REVIEW ARTICLE

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Cerebral protection: sites of arterial cannulation and brain perfusion routes

Proteção cerebral: sítios de canulação arterial e vias de perfusão do cérebro

Ricardo Ribeiro DIAS[1], Isaac Azevedo SILVA[2], Alfredo Inácio FIORELLI[3], Noedir Antonio Groppo STOLF[4]

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Abstract

Brain perfusion for adequate cerebral protection has changed over the years. The limitations of the time during total circulatory arrest with deep hypothermia, the inefficient cerebral metabolism during retrograde perfusion and special care to prevent cerebral embolism during antegrade perfusion have resulted in the development of different methods of cerebral protection during the evolution of aortic arch operations. Antegrade cerebral perfusion associated with moderate hypothermia is today, considered the best option for cerebral protection.

Descriptors: **Cardiopulmonary bypass. Brain. Perfusion. Hypothermia, induced.**

Resumo

O método de perfusão encefálica para a adequada proteção cerebral evoluiu desde o início da circulação extracorpórea. As limitações de tempo de atuação na parada circulatória total em hipotermia profunda, a ineficiente manutenção do metabolismo encefálico na retroperfusão cerebral e os cuidados relacionados à prevenção de eventos embólicos na perfusão cerebral seletiva resultaram em diferentes métodos de proteção cerebral durante sua evolução, principalmente nas operações que envolvem o arco aórtico. O fluxo arterial anterógrado, em oposição ao fluxo arterial retrógrado, e os sítios de canulação que permitem esse fluxo anterógrado são hoje, em associação à hipotermia moderada sistêmica, considerados o método mais efetivo de proteção cerebral.

Descritores: **Circulação extracorpórea. Encéfalo. Perfusão. Hipotermia induzida.**

1. Assistant doctor of the Surgery of General Heart Disease Unit of InCor HCFMUSP.
2. Resident of InCor HCFMUSP.
3. Director of the Surgery of General Heart Disease Unit of InCor HCFMUSP.
4. Full Professor of the Cardiovascular Surgery Section of the Medicine School of USP; Director of the Surgery Division of InCor HCFMUSP.

Work carried out in the Heart Institute of the Hospital das Clínicas, Medicine School of the University of São Paulo

Correspondence address:
Ricardo R Dias Av. Dr. Enéas de Carvalho Aguiar, 44 - 2ºandar sala 13 – São Paulo, SP - CEP: 05403-000
E-mail: diasrr@hotmail.com

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INTRODUCTION

The technique of cardiopulmonary bypass (CPB) was introduced by John Gibbon in 1953, changing the history of cardiovascular surgery. Due to the invention of the artificial heart-lung machine, intra- and extra-cardiac procedures could be accomplished in safety in a bloodless operative field.

However, particularly in surgeries involving the aortic arch, brain injury due to embolic phenomena, the period of total circulatory arrest (TCA) or methods of unsatisfactory partial or total cerebral perfusion, is still a cause of death and motor and cognitive sequels, which may be permanent or transitory.

With the purpose of reducing the neurological morbidity under these conditions, several methods have been proposed to provide better brain protection during operations of the aortic arch.

Undoubtedly, TCA under deep hypothermia is a simple, practical and reproducible method. It creates a bloodless operative field free of cannulae, allows a clear view of the structures, as well as offering safety whilst performing anastomosis. In spite of these advantages, TCA under deep hypothermia is not completely free of complications. Controlled clinical trials demonstrate frequent neurological complications in adults submitted to surgeries using TCA [1]. Apart from strokes secondary to embolic phenomena, temporary neurological dysfunction occurs in up to 20% of the patients [1,2]. Another important limiting fact is the TCA time. Studies suggest that cognitive deficit is more frequent when the circulatory arrest time is more than 25 minutes [3-5]. Moreover, recent studies in animals and humans suggest that cerebral metabolic suppression during hypothermia is less complete than initially postulated [4,6].

Faced with this condition of inadequate cerebral protection with deep hypothermia associated to TCA, alternative forms of maintaining cerebral perfusion during systemic circulatory arrest have been investigated. In 1988, Ueda et al. [7,8] reported cerebral perfusion by means of the infusion of oxygenated blood through the superior vena cava, which became known as retrograde brain perfusion. This continuous infusion of arterial blood by the venous system using blood pressures of less than 25 mmHg aims at continually supplying nutrients and oxygen to the central nervous system, as well as enabling the removal of debris and arterial emboli. However, subsequent studies in animals did not demonstrate a significant metabolic benefit with the use of retrograde brain perfusion. These studies only observed advantages related to the removal of emboli from the arterial system.

Even before the concept of retrograde perfusion, Frist et al. [9] and Cooley et al. [10], working separately, tried to maintain cerebral perfusion by anterograde irrigation through cannulation of the aortic arch. However, the results were unsatisfactory, mainly due to the utilization of normothermic or slightly hypothermic cerebral perfusion, which were common at that time.

Then, Crittenden et al. [11] demonstrated the superiority of anterograde cerebral perfusion compared to the other techniques. In experimental studies, with tight temperature control and at a low flow rate, these authors demonstrated that anterograde cerebral perfusion provided better preservation of the intracellular pH and of the energy reserves in the brains of animals.

Nowadays, anterograde cerebral perfusion with systemic circulatory arrest with hypothermia seems to be the most efficient technique for brain protection in aortic arch surgeries.

With the efficacy of anterograde perfusion demonstrated, questions emerged in respect to the best site of arterial cannulation to establish anterograde perfusion.

The current review work purposes to study previously described arterial cannulation sites and cerebral perfusion routes, highlighting the advantages and disadvantages of each.

It is important to note that, in spite of the analysis being specifically centered on thoracic aortic diseases, it is also relevant to other cardiovascular diseases as, when there is involvement of the descending aorta that does not allow its direct cannulation, knowledge and experience with alternative sites of arterial cannulation are necessary for CPB.

DISCUSSION

In a review of the literature in respect to this subject we found several arterial cannulation sites mentioned, from the ascending aorta itself, with or without local dissection, to arch vessels, and vessels of the upper limbs, cervical region and lower limbs.

Most are retrospective studies or reports of series of cases. When prospective, they are not randomized. But, they are important due to the information attained related to the benefits and complications of different cannulation sites.

As to the routes other than the ascending aorta, the right axillary artery (or right subclavian) was the most commonly mentioned access. This access route allows continuous anterograde perfusion and is frequently free of dissection and atherosclerotic disease. Those who are accustomed to using the femoral arterial, argue that it is a safe route, with easy access and that it is extremely well-understood. Some still recommend the use of less common

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access routes such as the brachial artery, the cervical segment of the carotid artery, transventricular cannulation of the aorta or, even, the ascending aorta itself with acute proximal dissection [12].

FEMORAL ARTERY

The femoral artery has been used to establish the arterial line of CPB since 1950 and although it has now been succeeded by descending aortic cannulation, it is still an important access route when CPB is necessary before sternotomy or when the ascending aorta is not viable.

It is easy to access as it is an easily identified surface vessel. If there is iatrogenic injury of the vessel, due to atherosclerotic plaques, its repair through plasties, tube insertion, or even by crossed grafts, is not difficult to achieve.

Once the arterial line is established through the femoral artery, blood flow up to the aortic arch branches is retrograde. With aortic atherosclerotic disease or thrombi, there have been reports of a higher incidence of strokes and visceral injury compared to anterograde perfusion owing to the embolic effect, [13-15].

Fusco et al. [16], in 2004, reviewed 79 patients surgically treated for Stanford type-A acute aortic dissection, where CPB was established by femoral access. In this series, only two (2.5%) patients had unsatisfactory retrograde flow with the necessity to change the site of arterial cannulation. No patient suffered visceral ischemia. Seven (8.8%) cases of strokes were reported, four in patients with severe preoperative hemodynamic instability (cardiac tamponade and patients submitted to cardiopulmonary resuscitation maneuvers). The authors defend the utilization of the femoral artery with Stanford Type-A dissections, as in this disease an association with severe aortic atherosclerotic disease is not common, as was reported by Kojima et al. [17]. However, they recognize that the risk of embolization counterindicates its use with severe atherosclerotic disease. Hence, they support flexibility in the indication of this access for CPB.

Kokotsakit et al. [18] advocated, by citing the work of Price and Harris [19], that the femoral access should not be utilized due to its high association with strokes and visceral ischemia. The same opinion is shared by Sabik et al. [13]. But, Lakew at al. [20], in a retrospective study of 327 patients surgically operated for descending aortic aneurysm repair, where 166 (50.8%) patients were submitted to aortic arch cannulation and 161 (49.2%) to femoral artery cannulation, reported no statistically significant difference in the results related to neurological complications. They also stated that, chiefly in aortic arch surgeries, the axillary and carotid arteries are important alternative routes when the goal of CPB is perfusion and brain protection.

RIGHT AXILLARY/RIGHT SUBCLAVIAN ARTERY

Axillary/subclavian artery cannulation was firstly described by Villard et al. [21] in 1976, but it was rarely mentioned until a group from Cleveland Clinic published their experience of 35 patients in 1995 [22].

There is currently a preference for axillary/subclavian artery cannulation to establish the arterial line because of the possibility of selective cerebral perfusion in aortic arch surgeries and in acute aortic dissections. The best access route, the use of grafts or direct cannulation of the artery and the complications of these different methods are still discussed today [13,14,18,22-25].

It is interesting to note that, even when atherosclerotic disease extensively involves the aorta up to the innominate artery, the axillary/subclavian artery is seldom affected [26,27].

In aortic dissection, femoral cannulation can cause perfusion by the false lumen, resulting in bad cerebral and visceral perfusion, with severe consequences for patients but this rarely occurs when using of the right axillary/subclavian artery [28].

Sabik et al. [13] reviewed 35 patients who underwent diverse surgeries where ascending aortic and femoral artery cannulation were impracticable due to severe vascular disease. In these patients, the axillary artery was chosen for cannulation through an infraclavicular incision. Cannulation was performed directly in the artery utilizing a specific cannula, without inserting grafts. Complications were observed in one patient, who suffered from a significant reduction in the ipsilateral radial pulse after the surgery, requiring a venous graft and a second patient who presented with mild paresis and paresthesia of the cannulated arm. No adverse central neurological events were reported.

Moizumi et al. [29] retrospectively analyzed 106 cases of Stanford type-A acute aortic dissections aiming at identifying predictors of in-hospital mortality. In multivariate analysis, they observed that not performing perfusion through the right axillary artery was an independent risk factor, with an odds ratio of 8.2.

Strauch et al. [22] reported the use of direct cannulation of the axillary artery in 284 patients by infraclavicular access. In 12 (4.2%) patients, adequate CPB arterial flow was not achieved and the cannulation site needed to be changed. Two (0.7%) patients presented paresis of the ipsilateral hand, which was irreversible in one. Lymphocele was a complication evidenced in five (1.8%) patients. No case of infection of the operative wound was diagnosed, nor were bleeding or local vascular impairment. These authors disagree with the use of synthetic grafts inserted in the axillary artery because, they believe, that this procedure requires time, presents greater risk of bleeding and may cause injury due to high blood flows in the ipsilateral limb.

Kokotsakit et al. [18] performed 27 surgeries with CPB using the right axillary artery. Of these, 4 patients were submitted to direct cannulation and 23 to the placement of a graft. There were two deaths, which were not related to the arterial access. One patient presented with paresthesia of the arm with spontaneous improvement. Cases of arterial or venous thrombosis in the axillary system were not observed, nor were strokes. In all cases the CPB flow was satisfactory.

Schachner et al. [23] reported their experience attained in 65 surgeries using CPB with axillary arterial access. Twenty patients were submitted to arterial cannulation using polytetrafluoroethylene grafts (PTFE), while direct cannulation was performed in the other patients. The complications observed were analyzed in three categories:

1. Direct arterial injury: 0/20 of the patients with PTFE grafts and 4/45 (9%) of the direct cannulation group had injuries;

2. Insufficient flow: 0/20 of patients with graft and 2/45 (4%) of the direct cannulation group;

3. Inadequate right upper limb perfusion: This happened in 3 (15%) patients, all from the group with grafts.

There were no operative wound infections, compartment syndrome or brachial plexus injury.

Yilik et al. [30] investigated 68 surgical patients, of whom 22 (32.4%) were submitted to direct right axillary artery cannulation (Group 1) and 46 (67.6%) to graft cannulation (Group 2). The authors observed that three (13.6%) patients of Group 1 presented with vascular complications of the ipsilateral upper limb with one requiring an aortobrachial bypass. In Group 2, no complications were identified. Permanent neurological dysfunctions were not observed, but transient neurological dysfunction was diagnosed in 4 (18.1%) patients of Group 1 and 1 (2.1%) patient of Group 2.

Bichell et al. [14] added to axillary artery cannulation the use of the axillary vein or axillary-axilla cardiopulmonary bypass, in seven patients in whom ascending aortic and femoral artery cannulation were not possible. Cannulation was direct and, in all cases, good flow was achieved without ischemic complications of the upper limbs, compartment syndrome or arterial thrombosis. Two patients presented transient paresis of the right hand.

Aoyagi et al. [24] reported another variation of axillary artery cannulation. They performed surgical procedures of the aortic arch in 11 patients using double-arterial cannulation: a cannula was inserted in the femoral artery and another in the axillary artery. No permanent or transient neurological problems were diagnosed.

Although the approach to the subclavian/axillary artery most commonly described is the infraclavicular access, Fabri et al. published their experience of four cases of supraclavicular approach with direct cannulation. These authors suggest that the supraclavicular incision is better than the infraclavicular incision, especially in obese patients.

BRACHIAL ARTERY

Küçüker et al. [31] reported their experience in 181 patients, in which the right brachial artery was utilized for the arterial cannulation of CPB, through a lengthwise incision along the bicipital groove in the axillary fossa. Complications related to brachial artery cannulation were observed in six (3.3%) patients. One of them evolved with the loss of both radial and ulnar pulses, with the necessity of re-operating the brachial artery under local anesthesia. An embolectomy using a Fogarty catheter was performed with resection of the arterial segment and end-to-end anastomosis. Five other patients complained of paresis of the right hand, which spontaneously improved by the 10th postoperative day. The incidence of permanent central neurological deficit was 1.6% but not related to the arterial cannulation site.

CAROTID ARTERY

For surgeries of the thoracic aorta by left posterior lateral thoracotomy, Veron et al. [32] cannulated the left common carotid artery in 42 patients using a cervical incision and inserting a PTFE graft. Fifty-seven per cent of these patients were also cannulated using the femoral access with the purpose of avoiding visceral ischemia during selective cerebral perfusion. All the patients came around after surgery without strokes, transient ischemic attacks or paraplegia.

Souza et al. [33], reported their experience of nine patients using the right common carotid artery anastomosed in a PTFE tube for the arterial line of CPB in aortic arch surgeries with selective brain perfusion. No patient presented with neurological sequels. Care with the use of the carotid artery in respect to brain injury due to hyperflow or the dislocation of atherosclerotic plaques was not mentioned in this reference.

ASCENDING AORTA TRANSVENTRICULAR ROUTE

The apex of the left ventricle was described as a cannulation site in surgeries to repair proximal aortic dissection. Flege & Aberg [12] introduced the cannula at the apex of the left ventricle and guided it to the ascending aorta. Some of the difficulties related to this exceptional approach are impairment of the ventricular function and the risk of valve injuries.

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