

Technical Note

Transit-time Ultrasound & Pen-tip Doppler Technologies in Cerebrovascular Surgery

Transit-time Ultrasound

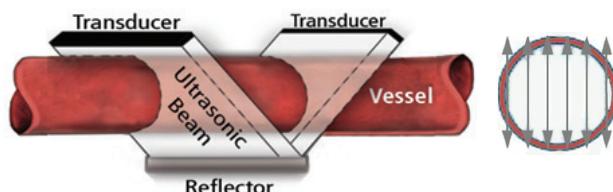
Transit-time Ultrasound directly measures Volume Flow in mL/min or L/min.

Transit-time ultrasound technology looks THROUGH a cross section of a tube or vessel and measures the AVERAGE DISPLACEMENT or phase shift of the fluid in the vessel.

Volume Flow = Time Average Displacement



Transducers pass ultrasonic signals back and forth through a vessel alternately intersecting it in upstream and downstream directions. The "transit time" it takes for waves of ultrasound to travel from one transducer to the other are measured. The difference between upstream and downstream integrated transit times is a measure of volume flow.

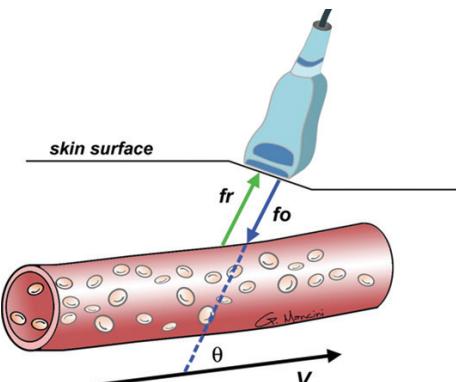


An ultrasound beam fully and evenly illuminates the entire lumen of the blood vessel. The transit time of the wide beam then becomes a function of the volume flow intersecting the beam, independent of vessel dimensions.

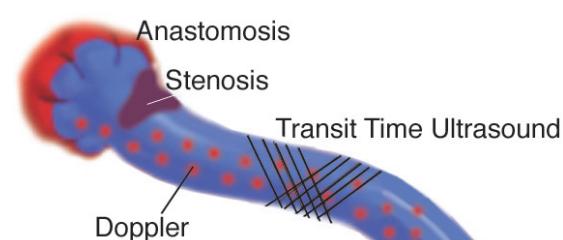
Because the transit times of the ultrasound waves are measured at all points across the tube or vessel's cross section with wide-beam illumination, transit-time ultrasound volume flow measurements are independent of the shape of the cross section in which blood flows.

Doppler Ultrasound

Doppler ultrasound looks INSIDE a tube or vessel to measure only the relative AVERAGE SPEED or velocity of the fluid passing through the tube or vessel. Doppler measures velocity in direction and intensity.



A pen-tip Doppler probe "looks" at the flow velocity under the angle between the pen-tip and the vessel. If this angle changes from 45° to 60°, the relative flow velocity drops 30% from 71% of true forward flow velocity to 50%. To make a reasonable measurement, the angle of the pen-tip Doppler probe with the vessel would have to be controlled.



Doppler measurements are dependent on moving particles in the blood (i.e., red blood cells) to measure flow velocity.

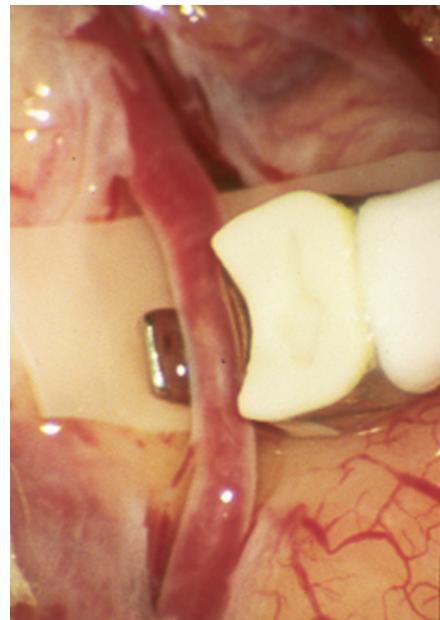
TTFM Volume Flow (ml/min) &

When is Transit-time Ultrasound Valuable in Cerebrovascular Surgery?

Dr. Fady Charbel's Flow-Assisted Surgical Technique (F.A.S.T) protocols rely on transit-time ultrasound's direct measurements of volume flow in mL/min to verify flow preservation or flow augmentation during cerebrovascular surgery.

Transit-time ultrasound flow measurements:

- Inform surgical decisions by helping the surgeon achieve optimal clip placement to completely isolate an aneurysm, AVM or dural fistula while confirming that flow is preserved in parent vessels and distal branches;
- Provide immediate assessment of residual and collateral flow reserve during temporary clipping;
- Confirm that a flow preservation or flow augmentation bypass is working before the patient leaves the OR, or by alerting the surgeon to dangerous, flow-limiting conditions.



Charbel Micro-Flowprobe measuring STA flow during a EC-IC Bypass.

Can't a pen-tip Doppler also assess flow preservation?

A pen-tip Doppler probe measures directional intensity, not flow. When a pen-tip Doppler is placed against the wall of an exposed vessel during surgery, it registers how fast particles are moving, not how much blood is moving as do Transonic's transit-time ultrasound Flowprobes.

Doppler Reliability

Doppler readings are unreliable because high velocities can occur despite low flows. Doppler measurements cannot distinguish between normal diameter flows and flows at a Grade IV stenosis (see figure on next page).

Transit-time ultrasound Flowprobes will identify Grade V (occlusive or near-occlusive) stenoses, and residual flow within an aneurysm if clip placement is incomplete. Moreover, pen-tip Doppler, with its subjective swoosh-swoosh sound representation of flow velocity, does not quantify flow reliably so it is impossible to compare absolute pre- and post-clip flow values to determine if flow has been compromised.

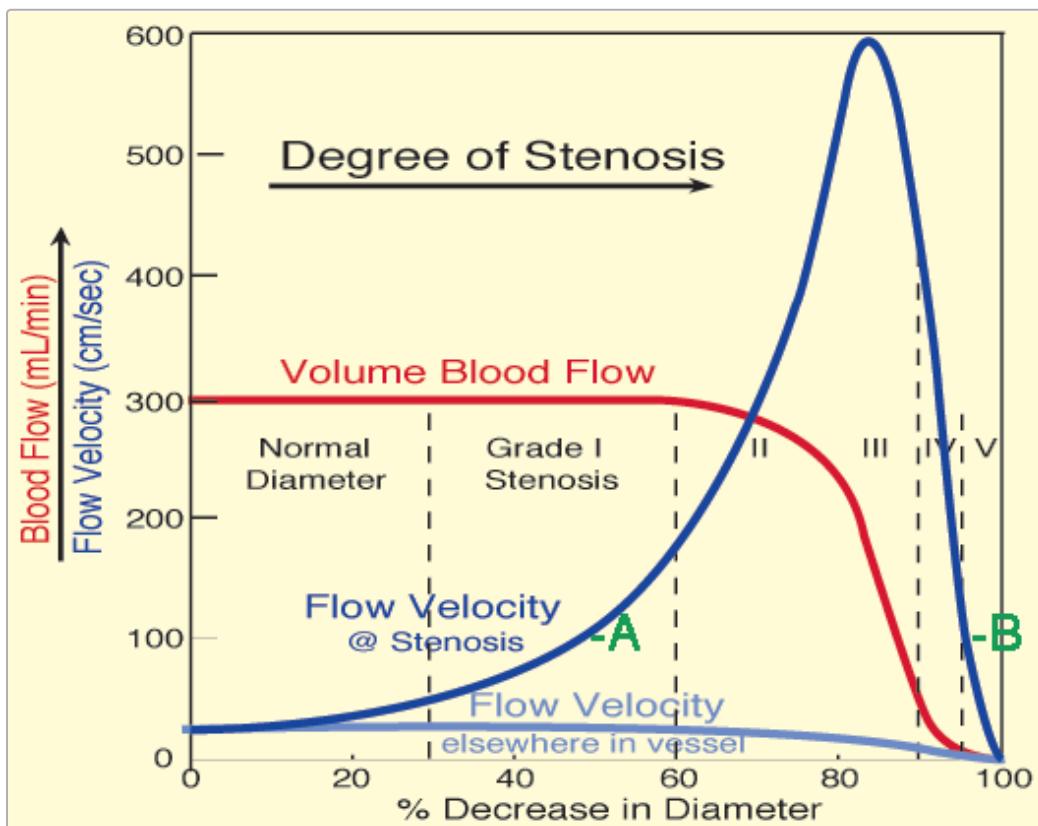
When is a pen-tip Doppler of value during surgery?

The pen-tip Doppler does have value in certain surgical protocols. For instance: if a surgeon does not clip an aneurysm completely, and the bulb of the aneurysm is still receiving arterial flow, blood will still be swirling within the bulb and a pen-tip Doppler will reveal this swirling blood. For other Transonic flow-assisted surgical protocols, the surgeon needs to measure an accurate rate of flow (mL/min). Pen-tip Dopplers cannot do this.

Scanning Across the Length of a Vessel

Flow velocity has little value in identifying a stenosis unless one can use a pen-tip Doppler to scan flow velocity across a length of the vessel. If the Doppler probe is held at one site where there is low flow velocity, it can be indicating that the probe is not being held above a flow constriction. If the probe is moved further along the vessel where the flow velocity is high, it can be indicating that there must be a narrowing of the vessel or stenosis at that point. In this way a pen-tip Doppler probe can be useful in locating the site of a stenosis.

Doppler Flow Velocity (cm/sec)



The above graph demonstrates that volume flow through a vessel (red line) as measured by Transonic transit-time ultrasound will begin to gradually decline at about 75% occlusion, but flow velocity (blue line) as measured with a pen-tip Doppler will spike before a steep drop during Grade IV and Grade V stenoses. Therefore, a 100 cm/sec flow velocity can be indicated either by a 50% Grade I mild [A] stenosis or by a 95% Grade V very serious [B] stenosis. Thus, one cannot tell from a Doppler velocity reading whether flow in the conduit is good or very bad.

Adapted from Spencer P, Reid, JM, "Quantification of Carotid Stenosis with Continuous-Wave (C-W) Doppler Ultrasound," Stroke 1979; 10(3) 326-330.

Transit-time Ultrasound Measurements Provide Quantitative Data, — Not Subjective (Qualitative) Clinical Impressions

Measurement of flow with transit-time ultrasound technology offers the surgeon immediate real-time feedback on the patency of a conduit. From this number, the surgeon can base his or her physiological assessment to determine if a surgical objective has been reached.

No longer does a surgeon have to rely solely on his or her clinical impressions in order to make surgical decisions. Having an actual quantitative number to substantiate clinical impressions adds immeasurably to a surgeon's armamentarium during surgical decision making.

Annotated References

Amin-Hanjani S, Meglio G, Gatto R, Bauer A, Charbel FT, "The utility of intraoperative blood flow measurement during aneurysm surgery using an ultrasonic perivascular flow probe," Neurosurgery 2008; 62(6 Suppl 3): 1346-53. (Transonic Reference # 7226AH) *"Use of the ultrasonic flow probe provides real-time immediate feedback concerning vessel patency. Vessel compromise is easier to interpret than with Doppler, and faster/less invasive than intraoperative angiography. Intraoperative flow measurement is a valuable adjunct for enhancing the safety of aneurysm surgery....Microvascular Doppler sonography has also been used to assess vessel patency during aneurysm surgery, with detection of vessel compromise in 18 to 31% of cases, and no unexpected vessel occlusions or strokes postoperatively. Firsching et al even reported a trend towards better outcomes compared with a historical control group. Doppler sonography, unlike angiography, can provide real-time assessment of vessel patency. However, given its primarily qualitative output, determination of the degree of vessel stenosis to distinguish between robust and poor flow in a non-occlusive vessel compromise can be difficult. Stendel et al have advocated use of certain velocity and Doppler profile signal characteristics to assess the degree of potential flow compromise, but as compared with the quantitative flow output from the ultrasonic flow probe, such interpretations can be cumbersome and difficult."*

Kirk HJ, Rao PJ, Seow K, Fuller J, Chandran N, Khurana VG, "Intra-operative Transit-time Flowmetry Reduces the Risk of Ischemic Neurological Deficits in Neurosurgery," Br J Neurosurg 2009; 23(1): 40-7. (Transonic Reference # 7744AH)

"Transit-time ultrasound flowmetry (ITTF) provides immediate feedback regarding vessel patency and clip-related arterial compromise and local vasospasm. It was found to have a broad utility in intra-cranial surgery including AVMs, fistulae disconnections and tumor excisions and was found to be safe, rapidly performed, easy to interpret and generally reliable. Its use contributes significantly to the safety of patients. ... ITTF is not the same as Doppler ultrasonography. Intra-operative microvascular Doppler ultrasonography (MDU) provides qualitative information on blood velocity in at-risk vessels rather than quantitative volume flow, ...distal branch flow diminutions may not be detected by the Doppler sound probe. Furthermore, in the presence of stenosis, a strong signal may be heard even though the overall volume of flow is decreased. Therefore, vessel compromise may still go undetected. Doppler ultrasound flow meters are also impractical as measurements are heavily influenced by the diameter and thickness of the target vessel wall, accurate probe contact and isonation angle.

Nakayama N, Kuroda S, Houkin K, Takikawa S, Abe H, "Intraoperative Measurement of Arterial Blood Flow Using a Transit-Time Flowmeter: Monitoring of Hemodynamic Changes during Cerebrovascular Surgery," Acta Neurochirurgica 2001; 143: 17-24. (Transonic Reference # 1831AH) *Transit-time flow measurements are useful for surgical management during cerebrovascular surgery. The technique was simple to use and provided sensitive, stable, reliable results. ...The greatest advantage of transit time Flowmeters is that the probe is only required to cover the entire blood vessel: it does not have to be in direct contact with the vessel wall, and blood vessels can be smaller than probes, because the ultrasonic wave is wide. The transducers integrate all information related to the velocity in the vessel of the wide ultrasonic plane wave, and transit time determinations are sampled at all points across the vessel diameter. Thus measurement of blood flow is possible even if the diameter of the blood vessel is not known, and the measurement is not influenced by the flow velocity distribution in the blood vessel. A further advantage is that the measurement of blood flow is not influenced by the angle of the probe relative to the vessel, because the two transducers are mounted in fixed positions within the probe. An increase in the angle between one transducer and the vessel will be compensated by a corresponding decrease in the angle between the other transducer and the vessel. This is a clear advantage over the Doppler method, in which the angle of isonation is critical. Finally, the transit time method is independent of vessel wall thickness, hematocrit fraction, and heart rate, because these factors cancel out between the upstream and downstream cycles.*



Transonic Systems Inc. is a global manufacturer of innovative biomedical measurement equipment. Founded in 1983, Transonic sells "gold standard" transit-time ultrasound flowmeters and monitors for surgical, hemodialysis, pediatric critical care, perfusion, interventional radiology and research applications. In addition, Transonic provides pressure and pressure volume systems, laser Doppler flowmeters and telemetry systems.

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