of DHCA and patient age correlate with postoperative neurologic outcome [Ergin 1999]. We report on a patient who had prolonged DHCA, necessitated by distal anastomosis disruption, but who sustained minimal neurologic damage.

CASE REPORT

A previously healthy 62-year-old woman, who had been treated only for hypertension, was admitted to a district hospital with chest pain of sudden onset. Routine laboratory test results were normal. Transesophageal echocardiography and computed tomographic angiography showed an acute type A aortic dissection that involved the ascending aorta. The dissection started at the sinus of Valsalva, extended into the aortic arch and descending aorta, and continued into the left iliac artery. The patient was hemodynamically stable and had no signs of neurologic damage.

The patient was urgently transferred to our center and was immediately taken to the operating room. The femoral artery was cannulated, and retrograde cerebral perfusion and DHCA were established to provide cerebral protection. At the beginning of extracorporeal circulation (ECC) sodium thiopental was administered (30 mg/kg body weight). The patient was cooled to 17°C, and circulatory arrest was maintained for 27 minutes. The ascending aorta and aortic arch were reconstructed with a Gelseal knitted graft (Vascutek, Inchinnan, Scotland) and running 4/0 Prolene suture. Suture lines were then sealed with BioGlue (CryoLife Inc., Atlanta, GA, USA).

After 20 minutes of rewarming, ECC was again discontinued for 5 minutes while extensive bleeding at the distal anastomosis was repaired. The patient's core temperature at that time was 22°C. When ECC was restarted, the bleeding worsened because of a disrupted distal suture line, and after 3 minutes, ECC was again stopped. Retrograde cerebral

Received July 22, 2008; accepted September 11, 2008.

Correspondence: Igor D. Gregoric, MD, P.O. Box 20345, MC 3-147, Houston, TX 77225-0345; 832-355-3000; fax: 832-355-6798 (e-mail: epongratz@heart.tbi.tmc.edu).

perfusion was not used during the final period of circulatory arrest (59 minutes) because of accidental ECC tubing damage that we were unable to repair during the operation. The patient's head was packed with ice to facilitate maintenance of brain hypothermia. Her average systemic temperature during the third period of circulatory arrest was 22.5°C.

A new graft was implanted with extreme technical difficulty. The new distal anastomosis was made 5 cm distal to the left subclavian artery, and brachiocephalic vessels were reattached to the graft by using a single-patch technique. Nonetheless, the bleeding continued because of profound coagulopathy, even after rewarming was completed, and could be controlled only by packing the chest and leaving the sternum open.

The patient was hemodynamically stabilized, transferred to the intensive care unit, and sedated with morphine and midazolam for 48 hours until reoperation. At that time, laps were removed. The coagulopathy was reversed, the bleeding was stopped, and the sternum was closed. The patient was extubated 3 days later. A computed tomographic scan of the head showed only moderate cortical atrophy and a small infarction in the right cerebellum. The rest of the patient's postoperative course was uneventful, and 17 days after the operation the patient was discharged and had no major neurologic deficits.

Extensive neuropsychologic testing was performed at 4-month follow-up to assess the patient's cognitive functions and abilities. Results showed an absence of global cognitive decline and only a moderate impairment of attentional capacity. The patient's standard attention score on the Neuropsychological Assessment Battery was 65 (moderate to severe impairment), and her score on the Repeatable Battery for the Assessment of Neuropsychological Status was 72 (indicating borderline impairment of short-term memory). The d2 Test of Attention showed that her information processing speed and mental concentration were below average. Overall cognitive functioning was within the normal range and did not interfere with everyday activities or quality of life (Table).

DISCUSSION

Our patient underwent 3 separate DHCA periods with a total circulatory arrest time of 91 minutes; in the last period of 59 minutes, retrograde cerebral perfusion was not used. Although the total arrest time vastly exceeded the recommended safe period, our patient survived and sustained minimal neurologic damage. We believe the 2 periods of restored circulation, although brief, replenished depleted oxygen stores in the brain tissue to some extent. In addition, embedding the patient's head in ice topically lowered the brain tissue temperature, thereby reducing its metabolic rate.

With new drugs such as glutamate antagonists, which further reduce the metabolic rate of the neural tissue, is it time to recalculate the DHCA "safe period"? Recent animal trials suggest that DHCA could be maintained for as long as 75 minutes without causing major neurologic deficits [Drabek 2007]. Monitoring techniques have been developed that,

Neurologic Testing Performed at 4-Month Follow-up to Assess the Patient's Cognitive Functions and Abilities

Neurologic Tests Performed	Score	Range
d2 Test of Attention		
Total number of items processed	82*	Below average
Concentration performance	85*	Below average
Stroop Color and Word Test		
Word score	32†	Below average
Color score	23†	Below average
Color-word	26†	Below average
Interference	63†	Within average
Color Trials Test		
Color Trials 1	94*	Within average
Color Trials 2	110*	Above average
Wisconsin Card Sorting Test		
Categories completed	6 (>16%)‡	Above average
Trials to complete first category	12 (>16%)‡	Above average
Failure to maintain set	0 (>16%)‡	Above average
Learning to learn	2.8 (>16%)‡	Above average
Perseverative responses	8 (>99%)‡	Above average

*Based on standard scores.

†Based on T scores.

‡Raw scores and percentile.

when used to guide the implementation of various surgical adjuncts, reduce spinal cord injury during thoracoabdominal aneurysm surgery [De Haan 1998]. Similar monitoring techniques might also be beneficial in patients in DHCA, enabling intraoperative assessment of functional brain integrity and alerting surgeons to the development of any ischemic lesions. These techniques would allow clinicians to take, in a timely fashion, additional protective surgical and medical measures that could prevent, or at least reduce, ischemic damage to the brain.

Improvements in surgical technique have led to a considerable reduction of overall morbidity and mortality in the surgical treatment of aortic dissections. Morbidity and mortality related to neurologic complications remain significant, however [Carrascal 1998]. The high risk of neurologic complications is partly attributable to the high metabolic rate of neurons and their limited ability to store extra glycogen and oxygen, which limit the anaerobic metabolic capability of brain tissue, so that most neuronal activity depends on instant delivery of glucose and oxygen from the bloodstream [Guyton 2000].

DHCA is the standard method of cerebral protection in aortic arch surgery, although a hybrid approach that includes debranching of arch vessels has been reported [Matalanis 2006]. Circulatory arrest gives the surgeon a limited period of time to carry out the aortic repair [Bachet 2002]. Retrograde cerebral perfusion is commonly used as an adjunct to DHCA to enhance cerebral protection [Safi 1997]; however, newer techniques use antegrade cerebral perfusion instead, with excellent results [Barnard 2004]. Retrograde cerebral perfusion provides metabolic support, expels atheromatous and gaseous emboli from the

cerebral vasculature, and maintains adequate hypothermia of the cerebral tissue [Reich 2001]. Okita et al [1998] suggested that retrograde perfusion safely extends the duration of DHCA.

McCullough et al [1999] calculated the theoretical safe duration of circulatory arrest on the basis of oxygen consumption rates in the adult human brain at various temperatures. According to their findings, the safe period of arrest is about 30 minutes at 15°C and about 40 minutes at 10°C. If the period of arrest exceeds these times, the risk for ischemic cerebral injury substantially increases.

CONCLUSION

Even though we greatly exceeded the safe period of 30 minutes of DHCA, our patient, a 62-year-old woman surgically treated for type A dissection, recovered with minimal neurologic damage. We believe that the beneficial outcome of the operation may also have resulted from the combination of neuroprotective measures used (sodium thiopental, hypothermia, and topical cooling of the head) and 2 short reperfusion episodes.

Our case confirms that little is known about brain metabolism during hypothermic circulatory arrest and that despite catastrophic complications such as anastomosis disruption, heroic efforts to save patients sometimes produce a good outcome.

REFERENCES

- Bachet J, Guilmet D. 2002. Brain protection during surgery of the aortic arch. *J Card Surg* 17:115-24.
- Barnard J, Dunning J, Grossebnier M, et al. 2004. In aortic arch surgery is there any benefit in using antegrade cerebral perfusion or retrograde cerebral perfusion as an adjunct to hypothermic circulatory arrest? *Interact Cardiovasc Thorac Surg* 3:621-30.
- Carrascal Y, Guerrero AL, Maroto LC, et al. 1998. Neurological complications of aortic artery surgery. *Rev Neurol* 27:854-61.
- De Haan P, Kalkman CJ, Jacobs M. 1998. Spinal cord monitoring with myogenic motor evoked potentials: early detection of spinal cord ischemia as an integral part of spinal cord protective strategies during thoracoabdominal aneurysm surgery. *Semin Thorac Cardiovasc Surg* 10:19-24.
- Drabek T, Fisk JA, Dixon CE, et al. 2007. Prolonged deep hypothermic circulatory arrest in rats can be achieved without cognitive deficits. *Life Sci* 81:543-52.
- Ergin MA, Uysal S, Reich DL, et al. 1999. Temporary neurological dysfunction after deep hypothermic circulatory arrest: a clinical marker of long-term functional deficit. *Ann Thorac Surg* 67:1887-90.
- Guyton AC, Hall JE. 2000. Textbook of medical physiology. 10th ed. Philadelphia: W.B. Saunders Company. p. 714.
- Matalanis G, Durairaj M, Brooks M. 2006. A hybrid technique of aortic arch branch transposition and antegrade stent graft deployment for complete arch repair without cardiopulmonary bypass. *Eur J Cardiothorac Surg* 29:611-2.
- McCullough JN, Zang N, Reich D, et al. 1999. Cerebral metabolic suppression during deep hypothermic circulatory arrest in humans. *Ann Thorac Surg* 67:1895-9.
- Okita Y, Takamoto S, Ando M, et al. 1998. Mortality and cerebral outcome in patients who underwent aortic arch operations using deep hypothermic circulatory arrest with retrograde cerebral perfusion: no relation of early death, stroke, and delirium to the duration of circulatory arrest. *J Thorac Cardiovasc Surg* 115:129-38.
- Reich DL, Uysal S, Ergin A, et al. 2001. Retrograde cerebral perfusion as method of neuroprotection during thoracic aortic surgery. *Ann Thorac Surg* 72:1774-82.
- Safi HJ, Miller CC III, Reardon MJ, et al. 1998. Operation for acute and chronic aortic dissection: Recent outcome with regard to neurological deficit and early death. *Ann Thorac Surg* 66:402-11.
- Safi HJ, Miller CC III, Iliopoulos DC, et al. 1997. Staged repair of extensive aortic aneurysm: improved neurologic outcome. *Ann Surg* 226:599-605.