Unilateral cerebral perfusion: right versus left

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Abstract

Objectives: Unilateral cerebral perfusion for brain protection is gaining increasing interest, although the pathways of collateral flow as well as many aspects of the surgical strategy regarding optimal perfusion pressure, flow and temperature remain unclear. This study evaluates the differences between right- and left-sided unilateral cerebral perfusion, if any, especially with regard to neurovascular monitoring findings and clinical outcome. Methods: Between January 2005 and April 2008, 200 consecutive patients underwent elective aortic arch surgery at our facility. One-hundred patients were selected for left-sided unilateral cerebral perfusion supplying the brain through the left common carotid artery and another 100 patients for unilateral cerebral perfusion supplying the brain through the right-sided carotid and vertebral arteries. Arterial return of the cardiopulmonary bypass and the unilateral cerebral perfusion were performed in all patients via cannulation of a corresponding carotid artery using a side graft. Results: Arch repair was performed under mild hypothermic circulatory arrest with a rectal temperature of 30.1 ± 1.8°C and 31.6 ± 1.6°C in the left- and right-sided cerebral perfusion, respectively. The duration of circulatory arrest with unilateral cerebral perfusion was identical for both groups (17.2 ± 2 min). Brain perfusion was performed through the arterial line at a blood temperature of 28°C and a flow rate of 0.9 ± 0.2 l min⁻¹ on the left and 1.5 ± 0.3 l min⁻¹ on the right. The flow velocities in the median cerebral artery contralateral to the side being perfused revealed no differences between the groups. There was no 30-day mortality. Two patients (one in each group) with severe calcification of the aortic valve suffered minor strokes. Conclusion: Unilateral cerebral perfusion under mild hypothermia is an efficient method of cerebral protection. The advantage of the right-sided perfusion in which two brain-supplying arteries are perfused could not be verified.

Keywords: Cerebral perfusion; Circulatory arrest; Aortic arch; Carotid artery

1. Introduction

The history of unilateral cerebral perfusion can be traced back to 1986 when the Stanford group first reported on one-sided head perfusion during arch surgery by using the innominate artery for cannulation [1]. However, due to anatomical—pathological conditions of the innominate artery, its usefulness for cannulation is very limited. The most important advantage of the unilateral cerebral perfusion is the simplification of the brain perfusion through an arterial line installed by arterial cannulation of an arch artery. Therefore, the technique of unilateral cerebral perfusion did not gain increased interest until the development of cannulation techniques using various arch arteries, such as axillary, brachial or carotid artery [2–5]. However, the pathways of collateral flow, as well as many aspects of the surgical strategy during unilateral cerebral perfusion, especially with regard to optimal perfusion pressure, flow and temperature, remain unclear.

If the arch arteries are free from anatomical—pathological abnormalities, then right-sided unilateral cerebral perfusion is through the right carotid and vertebral arteries regardless if the carotid, axillary or innominate artery is cannulated. In left-sided perfusion, although only the left common carotid artery is supplied, there are several pathological conditions in which cannulation of this artery can be advantageous [5–7]. This study evaluates the differences between right- and left-sided unilateral cerebral perfusion, if any, especially with regard to neurovascular monitoring findings and clinical outcome.

2. Patients and methods

Between January 2005 and April 2008, in our facility, a total of 200 patients underwent elective surgery of the aortic arch using circulatory arrest. In all patients, the carotid artery was cannulated for arterial inflow during the cardiopulmonary bypass and, as is our routine, the arterial line was used for unilateral cerebral perfusion during circulatory arrest. The first 100 patients operated on until the end of 2006 were assigned for cannulation of the left common artery (LCA group) and the remaining patients were assigned for cannulation of the right carotid artery (RCA group). Due to the vascular...
pathology in one patient in each group, the carotid artery contralateral to the assigned side had to be cannulated. All perioperative data were collected prospectively and an informed consent was obtained from all patients.

The main indication for surgery in this series was chronic degenerative or atherosclerotic aneurysm, and the most frequent surgical procedure was ascending aortic replacement with an open distal anastomosis to the aortic arch (hemiarch) followed by a total or subtotal aortic arch replacement. Detailed preoperative patient data are presented in Table 1, while the surgical procedures and operative data are shown in Table 2.

The preoperative neurovascular diagnostics included Doppler ultrasonography of the extracranial vessels, and when feasible, transcranial Doppler ultrasonography. Evaluation of the circle of Willis by a cranial computed tomography (CT) angiography was carried out until 2006 and was abandoned thereafter because we had not found a clinical relevance for this examination [8]. Cerebral monitoring tools included arterial pressure lines in radial arteries, electroencephalography, measurement of somatosensory-evoked potentials, near-infrared spectroscopy and, if feasible, transcranial Doppler ultrasonography of the middle cerebral arteries (75 in LCA group and 79 in RCA group). All measurements were recorded continuously and the mean values were calculated for each operative phase (before cardiopulmonary bypass (CPB) and during CPB cooling, circulatory arrest with cerebral perfusion, CPB warming and after CPB) for the purpose of the study.

The technique of carotid artery cannulation has been described previously [5]. In short, in all patients, after heparinisation, the exposed segment of the carotid artery was cross-clamped, a longitudinal incision was made and an 8- or 10-mm vascular sealed polyester graft (InterGard; InterVascular, La Ciotat, France) was anastomosed to the artery with a continuous 5/0 polypropylene suture. After connection of the arterial line and cannulation of the right atrium, CPB was started with a flow of 2.2–2.4 l min⁻¹ m⁻² of body surface.

The technique of unilateral cerebral perfusion has been described previously in detail [7]. In brief, the arterial line installed in a carotid artery included a Y-shaped cannula, which can be used to perfuse the other hemisphere of the brain to achieve bilateral cerebral perfusion. Nevertheless, neither in this study population nor in our total experience with more than 400 patients was a switch to the bilateral perfusion necessary. After the distal aortic anastomosis had been completed, and in total or subtotal arch replacements following re-implantation of the arch arteries, this Y-shaped cannula can also be used to switch the arterial perfusion from the carotid artery to an aortic graft. Because this manipulation is neither complicated nor time-consuming, we employed it in all patients (157) in whom aortic grafts with side branches (’InterGard Hemabridge’ with one side branch or ’InterGard Aortic Arch’ with four side branches; InterVascular, La Ciotat, France) were used. It led to the omission of re-perfusion through the carotid artery during re-warming and shortened the overall perfusion time through the carotid artery. The vascular graft initially anastomosed with the common carotid artery was severed near the anastomosis and oversewn during re-perfusion or after terminating CPB.

Values in the tables and text are expressed as mean ± standard deviation unless otherwise indicated. All statistical analyses were performed using SPSS software (SPSS Inc., Chicago, IL, USA). The continuous variables were analysed using the unpaired t test and the categorical variables were tested by the chi-square (χ²) test or Fisher’s exact test, when appropriate. A p-value less than 0.05 was considered as significant in all of the tests.

### 3. Results

In four patients of the LCA group the carotid artery was cannulated intrathoracically; however, the cross-clamp time of the carotid artery during cannulation revealed no significant difference between the groups (LCA, 7.7 ± 1.4 min vs RCA, 7.1 ± 1.2 min, p = NS). Arch repair was performed in all patients under mild hypothermic circulatory arrest with a rectal temperature of 30.1 ± 1.8 °C in the LCA group and 31.6 ± 1.6 °C in the RCA group (p < 0.001). However, the duration of the unilateral cerebral perfusion was identical for...
both groups (17.2 ± 2 min), and the brain perfusion was always performed at an arterial blood temperature of 28 °C. The arch arteries were cross-clamped, and the unilateral cerebral perfusion was set up by simply reducing the arterial flow to a mean flow of 0.9 ± 0.2 l min⁻¹ on the left and 1.5 ± 0.3 l min⁻¹ on the right. By modulating the flow, average pressure in the arterial line was maintained at about 100 mmHg. This flow rate resulted in an average pressure, in the right radial artery, of 39 ± 9 mmHg and 70 ± 15 mmHg in LCA and RCA groups, respectively. The mean pressure in the left radial artery, reflecting the true collateral flow to the left vertebral artery, was 35 ± 8 mmHg in LCA group and 40 ± 10 mmHg in RCA group. The same was true with regard to the mean flow velocities (cm s⁻¹) in the median cerebral artery and the regional cerebral tissue oxygen saturation (%), as examined by transcranial Doppler ultrasonography and near-infrared spectroscopy contralateral to the side being perfused. The flow velocity was 17.5 ± 12.4 in LCA group and 19.9 ± 12.4 in RCA group. The regional cerebral tissue oxygen saturation during unilateral cerebral perfusion was 60 ± 6 and 61 ± 7, respectively, showing a drop in saturation values to 90% of the baseline (measured before CPB) in LCA group and to 89% in RCA group. All values mentioned above revealed only slight differences between the groups. We have not considered a statistical comparison as being applicable because the flow rate during right-sided cerebral perfusion is strongly affected by the flow into the right arm. On the basis of our earlier observations, the pressure of about 30 mmHg in both radial arteries was considered to be sufficient for cerebral cross-perfusion when the left carotid artery was perfused; and therefore, the flow rate during right-sided cerebral perfusion has been modulated accordingly to achieve the same or similar values as during the left-sided cerebral perfusion. It should be emphasised here that all these data are only useable when the left subclavian artery is occluded during cerebral perfusion.

All patients regained consciousness postoperatively. There was no 30-day mortality. Two patients (one in each group) with severe calcification of the aortic valve suffered minor strokes. Postoperative temporary neurologic dysfunction such as confusion, delirium or agitation lasting more than 48 h but without focal deficit occurred in six patients (three in each group). None of the patients revealed any obvious aberrations of monitored neurovascular parameters from the average values during the entire surgery. In five of them, a hemiarch replacement was performed with a median time of 13 min (range: 10—23 min).

4. Discussion

The most tried-and-true method of cerebral protection is certainly a straight, deep hypothermic circulatory arrest, which offers favourable results when its duration is limited to 30 min or less [9]. The stroke risk increases significantly when the duration of the deep hypothermic circulatory arrest exceeds 40 min [10]. Moreover, in addition to the negative side effects of deep hypothermia on various organ systems, the duration of CPB had also been identified as an independent risk factor for an adverse outcome [11,12]. Consequentially, there are three potential goals to improve the results in a surgery necessitating circulatory arrest: extension of a safe period of cerebral protection, omitting the deep hypothermia and shortening the time of CPB. The only way to achieve all of these goals is through selective cerebral perfusion. This technique was originally used as an adjunct to deep hypothermia; however, there is a continuous trend to increase the body temperature during circulatory arrest and consequently shorten the bypass time [13,14].

Selective cerebral protection is associated with direct cannulation of the aortic arch arteries, which is regarded as a risk of cerebrovascular injuries resulting from an air embolism or a dislodgement of atherosclerotic debris [15,16]. In acute dissection of arch vessels, direct cannulation with perfusion catheters can also damage the fragile vascular wall, resulting in bleeding complications or malperfusion. The latter can also be caused by a failed positioning of the perfusion catheter [17]. The risk of manipulation-related injuries can be limited by cannulation of one arch artery for arterial return of CPB. In such cases, the cerebral perfusion does not have to be interrupted for placement of perfusion cannulas, and the additional manipulation on arch arteries for completion of bilateral perfusion is consequently limited but cannot be completely avoided.

Limiting cerebral perfusion to one side simplifies the surgery, decreases the risk of embolism and provides better exposure by not cluttering the surgical field with cannulas. After the development of the techniques of arch arteries cannulation, the unilateral cerebral perfusion underwent a renaissance. Recently, many experimental and clinical series documented the usefulness of unilateral perfusion for brain protection [4—7,18—20].

However, the aspect of adequate collateral circulation and its pathways, especially, the role of circle of Willis, remains unclear. To the best of our knowledge, there is only one report suggesting poor efficiency of unilateral cerebral perfusion [21]. This report raises, however, more questions than provide answers, especially because the unilateral cerebral perfusion was used as an adjunct to deep hypothermia, which even as a sole protection method with a duration of 33 min and nasopharyngeal temperature of 18—22 °C should have led us to expect a better neurologic outcome than a 29% stroke rate. Surprisingly, at least 60% of patients with stroke (not all had cranial CT after surgery) revealed bilateral lesions. These results can indicate that the cold cerebral perfusion can impair the regional cerebral flow due to the loss of vascular autoregulation. In experimental settings, such a situation could already be demonstrated [22]. A long duration of cold perfusion or unbalanced perfusion due to vascular pathology, for example, cerebrovascular microangiopathy, can therefore be considered as a cause of neurological damage during cerebral perfusion. To avoid the impairment of cerebrovascular autoregulation, we prefer the brain perfusion at a blood temperature of about 28 °C, regardless of the body temperature, which can certainly be much higher, especially during arch surgery with a short period of circulatory arrest. The cooling of the patients is adjusted to the expected duration of circulatory arrest, which can be primarily assessed in elective patients. In the cohort described, no patient had a rectal temperature that was lower than 26 °C and only 11 patients had a temperature lower than 28 °C, while in 21 patients the duration of circulatory arrest was longer than 30 min with a longest duration of 70 min.
In patients with acute dissection, an unexpected complex arch repair is often required; and therefore we cool the patients to a rectal temperature of about 28–30 °C, otherwise the technique of cerebral perfusion is identical. However, the choice of carotid artery to be cannulated is made according to the vascular pathology as diagnosed by the CT angiography. In patients with signs of malperfusion, a double cannulation of a carotid and femoral arteries is very reasonable [6].

The collateral pathways of cerebral circulation are still not completely understood. As we demonstrated previously, even in cases with an anatomically incomplete circle of Willis as documented by CT angiography, cross-perfusion during the unilateral cerebral perfusion remained unimpaired even when supplying the brain only through one arch artery [8]. For this reason, we consider that the circle of Willis is not the only pathway for cerebral cross-perfusion, but the extracranial collateral circulation plays a meaningful role, especially in patients with an incomplete circle of Willis. Possibly, the apparent incompleteness of the circle of Willis, as presented in CT angiography, changes its functional status by dilatation of angiographic invisible collaterals in case of impaired perfusion. Therefore, as a consequence of our previous study, we abandoned pre-operative examination of the anatomical status of the circle of Willis but still perform a functional occlusion test during cannulation of the carotid artery [8]. The theoretical advantage of the right-sided unilateral cerebral perfusion performed by supplying the brain through two arteries over left-sided perfusion performed by supplying the brain through only one (left carotid) artery has not been examined up to present.

The fact that patient recruitment was not randomised and the two groups of patients were treated during two different time periods are the limitations of the study. Apparently, the latter led even to the difference between CPB time and the lowest temperature in both groups because over time, we reduced the systemic cooling continuously, especially in patients with a short circulatory arrest period. However, the study was not focussed on lower body temperature during circulatory arrest but cerebral protection, and that was performed using comparable conditions, namely cannulation and perfusion through a common carotid artery under the same blood temperature.

In conclusion, the study supports the feasibility and effectiveness of moderate hypothermic unilateral cerebral perfusion for brain protection, regardless of the side being perfused. However, even though we were not able to demonstrate an advantage of the right-sided perfusion in which two brain-supplying arteries are perfused in a cohort of 200 patients, the theoretical possibility of improved cerebral perfusion through the right side cannot be completely eliminated in some very rarely seen vascular pathologies. For this reason, we consider the right-sided cerebral perfusion as the standard, especially because the right carotid artery and the innominate artery are more suitable for cannulation than the left carotid artery [23]. Nevertheless, if dictated by the patient’s pathology, cannulation of the left common carotid artery and left-sided cerebral perfusion can be considered as a very effective and safe alternative.

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References

I read with great interest the article by Urbansky et al. [1]. They described a large case study involving unilateral cerebral perfusion through the left carotid artery in 100 patients and the right carotid artery in another 100 patients associated with mild systemic hypothermia (rectal temperature 30—31 °C). The average duration of cerebral perfusion was 17 min, irrespective of whether the left or right carotid artery was used. The results were impressive without any early deaths in any of the 200 consecutive elective patients. Only one patient in each group suffered a minor stroke and three patients in each group suffered from transient neurologic dysfunction. The authors concluded that unilateral cerebral perfusion is an efficient method of cerebral protection and that any advantage of right-side perfusion, in which the two brain...