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Surgical Neurology 68 (2007) S1:4 – S1:11
SURGICAL NEUROLOGY
www.surgicalneurology-online.com

Technique

Flow-assisted surgical technique in cerebrovascular surgery

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Received 10 June 2007; accepted 12 July 2007

Abstract

Background: Cerebrovascular surgery is a technically challenging subspecialty of neurosurgery. A flow-based approach to cerebrovascular surgery can help to optimize neurosurgical interventions.
Methods: Direct intraoperative flow measurements can be made using a quantitative ultrasonic microvascular flow probe. In this article, we review the applications and utility of the FAST in aneurysm and EC-IC bypass surgery.
Results: In aneurysm surgery, flow measurements provide a quick and repeatable method to assess vessel patency and avoid complications related to vascular compromise. In bypass for flow augmentation in the setting of ischemia, flow measurements assess bypass patency and can assess the physiologic success of the bypass strategy. In bypass for flow replacement in the setting of planned vessel sacrifice, flow measurements can measure the flow deficit resulting from the vessel occlusion, assess the adequacy of in situ donor vessels, and confirm the ultimate adequacy of the bypass at the completion of surgery.
Conclusions: The FAST strategy provides a useful approach to optimizing decision making and outcomes during cerebrovascular surgery.

Keywords: Aneurysm; Blood flow; Extracranial-intracranial bypass; Flow measurement

1. Introduction

Cerebrovascular surgery is a technically challenging subspecialty of neurosurgery. With the advent and rapid advances in endovascular technologies, the pathologies that are brought to surgical attention are increasingly complex. To minimize the morbidity and mortality associated with the surgical treatment of cerebrovascular diseases, we propose that a flow-based approach to cerebrovascular surgery is beneficial. Direct vessel flow measurements intraoperatively can provide valuable data in decision making and in direct evaluation of the success of the surgical intervention. The utility of such as the FAST in the setting of aneurysm and bypass surgery will be reviewed in this article.

2. Aneurysm surgery

One of the major risks associated with aneurysm surgery is the potential for inadvertent occlusion or compromise of the vascular branches from which the aneurysm arises, which can result in stroke. Although the operative microscope has enhanced the ability to determine this complication by direct visual observation, visual examination alone does not identify all instances of vessel compromise. Microvascular Doppler [6,13] or routine intraoperative angiography [9,15,20,24] has been advocated as strategies to avoid

Abbreviations: AchA, anterior choroidal artery; AcoA, anterior communicating artery; BA, basilar artery; BOT, balloon occlusion test; CFI, cut flow index; CO_2, carbon dioxide; CTA, computed tomographic angiography; EC-IC, extracranial-intracranial; FAST, flow-assisted surgical technique; ICA, internal carotid artery; MCA, middle cerebral artery; MRA, magnetic resonance angiography; OA, occipital artery; PcoA, posterior communicating artery; PICA, posterior inferior cerebellar artery; QMRA, quantitative magnetic resonance angiography; STA, superficial temporal artery.

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0090-3019/$ – see front matter © 2007 Elsevier Inc. All rights reserved.
doi:10.1016/j.surneu.2007.07.051

inadvertent vessel compromise but have potential limitations and disadvantages. Use of direct quantitative flow measurements, however, can provide a technique to reliably avert vessel compromise during aneurysm surgery.

2.1. Technique of flow measurement for aneurysm surgery

Direct intraoperative flow measurements are made with the use of a microvascular ultrasonic flow probe (Charbel Micro-flowprobe; Transonic Systems, Inc, Ithaca, NY). The device consists of an electronic flow detection unit and a flow sensing perivascular probe. The flow probe uses the principle of ultrasonic transit time to sense flow in vessels independent of the flow velocity profile, turbulence, or hematocrit [7,19]. The flow in milliliters per minute appears as a digital display on the detection unit and is indicated as positive or negative dependent on the direction of flow in relation to the orientation of the probe. The probe is manufactured in a variety of sizes ranging from 1.5 to 3 mm in diameter. Close vessel contact with the probe is not a requirement because the space between the vessel and the encircling probe can be filled with an ultrasonic couplant such as saline. Low signal strength is suggestive of air bubbles or fat particles between the vessel and the probe, which need to be removed to allow accurate measurements. The accuracy of measurements with the ultrasonic flow probe has been well established with in vitro and in vivo studies [19].

During aneurysm surgery, flow in the vessels associated with the aneurysm are measured. A portion of the vessel of interest wide enough to accommodate the probe is dissected free from the surrounding arachnoid, and the probe is hooked around the vessel under direct vision. The field around the probe is filled with saline to allow flow measurements to be made. The flexible connection of the probe tip to its handle allows the instrument to be placed in multiple different trajectories for optimal application around the vessel. Flow measurements in all vessels of interest are performed preclipping, either directly or indirectly, to obtain a baseline and postclipping to confirm preserved flow. The target vessels of interest vary based upon the type of aneurysm involved. For example, in MCA aneurysms, the M_1 and/or M_2 vessels are routinely measured before and after clipping. For aneurysms along the ICA, the larger vessel diameter or the size and location of the aneurysm may preclude probe placement on the distal ICA. In such cases, the M_1 and A_1 trunk can be measured to reflect the distal outflow of the ICA (Fig. 1). For AcoA aneurysms, the flows in the A_1 and A_2 branches are of concern. However, the projection of the aneurysm can make adequate access to the A_2's difficult, especially for ruptured aneurysm cases, where it is desirable to avoid excessive manipulation of the dome of the aneurysm. In such cases, the flows in the territories of concern can be gained indirectly. A temporary clip can be placed on the AcoA itself, and the A_1 flow measured as a direct reflection of the ipsilateral A_2 flow. Another option is placement of the temporary clip on the contralateral A_1. The flow measured in the ipsilateral A_1 is a reflection of the total flow in both A_2 branches and can be compared pre- and postclipping. Small vessels (<1 mm) are not reliably measured. Therefore, vessels such as the PcoA or AchA can be assessed accurately only if they are of larger caliber. It is important to note that, in some cases, the flow probe can be used to assess vessels distant from the aneurysm. For example, during a transsylvian approach to BA aneurysms, the ICA or MCA branches may be at risk from retractor positioning, and measuring flows in these vessels during the approach can avert unintended distant vessel compromise.

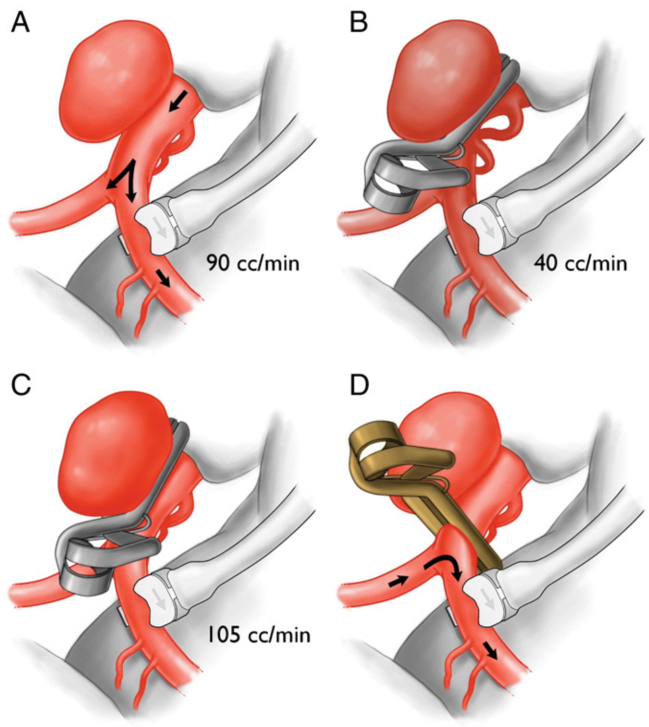

Fig. 1. Flow-assisted surgical technique in aneurysm surgery. A: Measurement of MCA flow before clipping of a proximal ICA aneurysm. B: Measurement of MCA flow after clipping of the aneurysm. A significant (>50%) reduction in flow is noted. C: The clip is repositioned with return of flow to baseline; often, a temporary mild increase in flow is encountered after clip repositioning consistent with postischemic hyperperfusion. D: The probe can also be used to assess the adequacy of distal flow during temporary clipping of the parent vessel, as demonstrated, or to determine the safety of parent vessel occlusion (From Amin-Hanjani S et al: The utility of intraoperative blood flow measurement during aneurysm surgery using an ultrasonic perivascular flow probe. Neurosurgery 2006;58:ONS-306 with permission).

Flow measurement of relevant vessels requires minimal time and requires little more dissection beyond that used for our routine aneurysm dissection. With careful attention to microsurgical technique, we have not encountered any instances of vessel injury resulting from the minor degree of additional perivascular dissection and probe placement. It is important to note that blood flow measurements can be affected by burst suppression, blood pressure, and arterial CO_2 —attention must be paid to assessing flow measurements under stable anesthetic conditions to avoid false-negative or false-positive values.