Cerebral revascularization: past, present and future

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Introduction

Since the first human bypass surgery performed by the French surgeon Alexis Carrel, the evolution of bypass techniques had been refined by the aim of microsurgery and technology. Nowadays, the use of surgical microscope, microsurgical instruments, the role of intraoperative indocyanine green video angiography and some preoperative studies like acetazolamide with single photon emission CT (SPECT), that allows studying the cerebrovascular reserve, plays an important role in cerebral revascularization surgery. Some complex aneurysms, skull base tumors and Moya-Moya disease, need to be treated by this modality. In this review we analyzed anatomical data of donor and recipients bypass vessels and the techniques involved.

1) "MICROSURGICAL ANATOMY OF CEREBRAL REVASCULARIZATION. PART I: ANTERIOR CIRCULATION"

Masatou Kawashima, Albert Rhoton Jr, Necmettin Tanriover, Arthur Ulm, Alexandre Yasuda, Kiyotaka Fujii
J Neurosurg 2005; 102: 116-31.

Information

This paper is divided in two parts: an anatomical study on 25 heads with a detailed description of the anterior circuit and an extensive description of principal cerebral bypass procedures for this vascular area. Internal carotid artery (ICA) anatomy is described from carotid triangle to supraclinoid segment. External Carotid Artery (ECA) is also review, with special relevance in superficial temporal artery (STA), being the main donor vessel for low-flow bypass.

Medial Cerebral Artery (MCA) and Anterior Cerebral Artery (ACA) anatomical review is focused in M2 and M4 segments and A3 segment, respectively, because these segments are the targets for cerebral revascularization. A minimum length of 4 mm is needed for an anastomosis, so it is important to know the length of cortical artery for the bypass strategy.

There is either radial artery (RA) and saphenous vein (SV) anatomy review due they are most common grafts used. RA has a complex trajectory between forearm and carpus muscles, in close relation with superficial branch of radial nerve. Great Saphenous vein is the longest vein. It has its origin in the medial marginal vein at foot and ends in the femoral vein 3cm below inguinal ligament.
Bypass techniques are divided in high and low flow. High flow bypass description include cervical ECA/ICA to M2 segment, cervical ICA to petrous ICA, cervical ICA to supraclinoidal ICA and Bonnet Bypass which supplies good irrigation to MCA/ACA territories. Low flow bypasses analyzed are: STA to MCA anastomosis, MMA to MCA anastomosis and side-to-side intracranial anastomosis. They can be made with a short arterial or venous interposition graft. These types of bypass are used for small areas such as different M4 branch territories. Extension of ischemia, diameter, and length of recipient vessel are critical angiographical tips for bypass planning. M2 is located at sylvian fissure, and usually its diameter is wider than 1.5mm, being an appropriate site for pedicled arterial low flow bypass or for high flow bypass with graft interposition.

Allen test has to be performed previously to dissect RA in order to check collateral blood supply by ulnar artery. For SV graft, an incision is done from medial malleolus up to the knee (15-20 cm of vein is obtained). Graft should be washed inside with heparinized saline solution, and placed in this solution until the anastomosis. SV carries in a high flow 110ml/min versus the half of RA. Nevertheless, SV has disadvantages such as donor size discrepancy or presence of valves. In cases that are needed, transient occlusion of ICA is mandatory to check collateral circulation and if it is not present ECA should be used.

Analysis

Bypass surgery to cerebral anterior circuit are still current techniques used in many diseases for which endovascular techniques are not able to resolve yet. The most important information a neurosurgeon needs to perform a bypass surgery to anterior circuit is written in this paper.

Vascular anatomy is well depicted which is essential for a successful surgery. A comprehensive description of usable grafts is the other great contribution of this work. Finally, thorough descriptions of all vascular recipients complete the essential information for this surgery.

2) “MICROSURGICAL ANATOMY OF CEREBRAL REVASCULARIZATION. PART II: POSTERIOR CIRCULATION”

Masatou Kawashima, Albert Rhoton Jr, Necmettin Tanriover, Arthur Ulm, Alexandre Yasuda, Kiyotaka Fujii
J Neurosurg 2005; 102: 132-47.

Information

The author examined 22 adult cadaveric specimens and performed various procedures for revascularization of the posterior circulation with and without graft (arterial/vein interposition grafting or side-to-side anastomosis respectively) describing the techniques, advantages and disadvantages of each one of them. For small areas some effective bypass include the superficial temporal artery-posterior cerebral artery, superficial temporal artery- superior cerebellar artery, occipital artery- anterior inferior cerebellar artery, occipital artery- posterior inferior cerebellar artery and PICA-PICA anastomoses. For larger areas a posterior cerebral artery to external carotid artery bypass is performed using saphenous vein graft.

The STA-PCA anastomosis. This procedure is performed using a subtemporal approach with gently retraction to avoid an injury of the Vein of Labbe and the temporal lobe. The author refers that is not necessary to make a dissection of the P1 segment because the anastomosis is performed at the P2 segment, between the crural and ambiens cistern, taking care of the P2 branches arising there.

The ECA-PCA anastomosis. The carotid triangle is exposed making a cervical incision along the anterior aspect of the sternocleidomastoid muscle. The P2 segment is dissected through a subtemporal route and the bypass is performed with a saphenous vein or a radial artery graft.

The STA-SCA anastomosis. Though a subtemporal approach, the tentorial edge is sectioned and reflected to expose the superior cerebellar artery, taking care of the IV nerve coursing beneath this level.

The OA-AICA anastomosis. The occipital artery is identified on the scalp by using a Doppler device. A long graft piece is necessary dissecting the artery until the superior nuchal line, in a tortuous and deeper course than the STA. A suboccipital craniotomy is performed opening the foramen magnum. The best receipt vessel is the floculo-nodular or the cortical segment of the AICA, distal to the facial-vestibulo-cochlear complex.

The OA-PICA anastomosis. Using a suboccipital approach, the occipital artery´s anastomosis is performed to the caudal loop of the PICA.

Side to side anastomosis of the PICA. This procedure is used for revascularization of the distal portion of the PICA through the anastomosis of the tonsillo-medullary or the telo-velo-tonsillar segments of the artery.

Analysis

The author performed a descriptive article with a thorough labor focus on the anatomy and the most relevant techniques for revascularization of the posterior circulation using 22 adult cadaveric specimens. The indications for this procedure include the treatment of giant aneurysm, skull base tumors and arteriosclerotic vertebra-basilar disease. However the efficacy of this practice remains uncertain due to a low experience, the abundant collateral flow and the lack of a randomized study. The challenge about this surgery concerns the small but critical areas it deals (cranial nerves, brainstem and cerebellum), the small diameters of the recipient vessels and the deep and narrow operative space.

3) "GRAFT SELECTION IN CEREBRAL REVASCULARIZATION"

Ali Baaj, Siviero Agazzi, Harry Van Loveren
Neurosurg Focus 2009; 26: 1-4

Information

Cerebral revascularization plays an important role in the treatment of complex aneurysms, carotid artery occlusion and Moya-Moya disease. The three main principal types of grafts used are: the saphenous vein (SV), the radial artery (RA), and the superficial temporal artery (STA).

Vascular grafts are characterized by low-flow (STA or occipital artery graft), moderate-flow (RA graft), or high-flow (SV graft). The choice of flow-rate of the graft depends on multiple factors such as the area of the under perfused region, the level of under perfusion, the chronicity of the deficit, and the degree of collateral flow formation.

The STA is an ideal graft for its accessibility and its proximity to the brain vascular system. It only requires one anastomosis. The STA-medial cerebral artery (MCA) is the graft of choice in most cases of revascularization.

The RA graft lends itself to anastomosis with equivalent diameter vessels such as M2 or P1 segments. The use of the RA graft is associated with a high rate of spasm. However, published reports have demonstrated the patency rate and safety of using the RA graft in cerebral revascularization.

The SV graft is used in revascularization for cerebral occlusive disease, aneurysms, and even dissections. It is suitable for cases in which extensive volume augmentation is necessary. This graft is more prone to kinking at the distal anastomotic site, where the turbulence across the anastomosis is greater.
Catheter angiography, balloon test occlusion and cerebral perfusion studies play a critical role in assessing the need for bypass as well as the type of graft needed. There are three categories of patients for the graft selection process: those who have clinical evidence of ischemia; those who are about to undergo intentional major vessel occlusion; those who are about to undergo an operation with the risk of major vessel occlusion. The first group needs only supplementary perfusion, which can be provided using a simple STA-MCA bypass or a RA graft as a second option. The second group requires an RA graft, and its patency must be demonstrated before major vessel occlusion; if an RA graft is not available, a lower extremity vein is used. Either RA or SV grafts may be used for the third group of patients.

Analysis

The aim of this paper is to analyze and describe the use of different types of bypass grafts in the treatment of cerebral revascularization. The choice of graft type plays a critical role in the surgical planning. At the moment of making a decision, it is essential to know the hemodynamic characteristics of the graft and the affected region, as well as the accessibility and patency rates.

These surgical procedures seem to be an important subject in the management of complex aneurysms, carotid artery occlusion and Moya-Moya disease, among others. Although others techniques such as the endovascular treatment stands out, it is not always possible to resort it when dealing with the before mentioned pathologies. It is then that the cerebral revascularization surgery appears to be a feasible and effective therapeutic alternative.

4) "THE EVOLUTION OF CEREBRAL REVASCULARIZATION SURGERY"

Melanie Hayden, Marco Lee, Raphael Guzman, Gary Steinberg
Neurosurg Focus 2009; 26: 1-7

Information

The International Cooperative Study of Extracranial/Intracranial Arterial Anastomosis (EC/IC bypass study, an international, multicenter, prospective, randomized study conducted from 1977 to 1985) suggested EC-IC anastomosis was no better at preventing stroke in patients with atherosclerotic arterial disease of the CA and MCA compared with best medical therapy.

Saint Louis Carotid Occlusion Study is a prospective cohort analysis that was found that asymptomatic patients had a lower frequency of hemodynamic abnormalities, as determined by significantly elevated OEF.

The JET – 1 Study is a multicenter, randomized, prospective study that revealed a significantly lower incidence of stroke recurrence for patients with Stage II ischemia undergoing bypass surgery than those treated with strict medical therapy.

The COSS is a randomized, controlled study looking at the ability of combined STA-MCA bypass and medical therapy to reduce subsequent ipsilateral ischemic stroke, in patients with atherosclerotic ICA occlusion with hemispheric symptoms and ipsilateral increased OEF. The COSS trial is currently expected to run until 2013.

The RECON trial is an ancillary study to COSS aimed at assessing the relationship between cerebral hemodynamics and cognitive function in patients undergoing treatment for unilateral CA occlusion with EC/IC bypass.

The JET – 2 Study examines the stroke recurrence rate on medical treatment for patients with stage I ischemia as determined by cerebrovascular reserve capacity and rest CBF value.

The JAM trial is a multicenter randomized trial looking at the efficacy of bypass revascularization to improve prognosis for patients with Moya-Moya disease who present with intracranial bleeding.

ELANA is an attractive, novel bypass technique for CBF augmentation as it avoids the temporary cessation of CBF. Sutureless ELANA technique can be used for EC-

IC and IC-IC bypass, and has the advantage that it is faster, with 89% patency rate.

Analysis

The article describes a brief review of the history of cerebral revascularization, sets the present state of the issue and shows future steps according to the results of ongoing trials. With a better understanding of the pathophysiology of cerebral ischemia and a better patient selection, revascularization surgery remains be a safe procedure with demonstrated efficacy.

Synthesis

Although the use of technology is important, microsurgical skills and the knowledge of vascular anatomy are mandatory. It is crucial to choose the correct graft in the bypass surgical strategy, due the flow which brings each of them (low, medium or high flow).

Although the "International Cooperative Study of Extracranial/Intracranial Arterial Anastomosis" was not favorable for bypass to prevent stroke in patients with atherosclerotic disease, in a subgroup of patients with elevated OEF (and with hemodynamic changes) bypass surgery could be a good indication.

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