The use of profound hypothermia and circulatory arrest in operations on the thoracic aorta

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Abstract

Objective: This retrospective study reviews the contemporary surgical outcome of our patients undergoing operations on thoracic aneurysms in deep hypothermic circulatory arrest. Methods: Between January 1989 and February 1995, 279 patients were operated on in our institution on various portions of the aorta. In 143 patients (97 male, 46 female), deep hypothermia and circulatory arrest were used as the standard operative technique. Patients age ranged from 16 to 83 years (mean 55). Final indication for operation was dissection Type A in 80 patients (61 acute, 19 chronic), dissection Type B in 21 patients (17 acute, 4 chronic) and atherosclerotic aneurysms in 42 patients (11 acute, 31 chronic). 16 patients were operated under preoperative unstable hemodynamic conditions, 6 patients had been resuscitated preoperatively. Surgical technique included cardiopulmonary bypass with femoral artery cannulation. For added cerebral protection all patients received Cortisone and barbiturates right before circulatory arrest (confirmed by 0-EEG). The segment of the aorta containing the area with the aneurysm, was resected and replaced with a tubular albumin coated graft. Results: The 30-day mortality was 31.15% (19/61) in the acute and 23.52% (4/17) in the chronic Type A dissection group, 35.29% (6/17) in the acute and 23.08% (1/4) in the chronic Type B group, 36.3% (4/11) in the acute and 22.58% (7/31) in the chronic atherosclerotic group. Causes of postoperative death in order of frequency were: multiorgan failure (n = 15), myocardial failure (n = 13), bleeding (n = 4), sepsis (n = 4), myocardial infarction (n = 3) and stroke (n = 2). Conclusion: Despite high mortality rates in the acute aneurysm groups, the technique of profound hypothermic circulatory arrest represents a relatively safe method for operations on the thoracic aorta. Copyright © 1997 Elsevier Science B.V.

Keywords: Circulatory arrest; Profound hypothermia; Thoracic aortic aneurysm

1. Introduction

Operations on the aorta still represent a great challenge for cardiac surgeons. Great strides have been made since the introduction of profound hypothermia and circulatory arrest in the surgical management of aneurysms or dissections of the thoracic aorta [2,7,8] including simultaneous decrease of neurological complications associated with this procedure. Initially employed for correction of congenital lesions in infants, the technique has been adopted for treatment of intracranial vascular anomalies, soft tissue tumors and a variety of cardiovascular lesions. The method affords certain advantages, namely a blood-less operative field as well as performance of an open anastomosis without placement of clamps on friable aortic tissue. Furthermore, experimental studies have shown that hypothermia has a protective effect on ischemic neural tissue [14,15]. Using hypothermia, the oxygen consumption of neural tissue can be reduced by about 3% for each degree that temperature falls [9]. Therefore, the tolerance of ischemia can be increased by direct perfusion cooling.
The present study was undertaken to review retrospectively our results in the surgical management of thoracic aortic aneurysm by use of profound hypothermic circulatory arrest.

2. Patients and methods

2.1. Patients

Between January 1989 and February 1995, 279 consecutive patients with either aortic dissections or aortic aneurysms were treated surgically in our institution. In 143 patients, profound hypothermic circulatory arrest was used as the standard surgical technique.

Ninety-nine patients were men and 46 were women. The age of patients ranged from 16 to 83 years (mean 55) (Fig. 1). The preoperative diagnosis was made by either computed tomography or transesophageal echo or by a combination of both methods. Final indication for operation was dissection Type A in 80 patients (61 acute, 19 chronic), dissection Type B in 21 patients (17 acute, 4 chronic) and an atherosclerotic aneurysm with an aortic diameter of greater than 6 cm in 42 patients (11 acute, 31 chronic). In addition, sixty concomitant procedures were done to the primary aortic operation. The most common procedure was aortic valve replacement (24 Composite grafts, 15 Tirole-David procedures), followed by coronary bypass grafting in 20 patients and one mitral valve replacement (Table 1).

16 patients were operated under preoperative unstable hemodynamic conditions, 6 patients had been resuscitated preoperatively. Fourteen patients had undergone previous operations of the aorta. In eight patients aortic valve replacement, and in 4 patients aorto-coronary bypass grafting had been performed earlier.

2.2. Technique

Operations on the ascending aorta and proximal arch were performed through median sternotomy, while access for operations on the descending aorta was through a posterolateral incision in the fourth ICS. In cases of ascending aorta involvement, cardiopulmonary bypass was established through the femoral artery and the right atrium, those confined to the descending aorta or distal arch were cannulated through the femoral artery and vein. Once the bypass was established, systemic cooling was initiated immediately. After onset of ventricular fibrillation, the aorta was clamped and cold blood cardioplegia was administered continuously until the end of the operation. The patient's temperature was monitored through nasopharyngeal, esophageal and rectal temperature measurement. To increase the tolerance of neurological tissue for ischemia, the patients head was packed in ice bags, and 1000 mg methylprednisolone as well as 1000 mg thiopental were given. Furthermore the hemoglobin oxygen saturation in the brain tissue was monitored by spectroscopy (InVos 3 100 A, Cerebral Oximeter, Somanetics, Michigan, USA) in the last 35 patients, placing infrared patches on the patient's forehead. A reticulature temperature of 18°C was considered adequate to start hypothermic circulatory arrest. Deep hypothermia was confirmed by isoelectric EEG. Depending on the extent of the pathological involvement, either the aortic arch, the ascending or descending aorta were resected and replaced by albumin-coated tubular grafts. In cases of arch involvement the period of circulatory arrest was used for inspection and reconstruction of this part. During this period retrograde cerebral perfusion was implemented in the last 22 patients with flow-rates of 300 ml/min, keeping the central venous pressure below 23 mmHg. By transcranial measurement (Multi-Dop X, DWL GesmbH.-Sippingen, Germany) of blood flow in the cerebral media artery a reversion of the latter could be seen in all patients. After finishing the proximal (A. descendens) or distal (A. ascendens) anastomosis, selective perfusion was installed via a side-line (Figs. 2 and 3). In cases of ascending aneurysm this gave as the possibility to begin with the extracorporeal circulation and rewarming of the patient. Meanwhile the proximal aortic anastomosis was reinforced with teflon strips above the level of the coronary ostia and studded with 4-0 prolene, resulting in a resuspension of the native

![Graph showing age distribution of 279 patients](image)

Fig. 1. Patients age at time of surgical intervention according to decade.

<table>
<thead>
<tr>
<th>Table 1: Concomitant procedures</th>
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<tbody>
<tr>
<td>Acute</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Composite grafts</td>
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<tr>
<td>Tirole-David</td>
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<td>CABG</td>
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<td>MVR</td>
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n = 60. CABG, coronary bypass grafting; MVR, mitral valve replacement.
prosthesis and the native aorta was sutured with 4–0 prolene and reinforced with teflon strips.

After finishing rewarming, cardiopulmonary bypass was discontinued and the cannulas were removed.

3. Results

The most common procedure was replacement of the ascending aorta and proximal arch followed by isolated replacement of the ascending portion of the aorta. Table 2 shows the overall extent of aortic replacement in detail.

Cardiopulmonary bypass data are shown in Table 3.
The intraoperative mortality was 3.8% (n = 5). Four patients (3 with acute Type A dissection and rupture, one with acute Type B dissection and rupture) died from intraoperatively uncontrollable bleeding. The last patient, an 83-year-old male with acute, ruptured Type B dissection could not be weaned from cardiopulmonary bypass. Neurological complications occurred in 20 patients (14.4%). The degree of cerebral injury is listed in Table 4.

The 30-day mortality in our series was 28.6% (n = 41). Out of these 41 deceased patients, 29 had preoperatively an acute aneurysm (29/41, 70%), 12 patients a chronic one (12/41, 30%). Table 5 shows the 30-day mortality based on the final indication for aortic replacement. Causes of perioperative death in order of frequency were: multiorgan failure (n = 15), myocardial failure (n = 13), bleeding (n = 4), sepsis (n = 4), myocardial infarction (n = 3) and stroke (n = 2).
Table 4
Neurological complications

<table>
<thead>
<tr>
<th>Type</th>
<th>Acute</th>
<th>Chronic</th>
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<tbody>
<tr>
<td>Stroke</td>
<td>4 (2.9%)</td>
<td>2 (1.4%)</td>
</tr>
<tr>
<td>Stroke + paraplegia</td>
<td>0</td>
<td>1 (0.7%)</td>
</tr>
<tr>
<td>Stroke + hemiplegia</td>
<td>2 (1.4%)</td>
<td>1 (0.7%)</td>
</tr>
<tr>
<td>Paraplegia</td>
<td>5 (3.7%)</td>
<td>1 (0.7%)</td>
</tr>
<tr>
<td>Hemiplegia</td>
<td>3 (2.2%)</td>
<td>1 (0.7%)</td>
</tr>
</tbody>
</table>

n = 20,138, 14.4% overall. Permanent n = 11 (7.9%); transient n = 9 (6.5%).

4. Discussion

There is no doubt that operations involving the thoracic aorta still represent a formidable surgical challenge. The success of surgical intervention depends on careful cerebral and spinal cord protection, avoidance of coagulopathy, and myocardial preservation.

Since the late 1950s, when the first successful resection of an aortic arch aneurysm was performed by DeBakey et al. [4], various methods have been employed to avoid cerebral damage during aortic arch replacement. These included temporary tube shunts [17], temporary and permanent bypass grafts [3] and cardiopulmonary bypass (CPB) with separate arterial perfusion of the head vessels. All these methods met with limited success. Cooley and DeBakey [1] first suggested the use of profound hypothermia to reduce the risk of neurological complications associated with aneurysm resections. Later, Griep et al. [8] introduced the technique of profound hypothermia and circulatory arrest. The application of this surgical method in the operative management of aortic arch aneurysm has several technical advantages.

Hypothermic circulatory arrest (HCA) gives the possibility to perform operations on the aortic arch without placing a clamp on the aortic wall. Therefore clamp injury of the fragile dissected aortic tissue can be avoided. Additionally this technique represents a way to accomplish the necessary repair in a dry and motionless field and enables us to meticulously inspect the aortic arch for further intimal tears.

Another important benefit of profound hypothermia and circulatory arrest is the reduction of neurological complications associated with complex reconstructions of the aortic arch.

Many experimental studies have already proven the protective effect of profound hypothermia which is known to reduce the neuronal injury caused by hypoxia [10,11,10]. This protective mechanism is due to a reduction in the metabolic rate of neural tissue simultaneously reducing the oxygen consumption of the latter. Nevertheless there is a distinct time limit before neurological damage or death become significant. Therefore the safe period of circulatory arrest is still a subject of considerable debate and has yet to be firmly established. Svendsen et al. [18] concluded in their large series performed on 658 patients, that the risk of neurological complications increased significantly when the arrest period exceeded 40 min and the risk of death increased when the arrest period exceeded 45 min. In another series of Ergin and Griep [6], none of their patients, whose time of cerebral ischemia was less than 40 min had neurological complications.

In our study the average duration of circulatory arrest was 29 min after replacement of the ascending aorta and proximal arch and 33 min after replacement of the descending aorta and distal arch.

To keep the cerebral circulatory arrest time as short as possible, we used in all cases the method of selective hypothermic cerebral perfusion (Figs. 2 and 3), which further minimizes the risk of neurological deficits.

Nevertheless, in 20 out of the 138 surviving patients neurological dysfunction occurred, which can be related to acuteness and/or rupture of the aneurysm and consequently prolonged circulatory arrest time.

Concerning pharmacological agents we used 1000 mg of Cortisone and 1000 mg of barbiturates in all our patients. These adjuncts were given right before the period of circulatory arrest. Steroids can lengthen the ischemic time of the spinal cord by acting as free radical scavengers, stabilizing membranes, and reducing both spinal cord edema and oxygen consumption of neurons [12]. Although experimental data concerning the benefit of barbiturates were mostly performed under normothermic conditions, we do believe, as many other centers, that barbiturates decrease synaptic transmission and relax vascular smooth muscle and therefore may have a neuroprotective effect [13].

For optimal myocardial protection cold blood cardioplegia was administered continuously ante- or retrograde during the entire operation, which prevents the occurrence of coronary artery air embolism. In cases, where antegrade cardioplegia was used, two small cardioplegia-cannulas were directly placed in both coronary ostiae. In all cases the patients could be weaned from cardiopulmonary bypass without complications.

Intra- and postoperative coagulopathy in association with profound hypothermia is still a major cause for high morbidity and mortality rates [5]. To avoid postoperative bleeding, we used albumin coated grafts and added aspirin (1 Mill. I. U.) to the extracorporeal
circuit in all cases. Albeit the use of aprotinin in combination with profound hypothermia is still a matter of debate, the low incidence of postoperative bleeding (4/138, 2.9%) can be construed as evidence of the positive effect of aprotinin even in this setting.

As mentioned above, time limitation is still one of the major disadvantages of circulatory arrest, and alternative methods have been employed in recent years to enhance the safety of prolonged circulatory arrest periods. One of these includes retrograde cerebral perfusion via the superior vena cava, which assures sufficient oxygen delivery to otherwise ischemic brain tissue during circulatory arrest. To obtain a more accurate reflection of cerebral oxygen delivery during RCP we used continuous spectroscopic measurement of cerebral hemoglobin oxygen saturation as an indicator of brain ischemia. Transcranial Doppler measurement in the middle cerebral artery was used to reflect flow characteristics in this vessel. In our series, we started to use this technique in May 1993, and until now it was performed on 22 patients with outstanding results. Only one patient in this group developed a neurological deficit in the form of a transient ischemic attack.

In conclusion the technique of profound hypothermic circulatory arrest represents a relatively safe method for operations on the thoracic aorta. Preliminary results obtained from the cohort treated with retrograde cerebral perfusion indicate an improvement in neurological outcome. Nevertheless, further studies are necessary to evaluate the efficacy and the exact mechanism of this new method.

References


Appendix A. Conference discussion

Dr. H. G. Borst (Hannover, Germany): You've covered a fairly wide range of aneurysms, so I'm very curious to see if, in your manuscript, these various categories are going to be scaled down a little more clearly. I only have a technical comment: you showed that side arm of the aneurysmatic graft that I suppose Stanley Crawford inverted. I consider this rather circumstantial, to say the least. We just make a hole in the aneurysm graft and then insert a tapered cannula which takes a second and then you have absolutely no blood leak.

Dr. M. Turina (Zurich, Switzerland): You stated in your conclusions that the retrograde cerebral perfusion improves cerebral protection. Do you have such proof in your own data, i.e. randomization of your patients into two groups with and without retrograde cerebral perfusion, or did you employ one method first and the other one later?

Dr. M. Ehrlich (UK): Well, frankly I just took 22 patients that had this performed and then I took 22 patients that were operated before those 22 patients with the retrograde cerebral perfusion and we saw much better improvement in cerebral function, but definitely it's a short time.

Dr. M. Turina: And overall mortality?

Dr. M. Ehrlich: Overall mortality was higher in the group without retrograde cerebral perfusion.

Dr. R. Bonser (Birmingham, UK): I enjoyed your paper very much. I was interested in your Doppler monitoring of cerebral blood flow during retrograde cerebral perfusion. In 12 of our patients we tried to evaluate cerebral blood flow with transcranial Doppler. We could only identify reverse flow in the middle cerebral artery in one patient during RCP. Could you give a little more detail of the findings in the whole of your 22 patients?

Dr. M. Ehrlich: Actually it's a brand new technique in our institution. So far, of those 22 patients we only had 3 patients where
We used that measurement, and basically in those three patients we could clearly see that the patients had reversed flow during the whole time of retrograde cerebral perfusion. There were just three patients and we have to continue to look at that measurement.

Dr F. Vermeulen (Nieuwegein, The Netherlands): I would like to ask you a question. We have been using, in the last years almost routinely, retrograde perfusion in total arch replacement. What struck us, in contrast to deep hypothermia in the previous years, is the time to awakening of the patient; it was almost immediate after surgery. Could you comment on the time to awaken the patient with retrograde cerebral perfusion?

Dr M. Ehrlich: In those 22 patients, all were awake 24 h after the operation. So it was a time frame between 6 and 24 h.

Dr H. G. Boxt: Dr Vermeulen, you also perfused retrogradely in dissection. Isn't it a little difficult to cannulate the true aortic lumen and get effective flow that way?

Dr F. Vermeulen: In dissection we rarely do total arch replacement. I would say we mostly do short, deep hypothermic arrest to make the distal anastomosis at the limit of the dissection or in the ascending aorta using the GIF glue. In those patients as well we noticed the relatively late awakening, even after 20, 25 or 30 min of circulatory arrest.

Dr M. Heinemann (Tuebingen, Germany): Just a brief question concerning the acute type B dissections. What's your indication for operation in these patients?

Dr M. Ehrlich: Only, if there would be some involvement of visceral organs, rupture and acute pain that lasts longer than 10 days.

Dr H. G. Boxt: Does that mean that you are replacing the aorta every time you have malperfusion, is that your standard method?

Dr M. Ehrlich: We have always replaced the aorta so far.