Technical Note

Comparison of Cerebrovascular Measurement Modalities

Studies that assess vessel patency after cerebral aneurysm clipping have revealed unexpected vessel compromise in up to 30% of cases leading to stroke-related disabilities and possibly death. Several intraoperative modalities are used to assess cerebral blood flow, perfusion or occlusion during aneurysm surgery. An overview of the various modalities follows.

Transit-Time Ultrasound Volume Flowmetry

Transit-time ultrasound flowmetry gives the surgeon quick, direct (real-time), quantitative measurements of pulsatile and average flow by applying a perivascular Flowprobe around an exposed major cerebral vessel. The measurements either prompt clipping adjustment or they confirm preservation of flow and avoid unnecessary clip adjustment. Used with an acoustic couplant such as saline or cerebrospinal fluid, the Probe does not constrict the vessel or require any direct contact with it. Measurements take less than five minutes per surgery and rarely require significantly more than routine dissection. The technology cannot discern residual aneurysm remnants. Flow in perforators or small vessels must be derived by measuring flow in larger branches.

Intraoperative Angiography

Angiography presents a visual (anatomical) image of a region of the circulatory system and is used both for intraoperative assessment of vessel patency and for assessment of residual aneurysm. Its invasiveness carries a certain risk. The time it takes to perform an intraoperative angiogram (20-30 min) may exceed the threshold for irreversible ischemia. Consequently, clip repositioning based on intraoperative angiography may be too late to avert a stroke. It is also impractical, for it requires the ready availability of an angiography team and equipment. When compared to conventional post-op angiograms, the quality of imaging is inferior and can lead to false positives or false negatives.

Microvascular Doppler Sonography

Microvascular Doppler uses a pen-tip sensor applied against the wall of a vessel exposed during surgery to hear how fast the blood is moving. It measures velocity, not volume flow. As demonstrated in Fig. 1, it is difficult to differentiate the degree of stenosis between robust and poor flow in a non-occlusive vessel compromise.

Grade I stenosis exhibits the same flow velocity as Grade V. Grade II stenosis velocities are similar to Grade IV velocities . Although velocity and Doppler profile analysis may also be used to assess the degree of potential flow compromise, it can be cumbersome and difficult, as the measurement is qualitative, not quantitative.

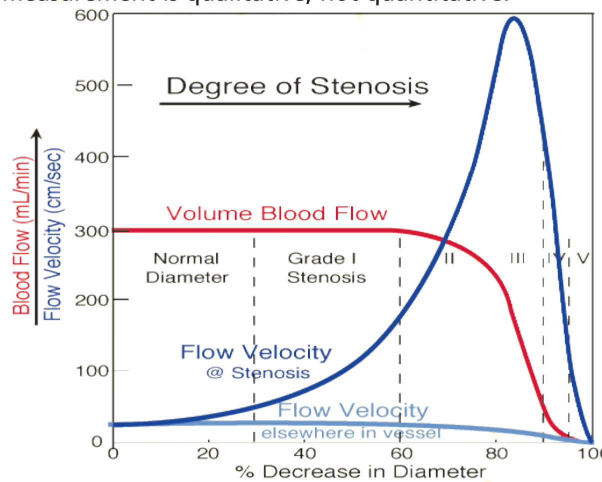

Fig. 1: Graph shows that volume flow will decrease during a Grade II & III stenosis (75% occlusion), as flow velocity is spiking before dropping during a Graft IV stenosis (90% occlusion). (Adapted from Spencer P, Reid, JM, "Quantification of Carotid Stenosis with Continuous-Wave (C-W) Doppler Ultrasound," Stroke 1979; 10(3) 326-330.)

Fluorescein Dye and Indocyanine Green (ICG) Video Angiography

Fluorescein angiography images vessels with light following intravenous administration of fluorescein dye. The image quality is problematic and there is potential for systemic adverse reactions. Fluorescence angiography is a one-time procedure and cannot be repeated after a clip adjustment.

Similar to fluorescence angiography but using indocyanine green (ICG) as an indicator, this modality can only assess vessels directly visible to the surgeon through the operating microscope field. Therefore, vessels obscured by anatomy or hidden aneurysm remnants will not be readily identified. ICG video angiography can be repeated following clip reapplication, but there is a required delay of ten or more minutes between injections. Nonocclusive but flow-limiting vessel compromise may be underestimated.

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THE MEASURE OF BETTER RESULTS.

Cerebrovascular Measurement Modalities Cont.

Electrophysiological Monitoring

Electrophysiological monitoring uses evoked somatosensory electrophysiological potentials (SSEP) of the cerebral cortex to avert cerebral ischemia during aneurysm surgery. This technology is labor intensive, influenced by anesthetic technique, prone to false negatives, dependent on vascular territory of interest and provides no anatomic information regarding specific vessel compromise.

Observation of Pulse

"A pulse" only indicates that an artery connects to the heart. If there is a partial occlusion, the proximal pulse will increase, the distal pulse will decrease. Determining arterial obstruction from the pulse is a tenuous art form at best, but may provide the experienced surgeon with qualitative information in cases where the vessel can be palpated.

Reference

Amin-Hanjani, Meglio, G., Gatto, R., Bauer, B.S., Charbel, F.T., "The Utility of Intraoperative Blood Flow Measurements in Aneurysm Surgery Using an Ultrasonic Perivascular Flow Probe," Department of Neurosurgery, Univ. of Illinois at Chicago. 2005. (3041AH)

COMPARISON OF MODALITIES: INTRAOPERATIVE ASSESSMENT OF CEREBRAL VESSELS

MEASUREMENT MODALITY	TRANSIT-TIME ULTRASOUND	INTRAOPERATIVE ANGIOGRAPHY	DOPPLER ULTRASOUND	FLUORESCEIN ANGIOGRAPHY	INDOCYANINE GREEN VIDEO ANGIOGRAPHY
Primary Measurement Parameter	Vessel volume flow; functional assessment	Anatomical image of cross-sectional width of vessel section	Flow velocity	Anatomical image of cross-sectional width of vessel section	Anatomical image of vessels in the surgeon's field of view
Measurement Units	mL/min	mm	Sound pitch (KHz)/color	mm	mm
Accuracy	± 10%	± 0.3 mm	Not quantitative	Not quantitative	Not quantitative
Measurement length (time)	Quick, ≤1 min/test; ≤ 5 min/surgery	Time consuming; >20-30 min	Very quick; ≤1 min/test; ≤ 5 min/surgery	15-20 min; one-time test	1st time:15-20 min; 10 minutes between tests
Advantages	Quick, direct, real-time quantitative measurement of pulsatile and mean flow; Non-constrictive; prompts reassessment of clipping if flow is significantly below baseline; confirms preserved flow and therefore avoids unnecessary clip repositioning	Anatomical (visual) image of aneurysm clipping and any residual aneurysm remnants	Quick Real-time Inexpensive	Anatomical (visual) image of aneurysm clipping and patency of cerebral arteries & perforators	Anatomical (visual) image of cerebral arteries; brain perfusion during aneurysm clipping, EC-IC bypass
Disadvantages	Can't discern aneurysmal remnants; can't measure perforator or tiny vessel flows	Slow; invasive, high risk; impractical, requires team; Questionable image quality;	Qualitative; can't discern between mild to severe vessel occlusion	One time procedure, can't recheck after repositioning; Systemic adverse reaction risk; Questionable image quality	Doesn't detect hidden remnants; 10 min delay between injections; may underestimate flow-limited vessel compromise
Effectiveness in Averting Ischemia	Highly effective	Low	Subjective	Subjective	Effective
Cost: Initial Per Measurement	 Moderate Low	 High High	 Low Low	 High Low	 High Low