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Safety of Unilateral Antegrade Cerebral Perfusion at 22°C Systemic Hypothermia

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ABSTRACT

Background. The superiority of antegrade cerebral perfusion (ACP) in aortic surgery is widely accepted, but the sufficiency of unilateral cerebral perfusion and the optimal systemic temperature during the operation are still controversial.

Methods. Thirty patients who underwent operation with unilateral ACP at a systemic temperature of 22°C between January 2005 and September 2007 were included in this study. The mean age (±SD) of the patients was 58 ± 11 years, and 21 (70%) of the patients were male. The indication for surgery was acute type A aortic dissection in 14 patients (47%), degenerative aortic aneurysm in 9 patients (30%), dissecting aortic aneurysm in 6 patients (20%), and intramural hematoma in 1 patient (3%). Supracoronary ascending aorta replacement was performed in 13 patients (43%). Eight patients (27%) underwent ascending aorta and hemiarch replacement. The Bentall procedure was performed with hemiarch replacement in 3 patients (10%). Three patients (10%) underwent total aortic arch replacement, and 2 patients (7%) underwent the Bentall procedure. The ascending aorta, aortic arch, and descending aorta were replaced in 1 patient (3%).

Results. Hospital mortality was limited to 1 patient (3.3%). A permanent or transient neurologic deficit was not detected in any of the survivors. The mean cardiopulmonary bypass, aortic cross-clamp, and ACP times were 144 ± 40 minutes, 82 ± 28 minutes, and 30 ± 11 minutes, respectively. The mean mechanical ventilation time was 18 ± 9 hours. The mean stay in the intensive care unit was 2.3 ± 1.1 days, and the mean hospital stay was 12 ± 6 days.

Conclusion. Unilateral ACP with systemic hypothermia at 22°C is safe and has satisfactory clinical results. Establishing ACP via cannulation of the right axillary artery is fast and simple. The presence of fewer cannulas in the operation field provides an operative condition as convenient as the deep hypothermic circulatory arrest technique.

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INTRODUCTION

The success in aortic procedures is directly related to cerebral protection techniques, especially during deep hypothermic circulatory arrest (DHCA). Recent studies have shown that neurologic complications are decreased with antegrade cerebral perfusion (ACP) [Kazui 2000; Hagl 2001]. Although the superiority of ACP is widely accepted, there is still debate regarding perfusion characteristics, such as the sufficiency of unilateral perfusion and the optimal systemic temperature [Harrington 2007]. Obviously, new clinical and laboratory studies are needed to obtain better results.

MATERIALS AND METHODS

Between January 2005 and September 2007, 30 patients underwent aortic surgery with unilateral ACP at a systemic temperature of 22°C. The mean age (±SD) of the patients was 58 ± 11 years, and 21 (70%) of the patients were male. The indication for surgery was acute type A aortic dissection in 14 patients (47%), degenerative aneurysm in 9 patients (30%), dissecting aneurysm in 6 patients (20%), and intramural hematoma in 1 patient (3%). Sixteen patients (53%) underwent emergency surgery for aortic rupture or acute aortic dissection. Three patients (10%) had a history of previous cardiovascular intervention. Sixteen patients (55%) had hypertension, 4 of 14 patients who underwent elective aortic surgery had coronary artery disease (preoperative coronary angiography was not performed for patients who underwent emergency surgery), 4 patients (13%) had diabetes mellitus, and the other 4 patients (13%) had chronic obstructive pulmonary disease. Preoperative creatinine levels were >1.5 mg/dL in 6 patients (20%), but none of the patients required hemodialysis. Cardiac tamponade was present in 3 patients (21%), and cerebral, visceral, or extremity malperfusion was not seen in any of the patients before the operation.

Operative Technique

In the majority of the patients (28, 93%), operation was performed via median sternotomy. In the other 2 patients (7%), a clamshell incision was preferred for replacing the descending aorta. In all of the patients, we cannulated the right axillary artery and the right atrium for cardiopulmonary bypass (CPB). The axillary artery was cannulated directly, as is described in one of our previous report [Sanioglu 2007]. Myocardial protection was achieved via antegrade and retrograde cold blood cardioplegia at 20 minute intervals, and the innominate and left carotid arteries were prepared before systemic arrest. When the rectal temperature reached 22°C during the cooling period, the pump flow rate was decreased to 10 mL/kg per minute, and the innominate artery was clamped. The retrograde blood flow from the left carotid artery was evaluated following the aortotomy, and when an adequate retrograde blood flow was observed, the left carotid artery was clamped. The left subclavian artery was clamped only in the patients who underwent total arch replacement. The blood pH was adjusted during CPB by means of an α-stat strategy. All distal aortic anastomoses were performed with an open distal technique. In patients with acute type A aortic dissection, dissected layers of the aortic wall were reconstructed with inner and outer Teflon felts with monofilament suture, as described for the sandwich technique. An arch-first technique and branched grafts were used in patients who underwent total arch replacement.

The supracoronary ascending aorta was replaced in 13 patients (43%). Eight patients (27%) underwent ascending aorta and hemiarch replacement. The Bentall procedure with hemiarch replacement was performed in 3 patients (10%). Three patients (10%) underwent total aortic arch replacement, and 2 patients (7%) underwent the Bentall procedure. The ascending aorta, the aortic arch, and the descending aorta were replaced in 1 patient (3%). Concomitant cardiac procedures were performed in 7 patients (23%). Table 1 lists all of the interventions.

RESULTS

ACP was set up successfully in all of the patients with no technical difficulty. A transient injury of the brachial plexus was observed as a complication of axillary artery cannulation in 1 patient (3%).

Hospital mortality was confined to 1 patient (3.3%). This patient underwent total aortic arch replacement for acute type A aortic dissection and could not be weaned from CPB. Without including this patient, the mean CPB, aortic cross-clamp, and ACP times were 144 ± 40 minutes, 82 ± 28 minutes, and 30 ± 11 minutes, respectively. The DHCA duration was longer than 30 minutes in 11 patients (37%). No permanent or transient neurologic deficits were observed in any of the survivors.

The mean postoperative drainage volume was 964 ± 268 mL, and the mean amount of blood transfusions was 2.3 ± 0.5 units. None of the patients required readmission for operation for excessive bleeding, and cardiac tamponade did not occur in any of patients. Serum creatinine levels >1.5 mg/dL were seen in 6 patients preoperatively and in 14 patients postoperatively. None of the patients required hemodialysis for acute renal failure. The mean mechanical ventilation time was 18 ± 9 hours. The mean length of the intensive care unit stay was 2.3 ± 1.1 days, and the mean hospital stay was 12 ± 6 days.

Table 1. Operative Technique*

Operation	No. of Patients
Ascending aorta + total arch + descending aorta replacement	1
Total arch replacement + CABG	1
Total arch replacement	2
Modified Bentall procedure + hemiarch replacement	3
Hemiarch replacement	3
Hemiarch replacement + aortic valve repair	1
Hemiarch replacement + CABG	1
Hemiarch replacement + AVR	1
Hemiarch replacement + CABG + AVR	2
Modified Bentall procedure	2
Ascending aorta replacement + aortic valve repair	1
Ascending aorta replacement	12
Total	30

*CABG indicates coronary artery bypass grafting; AVR, aortic valve replacement.

DISCUSSION

Deep hypothermia with circulatory arrest is the generally used method of cerebral protection in type A aortic dissections and aortic arch surgery. It is a safe procedure for short periods of circulatory arrest; however, circulatory arrest times that exceed 25 minutes, 40 minutes, and 60 minutes have been demonstrated to carry a high risk of transient neurologic deficit, stroke, and mortality, respectively [Svensson 1993]. Many techniques and approaches have been attempted to overcome the serious consequences of interrupting the arch-derived blood flow to the brain during repairs. Although satisfactory results have previously been reported for retrograde cerebral perfusion, recent randomized clinical trials have revealed no evidence of any cerebral metabolic, neurologic, or neuropsychological benefits for retrograde cerebral perfusion [Ehrlich 2000; Bonser 2002]. Nowadays, the widely used adjuvant method of cerebral protection during hypothermic arrest is ACP.

In aortic arch surgery, neurologic injuries may occur not only during but also immediately after the period of circulatory arrest. Experimental studies have shown that reactive hyperemia and cerebral hyperperfusion occur immediately after circulatory arrest, followed by decreased cerebral perfusion due to increased cerebral vascular resistance. Increased cerebral extraction of oxygen causes an improper cerebral blood supply, so this period has been termed the *vulnerable interval*. Animal studies have shown ACP to decrease the hyperemic reaction and the vulnerable interval [Harrington 2007].

Many ACP techniques have been described in the literature, the simplest being the establishment of unilateral ACP via the right axillary artery. Compared with bilateral perfusion, unilateral cerebral perfusion has the advantages of minimizing the manipulation of aortic arch vessels, providing an easy setup, and allowing for fewer cannulas in the surgical field; however, whether unilateral cerebral perfusion provides a sufficient blood supply for the contralateral hemisphere is still a controversial issue. Küçüker et al [2005] reported a 2.2% incidence of major neurologic injury during 181 aortic arch procedures with unilateral ACP. In the same clinic, Ozatik et al [2004] observed that neurocognitive functions were also protected with this technique; however, Dossche et al [1999] and Olsson et al [2006] reported a larger number of permanent neurologic events and increased mortality with unilateral ACP than with bilateral ACP. Resolving this issue requires prospective randomized clinical studies, which, unfortunately, have not yet been established. The results of the present study are encouraging regarding the safety of unilateral ACP. There were no neurologic complications, even with arrest times longer than 30 minutes (n = 11) and 40 minutes (n = 5).

The most important concern regarding unilateral ACP is Willis circle variations, such as hypoplasia of both anterior and left posterior communicating arteries, which may risk contralateral lobe hypoperfusion [Taşdemir 2002; Papantchev 2007]. Although these anomalies are very rare, preoperative computed tomographic imaging of the collateral vascularization of the Willis circle may be beneficial [Papantchev 2007]. In our experience, an intraoperative assessment of the left carotid artery's retrograde blood flow at the beginning of ACP reflects the adequacy of the collateral flow, and such information is valuable for evaluating contralateral hemispheric perfusion. In cases of acute obstruction of major cranial vessels, such as internal carotid and vertebral arteries, perfusion of the contralateral hemisphere totally depends on the Willis circle. The secondary collaterals, such as the ophthalmic, leptomeningeal, deep collateral, and extracranial arteries, supply blood during chronic hypoperfusion [Papantchev 2007]. Therefore, observation of a decreased retrograde blood flow in the left carotid artery during unilateral ACP is a safe method for considering critical Willis circle anomalies; however, such an assessment depends on a subjective evaluation, and no clear threshold level has yet been established.

The use of ACP eliminates the need for deep systemic hypothermia, which has many detrimental effects. Many studies have shown that the use of ACP avoids the adverse effects of hypothermia without an increased rate of neurologic complications [Kazui 2000; Kaneda 2005; Zierer 2005; Cook 2006; Panos 2006; Kamiya 2007; Kazui 2007; Pacini 2007]. However, the optimal systemic temperature during the operation is still controversial. Experimental animal studies and clinical reports have revealed different results [Strauch 2005; Khaladj 2006]. We believe that setting the hypothermic systemic temperature at 22°C provides optimal cerebral protection during ACP. Cooling reduces the cerebral blood flow and cerebral oxygen consumption. The decrease in cerebral oxygen consumption is exponential with a steep descent toward electrocerebral silence, followed by a flattened tail; a decrease in the cerebral blood flow is generally linear, however. Cooling leads to an uncoupling of flow and metabolism and to a loss of cerebral autoregulation with the development of "luxury" perfusion. The cutoff level of uncoupling is approximately 22°C [Ehrlich 2002]. Thus, 22°C systemic hypothermia provides a maximal cerebral protective effect by decreasing cerebral metabolism and protecting the constancy of cerebral autoregulation.

In conclusion, unilateral ACP with systemic hypothermia at 22°C is a safe method that yields satisfactory clinical results. Establishing ACP via the right axillary artery is fast and simple. The presence of fewer cannulas in the operation field provides an operative condition as convenient as the DHCA technique.

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