Role of a Perivascular Ultrasonic Micro-flow Probe in Aneurysm Surgery

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Abstract

There are various intraoperative monitoring devices available today for helping the neurosurgeons the progress of the intracranial aneurysm surgery. Till now the intraoperative ultrasonic blood flow probes has been used only in vascular, cardiac, and transplant surgery. In the University of Illinois at Chicago we have been able to use the same technology in various neurovascular surgeries. We describe the use of the ultrasonic perivascular blood flow probes in patients operated for clipping of intracranial aneurysm. The use of this perivascular micro-flow probe and its importance in cerebral aneurysm will be discussed.

Key words: perivascular flow probes, aneurysm surgery, basilar artery, superior cerebellar artery, posterior cerebral artery

Instrument and Method

The Transonic perivascular flow-measuring device comprises of a electronic flow detection unit with enhanced frequency resolution and volume flow-sensing perivascular probes (Transonic Medical Flowmeter; Transonic Systems, Inc., Ithaca, N.Y., U.S.A.). The flow meter uses ultrasonic transit-time principle to sense liquid volume flow in vessels independent of flow velocity profile, turbulence, and hematocrit. The electronic flow-detecting unit is a line-powered flowmeter that automatically identifies the scaling factor and individual calibration factor of the flow probe connected to it. The flow sensors connect to the flow-detecting unit via flexible cable. The ultrasonic transducers transmits ultrasound which helps to sense the volume of blood flowing through the blood vessel in which the sensor is applied. The perivascular flow probes can measure the average volume flow instantaneously in arteries anywhere from 0.5 to 48 mm in diameter. The flow probe (Fig. 1) consists of a probe body which houses two ultrasonic transducers and a fixed acoustic reflector. The transducer is positioned around the blood vessel (Fig. 2) and then the flow in that vessel is displayed in the digital form. The electrical excitation initially causes the transducer to emit a plane of ultrasound. This ultrasonic wave intersects the vessel under study in the upstream direction and then bounces off the “acoustic reflector” which again intersects the vessel and this is received by the upstream transducer where it is converted into the electrical signals. The flowmeter then from these signals derives an accurate measure of the “transit time,” which is the time the wave of ultrasound has taken to travel from one transducer to the other. A similar transit-receive sequence of the upstream cycle is repeated, but with the transmitting and receiving functions of the transducers reversed so that the blood flow under study is bisected by the ultrasonic wave in the op-
posite or downstream direction. The flowmeter again derives and records from this transit-receive sequence an accurate measure of the transit time.

The transit time of the ultrasound passing through a vessel is affected by the motion of the blood flowing through that vessel. During the upstream cycle, the ultrasound wave travels against the flow and the total transit time is increased depending in the amount and during the downstream cycle since the wave travels with the flow the total transit time is decreased. The flowmeter subtracts the total downstream transit time from the total upstream time by utilizing a wide-beam ultrasonic illumination and this difference in integrated transit times is a measure of volume flow. During the operation one ray of the ultrasonic beam undergoes a phase shift in transit time proportional to the average velocity of the blood times the path length over which this velocity is encountered. With wide-beam ultrasonic illumination the receiving transducer sums or integrates these velocity-chord products over the vessels' full width and yields volume of flow in that vessel, i.e. average velocity times the vessel's cross sectional area. Since the transit time is sampled at all points across the vessel diameter so the volume flow measurement is independent of the flow velocity profile. The ultrasonic beam rays which cross the acoustic window without intersecting the vessel do not contribute to the flow integral. The volume of flow is therefore sensed by the perivascular probes even when the vessel is smaller than the acoustic window.

These flow probes are designed to measure volume flow independent of vessel diameter and they are calibrated in the factory to meet the Transonic Flowprobe Specifications when applied to the vessel of interest. The probes are largely insensitive to the turbulence of the flow. When the probe is applied to the curved segment of the vessel, the plane defined by the probe's transducers and reflector bracket should be perpendicular to the plane defined by the curve of the vessel. The probe is applied to the vessel after cleaning the segment of the vessel for ultrasonic permeability. This measures the flow in the vessel under observation lying within the sensing window formed by the probe's transducer body and the attached reflector bracket. This also makes it easy to orient the direction of flow, i.e. upstream or downstream. The probe in a vessel which has gone into spasm following excessive manipulation during dissection as a part of the primary surgery or for application of the probe. The flow probes are usually kept secured in place by a temporary suture to the dural edge, which also helps to avoid vessel twisting or occlusion. The space between the circular vessel and the rectangular reflector bracket is filled with a ultrasonic couplant (saline, cerebrospinal fluid). A low signal strength when read is suggestive of air bubbles and or fat particles in between the vessel and the probe and this error should be removed till the probe attains the measurements accuracy. After the flow probe is secured well around the vessel it is

Fig. 2 Schematic diagram of the perivascular micro-flow probe on a vessel of interest (arrows).

Fig. 3 Changes in flow following temporary clipping during aneurysm surgery. “a” represents the opening of the temporary clip and “b” represents the point where the reopening of the clip following adjustment and “*” decreased flow despite removal of the clip suggestive of compromised blood flow.

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connected to the flowmeter using the probe extension cables. Figure 3 shows the changes in the flow before and after application of the temporary clip using the perivascular micro-flow probe in the patient undergoing surgery for intracranial aneurysm. Patient got full brain protection prior to commencing temporary occlusion and the flow measured by perivascular micro-flow probe before and after temporary occlusion was very helpful during the surgery.

Discussion

The cerebral blood flow has been measured by various techniques such as hydrogen clearance and xenon-133 clearance curves, however, their use intraoperatively is impractical and also they do not measure the dynamic flow. Further, the use of single photon emission computed tomography preoperatively to measure blood flow has already been demonstrated but this also has limitation of being non-continuous monitoring and is obtained at an interval of only 6 hours. More recently, the thermal diffusion flowmetry and laser Doppler flowmetry to measure continuously the cortical cerebral blood flow has been widely shown. None of the above-mentioned technology has been able to show the capacity to measure a real time and continuous blood flow in a particular blood vessel. We discuss the perioperative use of perivascular flow probes which gives a continuous and real time vessel flow measurements.

In the past the electromagnetic probes were used for perivascular flow measurements during aneurysm surgery. They unfortunately carried a limitation of not being able to keep constant contact with the vessel and it also use to end up by causing severe constriction of the vessel in which the probes are applied. The Transonic perivascular flow probes have a great advantage of being non-constrictive as it works with an acoustic coupling such as saline or even cerebrospinal fluid and required no direct contact with the vessel of interest. These flow probes can be also used to measure flow across various tubing’s or shunts used during surgery for example a shunt during carotid endarterectomy.

These perivascular flow had to be a representative of the actual flow and be easily reproducible and be obtainable with minimum pre- and intraoperative time. The ultrasonic transit-time volumetric flowmeter has been developed overcoming the problems which the other flowmeters had. It simply uses a wide beam illumination from the transducers it passes ultrasonic signals back and forth, alternately intersecting the flowing liquid in upstream and downstream direction. The flow meter derives an accurate measure of the “transit time” it takes for the waves of these ultrasound to travel from one transducer to the other. The difference between the upstream and the downstream integrated transit time is a measure of volume of flow in that area of interest. The accuracy of the Transonic Medical Flowmeters has already been established by Lundell et al. Also, routine use of ultrasonic flowmeters in vascular surgery, transplant surgery, and cardiovascular surgery has clearly demonstrated its potential application.

Conclusion

Our experience with the use of these ultrasonic perivascular micro-flow probe had been very good. We feel this flowmeter technique provides a very valuable, real-time, continuous, and accurate blood flow measurements in the vessels. We have found this to be of great value. The use of small, non-constrictive flow probes allows measurement of flow in the cerebral blood vessels down to 0.5 mm in diameter. Knowing the blood flow during surgery helps in the safe progress of the operation. Its use in intracranial aneurysm surgery is recommended.

References


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