Uni- versus bilateral antegrade cerebral perfusion during repair of acute aortic dissection: still a discussed matter!

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Central message
Cerebral perfusion during repair of acute aortic dissection is discussed controversially: attention should not only be drawn on cerebral protection but also on manipulations of supra-aortic vessels.

Central picture
Unilateral (left) versus bilateral (right) antegrade cerebral perfusion.

Perspective
Cerebral perfusion during repair of acute aortic dissection is an important issue but attention should not only be drawn on safety and efficacy of cerebral protection since manipulations on the supra-aortic vessels may have a potential for severe adverse effects.

Abstract
Unilateral versus bilateral antegrade cerebral perfusion (ACP) is controversially discussed in the setting of type A acute aortic dissection repair. This paper focuses on a topic which is independent of the quality of the cerebral protection itself but addresses some issues due to manipulations of the supra-aortic vessels.

We present 5 cases of postoperative occlusion of the innominate artery observed following emergency open arch ascending aortic replacement. We believe that occlusion of the innominate artery may have been caused at least partially by clamping this vessel during unilateral ACP through the right subclavian arterial line. All patients suffered from an ipsilateral neurological injury and one died. Two underwent emergency revascularization with a vascular graft interposition or complex stenting of the innominate artery. These two patients showed significant improvement of the neurological impairment and were discharged with a mild residual hemiparesis while two patients still suffered from significant hemiparesis at discharge. This paper addresses some caveat regarding unilateral ACP and clamping of the innominate artery in the setting of aortic dissection. Only prospective randomized studies would be able to definitively clarify which of these both protection techniques is safer with regard to all aspects.
Since the introduction of cerebral perfusion as a brain protection method during surgical repair of the aortic arch, a significant number of papers have analyzed which type of perfusion may provide the most optimal cerebral protection:

- antegrade cerebral perfusion (ACP) via the supra-aortic branches or retrograde cerebral perfusion (RCP) via the superior vena cava?
- unilateral ACP performed through the subclavian artery cannula of the cardiopulmonary bypass circuit? or
- bilateral ACP with two selective perfusion catheters introduced in the innominate artery (respectively the right common carotid artery) and the left common carotid artery?

This topic is still matter of debate and highly contradictory opinions are reported in the literature. While some surgeons defend the unilateral ACP as the most simple and efficient method of cerebral protection, other prefer to "mimick" the normal physiology and use bilateral ACP with two catheters combined or not to the occlusion of the left subclavian artery (1-6). Other groups still favor the RCP and/or demonstrated that the latter method may be associated with less radiographic neurologic injuries than ACP or no significant clinical differences (7,8).

In this short paper, we would like to focus on cerebral protection during repair of acute type A aortic dissection because the handling of the supra-aortic branches (clamping, snaring, occlusion with balloons) in the setting of a weakened arterial wall may imply some particular issues. Furthermore we report on some clinical observations made following clamping of the innominate artery.

**A controversial discussion**

In a recent paper from Vienna, 184 patients received aortic repair because of acute type A aortic dissection, using bilateral (n=91) and unilateral (n=93) ACP. Overall clinical outcomes were similar (1). However, subgroup analyses suggested that bilateral ACP was associated with superior survival in patients requiring a duration of circulatory arrest of 50 minutes or more.

The decision to proceed with unilateral or bilateral ACP depended on the surgeon’s preference and experience, as well as the estimation of the required duration of circulatory arrest. Before starting unilateral ACP, the surgeons at Vienna University Hospital clamped all three vessels (Figure 1). During the ACP, oxygen saturation was monitored bilaterally using NIRS. If the latter decreased by 15% to 20% during unilateral perfusion, the left common carotid artery was also cannulated and cerebral protection switched to bilateral ACP.
In this series, the rate of bilateral cerebral lesions and unilateral left-sided lesions was higher in patients receiving unilateral ACP, whereas the rate of unilateral right-sided lesions was higher in patients receiving bilateral ACP. From these findings, the authors concluded that the insertion of an additional perfusion cannula into the left common carotid artery does not increase the risk of left-sided cerebral lesions.

In contrast to this publication, Piperata published recently the results of a retrospective multicenter study that compared unilateral (39% of the patients) versus bilateral (61%) ACP during repair of acute type A aortic dissection (2). In this study, the flow for ACP was accomplished through the right subclavian artery arterial line from the main pump of the cardiopulmonary bypass circuit (1/3) and through a separate pump for the left carotid and left subclavian arteries (2/3). The relative blood flow through these two separated perfusion lines was regulated according to the observed NIRS values, the bilateral radial artery pressure monitoring and the pump line pressure. Using a propensity score analysis, the authors demonstrated that patients that received a bilateral ACP, had a significantly higher incidence of permanent neurologic deficits ($P < 0.001$), left brain hemisphere stroke ($P = 0.007$) and all-combined complications ($P < 0.001$). The hypothesis for this observation was that more manipulations around and within both carotid arteries during bilateral perfusion as well as some dysfunction of the cerebral autoregulation with significant unequal blood flow into both hemispheres may precipitate adverse cerebral outcome.

It is not a matter of perfusion only: handling with the supra-aortic branches is important!

In addition to the discussion regarding the perfusion and its characteristics, we would like to add one important point, namely the concern regarding manipulations to the supra-aortic branches, especially in the setting of a weakened arterial wall. The first author of this paper introduced hypothermic circulatory arrest combined with bilateral ACP during repair of aortic dissection and any type of aortic arch aneurysm at a previous institution in 2002 with a case load of 80 to 100 hypothermia cases per year (around 50% being cases of acute type A aortic dissection). Unilateral ACP was used only exceptionally, mainly when introduction of a perfusion catheter in one of the common carotid artery was technically not possible (kinking, severe ostial stenosis or occlusion). The classical setting for bilateral selective ACP was an additional small pump in the cardiopulmonary bypass circuit (identical to that one used for cardioplegia) and a tubing system connected to an "octopus" with two arms (similar to what is used for selective cardioplegia) (Figure 2A). As alternative the ACP line is connected with a Y to the arterial return line that is clamped during ACP (Figure 2B)
For the purpose of bilateral ACP, a special very smooth and small perfusion catheter with balloon occlusion was developed in the department and later commercialized by Le Maître (Figure 2C). There are three potential advantages using this approach:

1. No need to clamp or snare any of the supra-aortic vessel in the context of a fragilized vessel wall through acute dissection (especially when it is dissected) with the risk of an additional injury to these vessels with subsequent flow obstruction or complete occlusion.

2. The introduction of a smooth balloon into the true lumen may favor expansion of the dissected cylinder from inside the vessel and bring the dissected layers somewhat together, especially when biologic glue has been introduced in-between the layers. In fact, the balloon is inflated very gently just to avoid retrograde flow.

3. The balloon inflation into the carotid arteries (resp. the innominate artery on the right side) may prevent from unnoticed glue entrapment and cerebral embolization, a critical event that has been reported, when glue was routinely introduced for aortic dissection repair (9).

**Injury during clamping and consecutive occlusion of the innominate artery**

The first author moved recently to another tertiary care center with an annual volume of 60+ acute type A aortic dissections (2021: 82 cases) with a strategy of unilateral ACP. In a consecutive series of 55 patients operated during an 8 months interval, 5 cases (10%) of postoperative occlusion of the innominate artery were observed. All patients underwent replacement of ascending aorta with an open distal anastomosis at the level of the proximal aortic arch. ACP was performed according to the following characteristics: core temperature 26 to 30°C, tympanic temperature < 24°C, cerebral flow 10-15 ml/kg body weight, pressure 50-60 mm Hg. Occlusion of the innominate artery was thought to be caused or aggravated by clamping or snaring this vessel during unilateral ACP through the right subclavian arterial line.

In four patients, the innominate artery was already dissected at preoperative CT-scan, in one case it was intact.

All patients suffered from a major ipsilateral neurological injury and one died. Two underwent emergency revascularization with a vascular graft interposition between the ascending aorta and the bifurcation of the innominate artery in one (Figure 3) and complex stenting of the innominate artery up to the bifurcation of the right common carotid artery in the second case (Figure 4). In the two other cases, no additional revascularization was performed since the dissecting membrane extended distally to the carotid artery bifurcation up to the intracranial part of the internal carotid artery, and the neurologic deficit was thought to be irreversible.
Patients who received revascularization showed significant improvement of the neurological deficit and were discharged with a mild residual hemiparesis while the two patients treated conservatively still suffered from significant hemiparesis at discharge in a neuro-rehabilitation. The IRB/ERB’s of our university hospital granted the waiver since patients all signed the general consent that allows use of anonymized data for research purposes.

Comment

When weighting the risks and benefits of unilateral versus bilateral ACP, the interest should not only focus on the quality of cerebral protection but also consider the potential dangers during manipulations of the supra-aortic branches that emerges to be extremely important as well:

1. Those who do not use or support bilateral ACP, argue with the potential danger of manipulation of supra-aortic vessels during introduction of perfusion catheters into the innominate artery and the left common carotid artery and warn about the risk of carotid dissection or embolization of atherosclerotic particles. In fact, the presence of aortic arch and branches atherosclerosis is extremely uncommon in patients presenting with acute aortic dissection. In addition, it does not seem logical to believe that potential mobilization of thrombotic material from the false lumen may be better avoided by clamping a vessel than by occluding it with an intraluminal balloon.

2. One should be aware that clamping an already dissected supra-aortic vessel through a vascular clamp or a tourniquet for snaring represents an additional severe trauma, that has practically never been addressed in the literature.

3. The fact that a gently expanded intravascular balloon may safely occlude the vessel, and also prevent from embolization of glue or thrombotic material during the sealing process at the level of the distal aortic anastomosis when the aortic arch is open. This is also a poorly discussed potential advantage.

We have used the technique with small perfusion catheters and balloon blockage extensively in the setting of thoraco-abdominal and abdominal aneurysms repair to perfuse and/or occlude either spinal or visceral arteries and to block retrograde blood flow. We never observed any compression injury, because the balloon is inflated smoothly just until there is no backflow out of the perfused artery.
4. Finally, monitoring of the right radial artery pressure to assess efficacy and safety of ACP may not be optimal because the individual positioning of the cannula in the subclavian artery and/or the angle of the side-graft anastomosed to the subclavian artery may cause significant variations in flow and pressure during perfusion.

Conclusions

These are few considerations regarding unilateral and bilateral ACP that should provide additional informations about the potential dangers of clamping the supra-aortic vessels, in particular the innominate artery when it is dissected. Endovascular balloon occlusion seems at least safer in term of additional trauma to an already fragilized arterial wall. Nevertheless, only prospective randomized studies would be able to definitively clarify a question that is opened since the introduction of cerebral protection more than two decades ago.
References


Unilateral ACP during circulatory arrest through the arterial cannula of the cardiopulmonary bypass circuit. In this case, the innominate artery must be occluded (either by a clamp or by snare with tourniquet). In addition, occlusion of the left common carotid and subclavian arteries preclude backflow through the circulus Willisi and contribute to an increased intracerebral perfusion pressure.

**Figure 1**

A. Bilateral selective ACP with balloon catheters. Ideally, ACP is performed through a separate line connected to a smaller cardioplegia pump.

B. Alternatively, ACP may be performed through the normal arterial return line using a Y-connector and clamping the right subclavian line.

C. Perfusion catheter with balloon occlusion through a separate line for selective ACP.

**Figure 2**

Postoperative computed tomography imaging and 3D reconstruction showing revascularization of the proximally occluded innominate artery with a vascular graft (arrow) between the ascending aorta (*) and the bifurcation of the innominate artery.

**Figure 3**

A. Angiographic imaging of the innominate artery shows a retention of the contrast agent in the false lumen of the dissected common carotid artery (arrows).

B. The dissected innominate artery and the right common carotid artery were treated with two kissing stents, which reached out into the aortic arch (*). The technique of the kissing stents ensures optimal distal perfusion of both the right subclavian and right carotid arteries and preclude compression or occlusion of one vessel through the other one. In addition, kissing stents allowed a safe closure of the supposed entry in the trunk while vascular access in the true lumen was secured using ultrasound guided puncture of the right carotid artery.

C. Post-interventional computed angiography showing the two parallel stents in the innominate artery (arrows).

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Unilateral antegrade cerebral perfusion

Bilateral antegrade cerebral perfusion