The safety and usefulness of cool head–warm body perfusion in aortic surgery

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Abstract

Objective: To determine the safety and usefulness of antegrade hypothermic cerebral perfusion in conjunction with mild hypothermic (tepid) visceral perfusion (so-called cool head–warm body perfusion; CHWB) in aortic surgery; the clinical outcomes and perioperative data on this new technique were retrospectively analyzed. Methods: From January 1990 to March 1999, 59 patients underwent ascending aorta or aortic arch surgery using antegrade selective cerebral perfusion (SCP). Three perfusion techniques, differentiated by perfusion temperature, were used, those being deep hypothermia (DH; nasopharyngeal temperature of 20°C, n = 14), moderate hypothermia (MH; nasopharyngeal temperature of 28°C, n = 17) and CHWB (nasopharyngeal temperature of 25°C and bladder temperature of 32°C, n = 28). Selection of the technique largely followed a chronological pattern, in this order: DH, MH and, more recently, CHWB. The three groups were retrospectively compared in terms of operative outcome, duration of cardiopulmonary bypass (CPB) and operation, and intraoperative blood loss. Results: The early (within 30 days after surgery) mortality/hospital mortality (including operative mortality) was 7.1/21.4, 5.9/11.8 and 3.6/7.1% in the DH, MH and CHWB groups, respectively. The rate of stroke was 7.1, 6.3 and 3.6% in the DH, MH and CHWB groups, respectively. No statistical difference was found in early or hospital mortality, or in the rate of stroke among the three groups. The CPB time, especially the time for rewarming, was significantly shorter in the CHWB than in the DH group. Likewise, the operation time, especially the time after CPB, was significantly shorter in the CHWB than in the DH and MH groups. Blood loss was significantly less in the CHWB than in the DH group. Conclusion: Our data suggest that CHWB perfusion in aortic surgery is a safe and useful technique in shortening the operation time and reducing blood loss, but further prospective study is necessary.

Keywords: Aortic aneurysm; Extracorporeal circulation; Perfusion; Cerebral ischemia; Hypothermia; Postoperative complication

1. Introduction

Surgery for aortic arch aneurysm is still a challenge, mainly because it requires the brain to be protected during arch repair. Although circulatory arrest under deep hypothermia (DH) is the most frequently used method of cerebral protection [1,2], antegrade selective cerebral perfusion (SCP) is also a beneficial protective method because it provides unlimited time to perform the aortic arch repair. In order to reduce cerebral oxygen consumption during the procedure, and thereby avoid cerebral complications, moderate to deep hypothermia is usually utilized for SCP [3–9]. However, hypothermia may not be essential for visceral perfusion during SCP, and it often leads to coagulation disturbance [10,11]. Moreover, cooling and rewarming the patient prolongs cardiopulmonary bypass (CPB). To resolve this dilemma, we combined hypothermic cerebral perfusion with tepid visceral perfusion, so-called cool head–warm body (CHWB) perfusion [12], and applied it in 28 cases. To examine the safety and usefulness of CHWB perfusion, we retrospectively assessed the clinical outcomes and perioperative data on this new technique and the two other SCP techniques usually used in aortic surgery.

2. Patients and methods

2.1. Patients

The data from 59 consecutive patients with aortic aneurysm who underwent surgical repair using antegrade SCP from January 1990 to March 1999 were retrospectively analyzed. Antegrade SCP was the only brain-protecting adjunct used for the repair of the aortic arch or the adjacent
aorta during this period. The patients’ ages at operation ranged from 46 to 87 years, with a mean age of 67.3 years. Thirty-seven patients were men, and 22 were women.

Three antegrade SCP techniques were used, each distinguished by a different perfusion temperature: DH (20°C nasopharyngeal temperature) was used in 14 patients (DH group); moderate hypothermia (MH; 28°C nasopharyngeal temperature) was used in 17 patients (MH group); our own innovation, the simultaneous use of moderate hypothermic cerebral perfusion and tepid visceral perfusion, so-called CHWB perfusion (nasopharyngeal 25°C and bladder 32°C), was used in 28 patients (CHWB group).

Selection of the technique largely followed a chronological pattern. From 1990 to 1993, DH was the only technique used (eight patients). From 1994 to January 1997, MH was the technique of the choice (17 patients). In February 1997, we introduced CHWB perfusion, and have used this technique in 28 patients, as of March 1999. In addition, between 1994 and 1998, DH was used in six patients in whom other techniques could not be used. All six patients were emergent cases.

The data on age, gender, type of aortic lesions and surgical procedures are shown in Table 1. Across the three groups, age, gender and type of aortic lesions (true aneurysm or dissection) were not significantly different. However, the rate of emergency operation was higher in the DH group than in the MH group. The extent of surgical repair was also different from group to group; the proportion of total arch replacement was significantly higher in the CHWB group than in the DH group. Moreover, the use of branched vascular graft to reconstruct arch vessels separately was more frequent in the CHWB group than in the other two groups. The proportion of concomitant coronary artery bypass grafting was not statistically different among the three groups.

2.2. CPB and SCP circuit

Three roller pumps, one for systemic or visceral perfusion and two for cerebral perfusion, were placed between the oxygenator (Capiox E, Terumo Corp., Tokyo, Japan; incorporating a heat exchanger and a reservoir) and the patient. To allow independent control of temperature in the brain and visceral organs, an extra heat exchanger (MHE-3LP, Senko Medical Instrument Co., Tokyo, Japan) was put into the CHWB perfusion circuit (Fig. 1).

2.3. Surgical procedure and perfusion protocol

Anesthesia was introduced with moderate doses of fentanyl, midazolam and a long-acting muscle relaxant, and was maintained with isoflurane or sevoflurane in 100% oxygen and supplemental intravenous opioids. The aortic arch was approached through a median sternotomy in 57 patients and antero-axillary thoracotomy in two patients. A left thoracotomy (fourth intercostal space) was used to supplement median sternotomy in two patients to expose the distal portion of the descending aorta.

Both nasopharyngeal and bladder temperature were monitored throughout the operation. The jugular venous oxygen saturation (SjO₂) was continuously monitored with a 4-F fiber-optic Oxymeter catheter (Opticath, Abbott Laboratories, North Chicago, IL) placed in the right jugular bulb.

<table>
<thead>
<tr>
<th>Table 1: Patients’ profiles</th>
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<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>Number of patients</td>
</tr>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>Sex</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Type of lesion</td>
</tr>
<tr>
<td>True aneurysm</td>
</tr>
<tr>
<td>Aortic dissection</td>
</tr>
<tr>
<td>Timing of operation</td>
</tr>
<tr>
<td>Elective</td>
</tr>
<tr>
<td>Emergent</td>
</tr>
<tr>
<td>Extent of aortic repair</td>
</tr>
<tr>
<td>Total arch</td>
</tr>
<tr>
<td>Distal arch (+descending aorta)</td>
</tr>
<tr>
<td>Proximal arch (+ascending aorta)</td>
</tr>
<tr>
<td>Ascending aorta</td>
</tr>
<tr>
<td>Patch repair</td>
</tr>
<tr>
<td>Use of branched graft</td>
</tr>
<tr>
<td>Concomitant CABGd</td>
</tr>
</tbody>
</table>

a Figures in parentheses represent percentage values.

P < 0.05 vs. DH.

P < 0.05 vs. MH.

d CABG, coronary arterial bypass grafting.
CBP was initiated with ascending aortic perfusion in 31 patients, femoral arterial perfusion in 24, and right axillary arterial perfusion in four. Venous drainage was established from the right atrium or both venae cavae. Alpha stat management was used in all patients.

When the patient was cooled to 20°C in the DH group, or 28°C in the MH and CHWB groups, CBP was discontinued. For total arch replacement using a branched vascular graft, each cephalic artery was transected at its origin, and a 14- or 12-F balloon-tipped perfusion cannula with its own pressure-monitoring line (Retro-TH Catheter, Fuji Systems Corp., Tokyo, Japan) was inserted into the innominate and left common carotid arteries with great care. In the most recent 16 patients in the CHWB group, the left subclavian artery was also cannulated (Fig. 2). For replacement of the ascending aorta or hemiarch using a tube graft, the aorta was transected just proximal to the origin of the innominate artery, and the cerebral perfusion cannulae were inserted into the cephalic arteries through the orifice of the aortic arch. For replacement of the distal arch or descending aorta using a tube graft, the side wall of the aortic arch was incised and the perfusion cannulae were inserted into the cephalic arteries through the incision of the arch, which was closed after the aortic repair. It usually took only 1 or 2 min to establish antegrade SCP after the initiation of circulatory arrest.

Antegrade SCP was started using two separate roller pumps, one for the innominate and one for the left common carotid and left subclavian arteries. The temperature of antegrade SCP was set at 20, 28 and 25°C in the DH, MH and CHWB groups, respectively. The cerebral perfusion flow for each vessel was adjusted to maintain the mean carotid arterial pressure between 40 and 50 mmHg, measured through the built-in pressure-monitoring line in the cannula. When the SjO₂ was lower than the control value obtained from our previous study [5] and from our experience with deep hypothermic CPB (unpublished data; 92% at 20°C, 81% at 25°C, and 73% at 28°C), the cerebral perfusion flow was increased, and vasodilators were administered if the carotid arterial pressure rose above 60 mmHg. The patient’s head was covered with ice packs.

For patients with a normal descending aorta, a 12-F balloon aortic occlusion catheter (Pruitt, Ideas for Medicine, Inc., Clearwater, FL) was inserted into the descending aorta and visceral perfusion was initiated via the femoral artery. For patients with an associated aneurysm or dissection in the descending aorta, or for patients in whom distal anastomosis was very deep and difficult, open distal anastomosis was performed. In these patients, visceral perfusion was initiated after completion of distal anastomosis. In the DH and MH groups, the temperature of visceral perfusion was the same as that of SCP. In the CHWB group, the temperature of visceral perfusion was raised to 32°C. An occlusion balloon was used in 35 patients (four in the DH group, 14 in the MH group and 17 in the CHWB group).

Rewarming for both cerebral and visceral perfusion was begun when the arch repair was nearing completion. When repair of the aortic arch was almost completed, antegrade SCP was discontinued and the SCP cannula removed. It always took less than 1 min (usually less than 10 s) after the removal of the cannula to restart the cerebral perfusion through the vascular graft. CPB was terminated when all repair procedures were completed and rewarming was completed. Fig. 3 shows the protocol for CHWB perfusion.

2.4. Statistical analysis

Values were expressed as means ± standard deviations or as medians (25%–75%). Whenever the distribution strongly deviated from normality (P < 0.05 by normality test), the analysis was performed with non-parametric methods. Analysis of variance followed by the Student–Newman–Keuls multiple comparison test for means was used to assess the significance of difference between groups, and the Kruskal–Wallis one way analysis of variance on ranks followed by the Dunn’s test was used for comparison of ordered values. The differences in rates and proportions between the three groups were analyzed by the Steel test. Statistical analysis was done with SigmaStat for Windows Release 2.0 (SPSS, Inc., Chicago, IL). Statistical significance was based on a P value less than 0.05.

3. Results

3.1. Mortality

Clinical outcomes and perioperative data in the three SCP groups are listed in Table 2. The total mortality was 11.9%. Three patients (5.1%) died early, within 30 days after the operation. The causes of early death were pulmonary bleeding from an aneurysm that ruptured into the left lung in one patient (DH group); perioperative myocardial infarction due to retrograde aortic dissection extending to the right coronary ostium caused by cannulation into the axillary artery in one patient (MH group); and multi-organ failure in one patient with acute aortic dissection causing profound cardiogenic shock with anuria preoperatively (CHWB group).
Four patients (6.8%) died afterwards while hospitalized. The causes of late hospital death were pneumonia (died on postoperative day 132) and recurrent cerebral infarction (postoperative day 203; DH group); sepsis (postoperative day 242; MH group); and respiratory failure (postoperative day 61; CHWB group). Thus, the early mortality (within 30 days after operation) was 7.1, 5.9 and 3.6%, and hospital mortality (including early mortality) was 21.4, 11.8 and 7.1%, in the DH, MH and CHWB groups, respectively. The differences in the early mortality and hospital mortality in the three SCP groups were not statistically significant. Data from a patient in the MH group who died intraoperatively of myocardial infarction were excluded from the following analysis.

3.2. Stroke

Stroke occurred in three patients (5.1%), one in each of the three groups. The rate of stroke was 7.1, 6.3 and 3.6% in the DH, MH and CHWB groups, respectively, and did not differ significantly among groups. Two of the three stroke patients probably had an embolism, as determined by...
computed tomographic scanning of the brain. The cause of the embolism was speculated to be debris from the arterial cannulation site in the severe atheromatous ascending aorta in one patient (MH group), and thrombi in the arch aneurysm, which was manipulated before initiation of CPB in the second patient (CHWB group). The cause of stroke in the third patient (DH group) was unknown. The patient in the MH group did not awake and died of sepsis. The other two patients awoke with a permanent neurological deficit, but died afterwards of recurrent cerebral infarction and respiratory failure, respectively.

3.3. Duration of perfusion and operation

The CPB time was shorter in the MH and CHWB groups than in the DH group. The SCP time was longer in the CHWB group than in the DH and MH groups. The reason for the longer SCP time in the CHWB group is that more CHWB patients underwent total arch replacement using a branched graft, which has more anastomosis sites. Rewarming time, defined as the time from completion of SCP to the point at which the nasopharyngeal temperature reached 34°C, was shorter in the CHWB than in the DH and MH groups, as was operation time. The operation time after CPB discontinuation, during which hemostasis was carried out, was shorter in the CHWB than in the DH group.

3.4. Intraoperative blood loss

Intraoperative blood loss (including the shed blood collected into a cell-saver device) in the DH, MH and CHWB groups was 3150 (2900–4000), 2300 (1300–2650) and 1345 (1105–2250) ml, respectively. The blood loss was significantly smaller in the CHWB group than in the DH group.

Table 2
Clinical outcome and perioperative variables in the three groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>DH (n = 14)</th>
<th>MH (n = 17)</th>
<th>CHWB (n = 28)</th>
<th>Total (n = 59)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early death (≤30 days)</td>
<td>1 (7.1)b</td>
<td>1 (5.9)b</td>
<td>1 (3.6)b</td>
<td>3 (5.1)b</td>
</tr>
<tr>
<td>Hospital death (including early death)</td>
<td>3 (21.4)b</td>
<td>2 (11.8)b</td>
<td>2 (7.1)b</td>
<td>7 (11.9)b</td>
</tr>
<tr>
<td>Stroke</td>
<td>1 (7.1)</td>
<td>1 (6.3)</td>
<td>1 (3.6)</td>
<td>3 (5.2)</td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>182 ± 54</td>
<td>137 ± 43f</td>
<td>147 ± 33c</td>
<td>153 ± 44c</td>
</tr>
<tr>
<td>SCP time (min)</td>
<td>65 ± 29</td>
<td>67 ± 25</td>
<td>91 ± 34d</td>
<td>78 ± 33</td>
</tr>
<tr>
<td>Myocardial ischemia time (min)</td>
<td>110 ± 44</td>
<td>89 ± 37</td>
<td>92 ± 23</td>
<td>95 ± 33</td>
</tr>
<tr>
<td>Rewarming time (min)</td>
<td>54 ± 27</td>
<td>27 ± 13d</td>
<td>13 ± 11c</td>
<td>27 ± 24</td>
</tr>
<tr>
<td>Operation time (min)</td>
<td>461 ± 54</td>
<td>408 ± 84</td>
<td>349 ± 66d</td>
<td>392 ± 89</td>
</tr>
<tr>
<td>Operation time after CPB (min)</td>
<td>198 (150–300)c</td>
<td>135 (123–168)c</td>
<td>115 (102–144)c</td>
<td>135 (115–185)c</td>
</tr>
<tr>
<td>Intraoperative blood loss (ml)</td>
<td>3150 (2900–4000)c</td>
<td>2300 (1300–2650)c</td>
<td>1345 (1105–2250)c &amp;</td>
<td>2100 (1251–3925)c &amp;</td>
</tr>
</tbody>
</table>

* One patient in the MH group who died intraoperatively was excluded from the analysis except for statistics on mortality.

b Figures in parentheses represent percentage values.

c P < 0.05 vs. DH.
d P < 0.05 vs. MH.

Table 2* Values are means ± standard deviations or medians (25–75%).

4. Discussion

Antegrade SCP was introduced since the 1950s as an adjunct during aortic arch surgery [13,14]. This technique was first used under normothermia, but was associated with a relatively high rate of neurological complication [15,16]. Recently, moderate to deep hypothermia has been used for antegrade SCP, and this combination has been reported as an excellent brain protection method [3,4,8,17]. Although deep hypothermic circulatory arrest with or without retrograde cerebral perfusion has recently been most frequently used during aortic arch operations [1,2,18–20], antegrade SCP is still advocated by many authors because it provides an unlimited time to perform arch repair. However, the proper protocol for SCP, such as optimum flow rate or perfusion pressure and temperature, is still uncertain [21], and each institution has its own protocol.

In terms of temperature during antegrade SCP, DH or MH may provide a wider safety margin and be more protective against cerebral ischemia than normothermia is [4,22]. However, hypothermia, which leads to coagulation disturbance and requires a longer CPB time, may not be essential for visceral perfusion. In 1991, Bachet and associates [23] introduced antegrade cold blood cerebral perfusion at 6–12°C, during which CPB is discontinued at moderate core hypothermia of 25–28°C. Using this technique, they reported fatal and non-fatal neurological complications of 3.5 and 9.3%, respectively [17]. We provisionally conclude that such a cold temperature may not be essential for cerebral perfusion because many authors have reported maintaining good neurological results using moderate hypothermic antegrade SCP. We also hypothesized that maintaining visceral perfusion at a higher temperature may be better because tepid or normothermic CPB have been reported to reduce postoperative bleeding [10,11] and inflammatory reactions [24] compared with moderate to deep hypothermic CPB. Therefore, we applied a combi-
nation of moderate hypothermic cerebral perfusion (25°C) and tepid visceral perfusion (32°C).

The first finding in this study of 59 patients was that CHWB perfusion is a safe technique in aortic surgery. CHWB perfusion did not increase the rate of operative death, or stroke, despite mean CPB and SCP times of 147 and 91 min, respectively. Relative to data from recent reports of deep hypothermic circulatory arrest with retrograde cerebral perfusion, the CPB time in the CHWB group was comparable, but the SCP time was much longer than the time for circulatory arrest. The long SCP time is required because we have recently used a branched graft and we reconstruct cephalic arteries separately, and discontinue the SCP only at the very end of the surgical procedures (Fig. 2). The reason we began to use a branched graft is that we often found the orifice of the cephalic arteries to be severely atheromatous, and we chose not to leave this possible source of the cerebral infarction. Despite the long SCP time, the rate of stroke was 3.6%, which is comparable with the other brain protection methods. Our findings also suggest that in terms of the temperature of antegrade SCP, DH may be no better than MH for brain protection because there were no statistical differences in the rate of stroke among the three groups.

The second finding in this study is that CHWB perfusion may contribute to shortening the CPB and operation times and to reducing intraoperative blood loss. The CPB time, especially the time for rewarming, was significantly shorter in the CHWB group than in the DH and MH groups. Likewise, the operation time, especially after CPB is discontinued, was shorter in the CHWB group than in the DH and MH groups. Intraoperative blood loss was significantly less in the CHWB group than in the DH group. The reduced rewarming time in CHWB perfusion can probably be attributed to the tepid temperature of visceral perfusion; less time is required to achieve the requisite temperature for continuing CPB. A reduced operation time after CPB discontinuation, which means less time required for hemostasis, together with a reduction in intraoperative blood loss suggest that coagulation function is preserved during CHWB perfusion. This suggestion is consistent with the observations of Yau et al. [10] and Boldt et al. [11] that normothermic CPB reduced postoperative bleeding and preserved platelet counts or platelet aggregation compared with hypothermic CPB.

Broadly speaking, there were definite differences between the CHWB and DH groups. However, there were no significant differences between the CHWB and MH groups across all variables studied. It is probable that during cerebral perfusion at 25°C, the core temperature of the patients in the CHWB group drops below 32°C and that the gap in temperature between the various parts of the body is reduced. This may be especially true when open distal anastomosis was employed. Therefore, MH and CHWB groups may be very comparable in terms of physiological behavior. To clarify whether CHWB perfusion is merited over moderate hypothermic SCP, further study will be necessary.

There are, however, some limitations of the study that need to be considered. Firstly, the number of patients in each group is relatively small. Therefore, the statistical power for comparing the three groups is weak, and there is the possibility that we failed to find a significant difference between the groups because of the small number. Secondly, our study is not a prospective randomized study. Certain operative variables, such as the timing of operation (elective or emergent), extent of surgical repair and use of a branched prosthesis, were not evenly distributed among the three groups. Moreover, selection of the SCP technique largely followed a chronological pattern, in this order: DH, MH and, more recently, CHWB. Surgical equipment, anesthesia, and intraoperative and postoperative management have been significantly improved during these roughly 10 years, and these improvements may have influenced the result. Thus, although the DH group includes six patients who were operated on rather recently, we cannot exclude the possibility that the results may be due to chronological differences. To resolve this uncertainty, a prospective randomized study will be necessary.

There are some disadvantages to the CHWB technique. The circuit and management of antegrade SCP and visceral perfusion are somewhat complicated, requiring the perfusionist to be well trained in this method. Also, the surgeons need to have the patience to handle the two or three cerebral perfusion cannulae and the aortic occlusion catheter in the operating field. Despite these disadvantages, we believe that the simultaneous use of hypothermic cerebral perfusion and tepid visceral perfusion, so-called CHWB perfusion, is a safe and useful supportive technique in aortic arch surgery, particularly for patients undergoing complex arch replacement. Further study will be necessary to clarify the effectiveness of this technique.

Acknowledgements

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References


Appendix A. Conference discussion

Dr H. Borst (Munich, Germany): Again, I think this is a very important and significant study, raising the question whether we are really right in performing long-term circulatory arrest of the brain, and before we start out the discussion, I would like to ask the audience who is using antegrade perfusion?

(Show of hands)

Had you asked that question 5 years ago, there would have been not as many positive responses.

Dr T. Mesana (Marseille, France): Did you use this technique in aortic dissection?

Dr Takano: Yes, we did.

Dr Mesana: Did you find any problem inserting the balloon and occluding the descending aorta? The false lumen didn’t show back flow? In aortic dissection, if you inserted your balloon, where do you put it?

Dr Takano: For acute aortic dissection we do not use an occlusion balloon because inflating a balloon in the dissecting descending aorta would be dangerous. We do not use an occlusion balloon for patients with an associated dissecting aortic aneurysm either. Furthermore, when the distal anastomosis is very deep and difficult, we occasionally stop visceral perfusion and remove the occlusion balloon to facilitate the distal anastomosis. In such cases, we perform open distal anastomosis, and perfuse the visceral organs after completion of the distal anastomosis.

Dr Mesana: So there is a certain period of time when the lower part of the body is warm and not perfused?

Dr Takano: Yes, that’s right.

Dr Mesana: Can you comment about that?

Dr Takano: As I mentioned, in some patients, whether as planned or unexpectedly, we apply open distal anastomosis. That is the reason why we first cool the patient to 28°C, not 32°C, before beginning selective cerebral perfusion. When we can use an occlusion balloon in the descending aorta, we perfuse the visceral organs at 32°C. When we cannot use an occlusion balloon, we delay the visceral perfusion until the distal anastomosis is completed. In the latter case, the merit of CHWB perfusion is somewhat attenuated. However, during the arch reconstruction, we always perfuse the visceral organs at a tepid temperature.

Dr R. Bonser (Birmingham, UK): Just a small technical point. At what temperature do you come off bypass?

Dr Takano: In most cases, at 35–36°C.

Dr Bonser: And you necessarily see a temperature afterdrop after that. Do you see any hemodynamic instability or other problems associated with that?

Dr Takano: No, we don’t see hemodynamic instability or bleeding problems associated with temperature afterdrop. Actually, we see a slight temperature afterdrop of only 1°C or less after the CPB is discontinued.

Mr F. Wauders (Doorn, The Netherlands): Did you see any paraplegia in those groups?

Dr Takano: No, we didn’t see any paraplegia in these 59 patients.

Mr Wauders: And what is the reason that in the latest operations you
perfused the left subclavian as well? Why did you switch to that? So, as well, the innominate, left carotid artery and the left subclavian.

**Dr Takano:** The reason we perfuse the left subclavian artery is that there is a small chance that the right vertebral artery does not connect with the basilar artery and the bilateral posterior communicating arteries are closed. In such a patient, the left subclavian artery is crucial for the brain stem and cerebellum. In addition, we didn’t encounter any difficulty in perfusing the three cephalic arteries as opposed to two.

**Mr Waanders:** We have now done about 166 cases in the last three years and we didn’t see any problem with cerebral perfusion of the left carotid artery and the innominate, as long as you occlude the left subclavian artery to avoid malperfusion. Thank you.

**Dr Takano:** I assume that you had excellent results because your selective cerebral perfusion time was short. I say that because I have encountered one patient in a different hospital, in whom we perfused only the innominate and left common carotid arteries and reconstructed the left subclavian artery at the very end of the procedure, when the blood temperature was fully warmed up. The patient developed a cerebellar and brain stem infarction and never awoke.

**Dr Borst:** What do you think of using self-inflating balloons? I don’t like so much the idea that you would have to encircle the cerebral arteries and put snares on, especially in cases of dissection.

**Dr Takano:** I agree with you that placing snares around the cephalic arteries would be risky. However, if we don’t put the snares on, the cannulas would be pushed out by the perfusion pressure of 40–50 mmHg. A new cannula which has some ribs arrayed in a lattice on the external surface of the balloon has been introduced in Japan, and some surgeons have started to use it without snares. We now plan to try that cannula.