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Axillary cerebral perfusion for arch surgery in acute type A dissection under moderate hypothermia

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Abstract

Backgound: Aortic arch surgery is still associated with increased mortality and morbidity especially in acute type A aortic dissection. Adequate brain protection is essential and commonly performed by either antegrade selective perfusion of the brachiocephalic arteries or an interval of profound hypothermic circulatory arrest. We present our experience for open aortic arch repair with continuous antegrade brain perfusion by means of direct cannulation of the right axillary artery, under moderate hypothermia in patients with acute type A aortic dissection. **Methods:** In, 25 consecutive patients (17 men) with a mean age of 62.6 ± 14.8 years, aortic repair extended to the arch, for acute type A aortic dissection, was performed through a midline sternotomy. The right axillary artery was used for arterial systemic and brain perfusion at a rectal temperature of 25—27 °C. **Results:** Mean duration of CPB and aortic cross-clamping was 241 ± 55 and 155 ± 72 min, respectively. The mean duration of circulatory arrest of the lower body and brain perfusion was 39.7 (range, 24—55 min). All the patients survived the procedure and all but one were discharged from hospital. One patient had left arm paralysis which he recovered the first postoperative month. There were no other transient or permanent neurologic deficits. A CT scan was performed at discharge for routine postoperative evaluation. There were no local neurovascular complications related to the cannulation site except for one local re-exploration for bleeding. **Conclusions:** The absence of any major permanent neurologic deficit or any visceral damages in our patients suggests that continuous moderate hypothermic cerebral perfusion, with an interval of circulatory arrest of the lower body, is adequate for acute type A aortic dissection surgery, allowing safe open repair of the distal aortic arch.

Keywords: Aortic dissection; Cerebral perfusion; Circulatory arrest

1. Introduction

Open distal aortic repair is widely admitted in acute type A aortic dissection. This technique requires an interval of circulatory arrest by means of total deep hypothermic circulatory arrest, retrograde cerebral perfusion and more frequently antegrade selective perfusion of the brachiocephalic arteries. Despite the fact that the later technique provides better brain protection it is not optimal because of additional manipulations needed on the dissected and fragilised tissues of the brachiocephalic arteries, requirements of a separate perfusion circuit and increases the clutter in the operative field.

In this study the clinical and neurological outcome for aortic arch repair using continuous antegrade brain perfusion by means of direct cannulation of the right axillary artery, under moderate hypothermia in patients with acute type A aortic dissection were evaluated.

2. Patients and methods

Between July 2001 and January 2005, 25 consecutive patients (17 men), with type A aortic dissection, underwent surgery for replacement of the ascending aorta extended on the hemi-arch or arch according to the lesions and were evaluated. Age at operation ranged between 32 and 82 years (mean, 62.6 ± 14.8 years). Preoperative evaluation included a CT scan and/or transesophageal echocardiography (TEE) and revealed type A aortic dissection involving the descending aorta with a circulating false lumen in all patients. In four patients the dissection extended into the neck vessels but without any neurological symptoms. Surgery was performed emergently and was a primary operation for all patients. Seventeen patients underwent replacement of the ascending aorta and had the repair extended to the 'hemi-arch' and eight had total aortic arch replacement. A Bentall operation was performed in five patients otherwise aortic valve was preserved. In one patient with the dissection extended into the neck vessels, the continuous per-operative transcranial Doppler showed a malperfusion of the right middle cerebral and an additional

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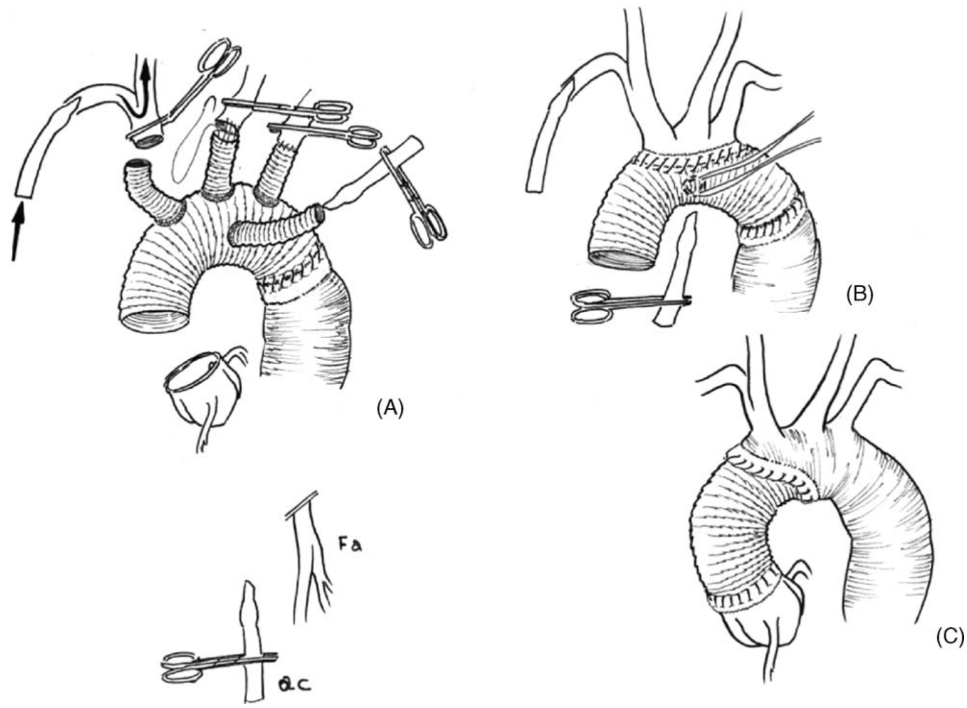

Fig. 1. Technique with single axillary artery cannulation, for total aortic arch replacement (A and B) and hemi-arch replacement (C) with a median sternotomy. Note the possibility of additional cannulation (ac) sites if necessary. fa: femoral artery.

bypass between the aortic graft and the right common carotid artery was performed.

2.1. Operative details

The right axillary artery was exposed through a subclavicular incision and cannulated with a straight 20—24 Fr. arterial cannula (Terumo, Ann Arbor, MI) after systemic heparinisation. The right axillary artery was found free of dissection in all patients. The distal axillary artery was clamped. A median sternotomy was performed and cardiopulmonary bypass (CPB) initiated by cannulation of the right atrium with a single two-staged venous cannula. Body temperature was cooled to 25—27 °C. The left heart was vented with a catheter inserted in the right superior pulmonary vein. The aortic arch and the brachiocephalic arteries were dissected from the surrounding tissues. The ascending aorta was cross-clamped and cold blood cardiolegia was delivered continuously in a retrograde manner to achieve cardiac arrest. During the cooling period, the ascending aorta was opened and inspected for proximal extension of the dissection and presence of entry tears. Repair was planned according to the extension of the lesions on the aortic arch. When the supra-aortic arteries were involved in the aneurysmatic or dissection process, total arch repair included reconstruction of the proximal supra-aortic arteries. The dissected aorta was transected proximally according to the lesions and the diseased aortic wall reinforced with Teflon felt strips and biological glue. The aortic valve cusps were resuspended when necessary or the aortic root prepared for a Bentall procedure ($n = 5$).

While rectal temperature had reached 25—27 °C the flow rate of the CPB was decreased to a mean volume flow of 12 ml/kg/min. The neck vessels were clamped individually with atraumatic neonatal clamps and the aortic cross-clamp was released. Per-operative blood flow through the middle cerebral arteries was monitored continuously with bilateral transcranial Doppler, when available. During this period of systemic circulatory arrest, the brain was continuously perfused via the right axillary artery to a mean rate flow of 12 ml/kg/min and at a temperature of 25—27 °C. After distal aortic anastomosis was performed on hemi-arch or total arch (Fig. 1) systemic flow was resumed by releasing clamps on the brachiocephalic arteries. The aortic graft was then clamped just proximal to the origin of the innominate artery and rewarming initiated. During this time the proximal aortic repair was completed.

3. Results

Mean duration of CPB and aortic cross-clamping was 241 ± 55 and 155 ± 72 min, respectively. The mean duration of lower body circulatory arrest and brain perfusion at a temperature of 25 °C, was 39.7 min (range, 24—55 min). Mean intensive care unit stay was 3.4 days (range, 1—14 days). All patients survived the procedure and all but one were discharged from the hospital. There was one in-hospital death from acute respiratory distress syndrome, on the twentieth postoperative day. One patient had a left arm paralysis of central origin, which recovered in the following month. There were no other transient or permanent neurologic deficits. Three patients presented a postoperative malperfusion syndrome. The first one presented a sepsis on the second postoperative day and the exploration laparotomy revealed an ischemic colitis, successfully treated with bowel resection. The second patient presented a dynamic malperfusion of the right arm, on the fourth postoperative day, related to the occlusion of the ostium of the right subclavian artery. In this case, perfusion of the right arm was re-established by deployment of a uncovered stent-graft in the level of the innominate artery. The last patient presented a left leg claudication at discharge related to the dynamic compression of the origin of the left common iliac artery by the patent false lumen. This complication was treated successfully by deploying an uncovered stent at the origin of the left common iliac artery. There were no local neurovascular complications related to the cannulation site. Postoperative echocardiography showed only grade I aortic regurgitation in four patients and no regurgitation in the other patients. A CT scan was performed at discharge for routine postoperative evaluation in all patients. In the follow-up period, which ranged from 4 to 30 months (mean 19 months) 23 patients were doing well and 1 patient was found dead in his bed 8 months after being discharged from the hospital. The cause of death remained unknown.

4. Discussion

Surgical treatment for acute type A aortic dissection may require replacement of the ascending aorta and various portions of the aortic arch. Open distal aortic anastomosis is widely admitted in this situation. Since Bachet et al. [1] reported first, in 1991, the use of antegrade selective cerebral perfusion with the use of distal circulatory arrest at moderate hypothermia, many combinations of different approaches were proposed for the surgery of the aortic arch. The best approach for cerebral protection during these operations is still a matter of controversy. Our protocol avoids the direct cannulation of the brachiocephalic arteries and associates the benefits of a moderate hypothermic (mean, 26 °C) circulatory arrest of the lower body to the advantages of the continuous moderate hypothermic perfusion of the brain. Perfusion of the brain is achieved through the right carotid and vertebral arteries by establishing the CPB arterial line via the right axillary artery. One may stretch out that this technique has the potential limitation of inadequate protection of the left hemisphere because of insufficient collateral circulation in the circle of Willis. Indeed left hemisphere blood supply is provided not only by intracranial collateral circulation but also from an extracranial vascular bed mostly dependent on the external carotid arteries. However, the most important data for this discussion should be the clinical results and in particular the neurological outcome which is excellent in our study. The one left arm paralysis was not attributed to poor protection of the right hemisphere but probably to an embolism. We have changed our surgical protocol in acute type A dissection in favour of the antegrade perfusion via the right axillary artery since 2001 because of the following considerations: (1) unique arterial cannulation site; (2) avoidance of any additional manipulation of the brachiocephalic arteries; (3) antegrade flow pattern of the CPB; (4) continuous antegrade cerebral perfusion; (5) use of moderate hypothermia for both, brain and lower body; (6) limited circulatory arrest of the lower body. However, contrary to other surgeons, who report similar techniques, we adopted a unique moderate hypothermia (25–27 °C) for both, the brain and the lower body associated with continuous brain perfusion. Previous studies [2] established that a continuous brain perfusion at a mean volume flow of 12 ml/kg/min (range, 10–15 ml/kg/min) offers adequate protection to the brain. Because the brain was continuously perfused at a mean temperature of 26 °C during lower body circulatory arrest, our main concern was the 'safe' duration of the circulatory arrest for the lower body and especially the spinal cord and slpachnic organs at this temperature. According to previous studies [3] at normothermia, a 35–40 min of safe duration of circulatory arrest is expected for the liver, this safe period extends to 30–90 min for the warm ischemia in the kidney [4,5]. These times are considerably longer in conditions of moderate hypothermia. Concerning the spinal cord, a safe period of up to 20 min was reported in the Kirklin and Barrat-Boynes [3] in case of aortic cross-clamping at normothermia. It is also reported in the Kirklin and Barrat-Boynes [3] that the spinal cord can recover normal function after ischemia of 60 min duration at a whole body temperatures of 30 °C. In our patients with the perfusion through the right axillary artery, the basilary and internal thoracic arteries are bilaterally perfused. In this way we can expect some degree of perfusion in the spinal cord via the spinal arteries. In addition, moderate hypothermia extends the duration of protection. In our study the maximum circulatory arrest duration of the lower body was 55 min with no neurologic nor splachnic significant complications. All these arguments suggest that moderate hypothermic perfusion of the brain and circulatory arrest of the lower body, through the right axillary artery provides adequate protection to the brain and lower body during surgery of the ascending aorta and aortic arch for type A dissection. According to our experience, which is certainly limited, with the use of moderate hypothermia we are avoiding the central neurologic complications and systemic deleterious effects of deep hypothermia, especially on platelet activation pathways and on the enzymatic activity of clotting factors [6] decreasing bleeding. However, one may question that if the operation should be prolonged because of any complication, the moderate hypothermia would not give us enough time to deal with it.

Indeed in order to prevent such a situation we always perform and secure first the distal anastomosis between the graft and the aorta. In this way it is possible to cannulate the graft or the femoral artery and initiate systemic perfusion after clamping the already sutured graft on the proximal part of the descending aorta. For this purpose we always mount an 'Y' cannula on the arterial line of the CPB circuit (Fig. 1). Nevertheless we never had to use this additional manipulation in our series.

Despite we do not directly cannulate the arch vessels, as do others surgeons, our technique is not less harmless because of the need of clamping these vessels. In order to be the less aggressive on these fragilised vessels we adopted the use of softer 'atraumatic' neonatal clamps. On the basis of these initials findings we believe that this technique of antegrade cerebral perfusion through the right axillary artery and under only moderate hypothermia is safe and applicable in the surgery of the acute aortic dissection. It is simple, provides shorter cardiopulmonary bypass times and excellent neurological results for the patient. Further evaluation of this technique in larger series of patients is needed to confirm these benefits.

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Editorial comment

Which is more appropriate as a cerebral protection method – unilateral or bilateral perfusion?

I read the article by Panos et al. [1] with great interest. They describe their experience with the unilateral cerebral perfusion through the right axillary artery (RAxA). In a series comprising 25 patients with acute type-A aortic dissection, the authors performed the RAxA cannulation for both cardiopulmonary bypass and antegrade cerebral perfusion under moderate hypothermia. The average duration of cerebral perfusion was just under 40 min. The authors achieved commendable results both in terms of mortality and neurological deficits based on which, they emphasize that unilateral cerebral perfusion through the RAxA provides adequate cerebral protection to allow safe distal aortic arch repair.

Selection of an appropriate cerebral protection method is a key issue in aortic arch surgery. Although the choice is mostly determined by surgeons' preference and experience, an important consideration is the duration of cerebral protection expected to be required. Recent research indicates that deep hypothermic circulatory arrest (DHCA) with or without retrograde cerebral perfusion (RCP) is limited in its ability to protect the brain for more than 30 min. Thus, it may be appropriate for procedures requiring brain protection for 30 min or less whereas antegrade selective cerebral perfusion (SCP) is desirable for longer durations. Thus in most cases requiring extensive arch repair like total arch replacement (TAR), antegrade SCP is usually the cerebral protection method of choice. The history of antegrade cerebral perfusion dates as far back as 1957 when Dr DeBakey first proposed the idea of perfusing all three neck vessels under normothermia [2]. However, the issue as to how many arch-vessels needs be perfused for adequate cerebral protection continues to be debated.

We have used bilateral two-vessel perfusion through innominate artery (IA) or RAxA when necessary, and left common carotid artery (LCCA) at 25 °C with systemic circulatory arrest for TAR particularly in patients with acute type-A aortc dissection [3]. We have seen that the cannulation-related complications can be avoided when the vessels are cannulated through the arteriectomy sites under direct vision. We employed three-arch-vessel perfusion in selected patients having occlusion of right vertebral artery, dominant left vertebral artery, and lack of sufficient intracranial collateral circulation to avoid the left vertebro-basilar insufficiency that may result in cerebellar infarct. We applied DHCA $\pm$ RCP for hemiarch replacement (HAR) procedures at a rectal temperature of 20 °C for acute type-A aortic dissection which require a relatively shorter period of brain protection than TAR. However, we have noticed a somewhat increased incidence of neurological dysfunction with this strategy. Therefore, we switched to unilateral antegrade cerebral perfusion through the RAxA at a flow rate of 5–10 ml/kg/min at 20 °C for hemiarch repair procedures. Antegrade perfusion is instituted through an 8 mm graft attached to the RAxA which avoids direct cannulation-related complication. Neurological outcome in these patients were comparable to that reported in the present study.

The history of unilateral cerebral perfusion can be traced back to 1986 when Frist et al. [4] first reported IA or LCCA perfusion. After that, Baribeau et al. [5] in 1998 and Tasdemir et al. [6] in 2002 reported RAxA perfusion and right brachial artery perfusion, respectively. Based on our previous experimental study, a perfusion flow of 10 ml/kg/min at a perfusion pressure of 40 mmHg seems to be adequate for bilateral perfusion. However, we are still unsure as to what should be considered an adequate flow in case of unilateral perfusion through the RAxA. How do we know that the 12 ml/kg/min flow used in this study at a temperature of 25–27 °C flow was adequate? Another important question is: what is the safe duration of circulatory arrest for this technique with regard to cerebral, spinal cord and visceral perfusion?

Possible hypoperfusion of the left cerebral hemisphere is a major concern with unilateral perfusion. There are a number of techniques to assess whether cerebral circulation in the left hemisphere is adequate or not. They are: (1) preoperative angiography or MRI of intra and extracranial arteries, (2) carotid occlusion test using cerebral balloon catheter to determine the adequacy of collateral blood flow, (3) intraoperative transcranial Doppler sonography to assess the blood velocity in the left middle cerebral