T400-Series Technical Note

Keys to Accurate Perivascular Flow Measurements with Transit-Time Ultrasound

Importance of Acoustic Coupling for Accuracy

Highest accuracy with ultrasonic transit-time Flowprobes is achieved when the ultrasound signal is transmitted under uniform acoustic conditions. This occurs when the acoustic properties of the coupling media and tissue are stable and most closely match the acoustic properties of the liquid being measured. Since volume flow measurement with Transonic® Flowprobes is derived from a phase shift (the difference in upstream and downstream transit times) and is impacted by changes in the acoustical velocity of the ultrasonic beam, discrete sources of error from acoustical mismatch can be eliminated by observing the following guidelines.

Fig. 1: Upper graphic shows a Perivascular Flowprobe without acoustic couplant. Bottom graphic shows the same Flowprobe with acoustic couplant filling the spaces between the Probe and the vessel.

AIR

Air attenuates the Probe's ultrasound signal and effectively blocks ultrasound transmission. With large air pockets in the path of the ultrasound beam, the Flowprobe receives little or no transmitted signal and accurate flow measurements are not possible. Even small air bubbles can compromise measurement accuracy. Therefore, all spaces between the vessel and Probe must be filled with a suitable coupling agent (Fig. 1).

COUPLANT

The best acoustic couplant is Surgilube (E Fougera & Co.) because it matches the acoustic properties of blood. Media with lower acoustical velocity and impedance than blood are poor coupling agents for blood flow measurement with current ultrasonic transit time Flowprobes. These agents include saline, water, and NALCO 1181 mixed with saline. Aquasonic 100, an acoustic coupling agent used for sonography proved to be only on the borderline of acceptability for use with transit time Probes. Acoustically mismatched media cause reflections of the ultrasound at the vessel boundary, can substantially change the acoustical beam direction within the Probe, and impose uneven changes in the ultrasonic transit time. Measurements may be unstable and unpredictable in both positive and negative directions.

FAT

Fatty tissue also has a low acoustic velocity and affects the ultrasonic beam similarly. A pad of fat on the vessel wall in the acoustic pathway of the ultrasonic beam can act like a lens, reflecting or defocusing the ultrasound and altering the transit time.

TEMPERATURE

Temperature also effects the velocity of ultrasound and should be controlled for the most accurate measurements. Acoustical velocity increases with temperature increase. Transitions of the ultrasound beam from room temperature coupling agent to body temperature vessel wall and blood will alter the transit time and may exacerbate errors from other sources.

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Keys to Accurate Perivascular Flow Measurements with Transit-Time Ultrasound Cont.

Importance of Acoustic Coupling for Accuracy cont.

SUMMARY

Subtle phase shifts in the ultrasonic beam may be caused by inappropriate acoustic conditions during the experiment and will affect the accuracy of the measurement. Acoustically tested and approved coupling agents should be used with Transonic® Flowprobes. Fatty tissue should be carefully cleaned from the vessel where the Probe is placed. Controlling temperature in the acute experiment makes excellent physiological sense, in addition to being good acoustic practice. Transonic® Perivascular Flowprobes are calibrated for measurements of blood at 37°C and will give the most accurate readings if used within a ± 2 - 3 degree range. Gels may be warmed on a heating plate and the Probe itself should be allowed to equilibrate to this temperature for about an hour prior to use.

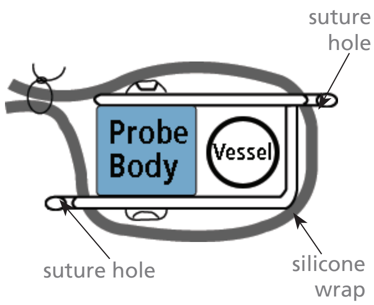

Fig. 2: Silicone wrap applied around a Flowprobe, leaving the Probe suture holes exposed.

Optimizing Conditions

Accurate flow measurements with ultrasonic transit time technology depend on careful attention to several variables. These include:

CHOICE OF A PERIVASCULAR PROBE

Although Transonic® Flowprobes are designed for a non-constrictive fit on the vessel, the vessel/Probe fit can influence accuracy significantly. For acute applications, the vessel must fill at least 75% of the Flowprobe lumen to meet published accuracy specifications. A close or snug fit will result in the least measurement variability. A close fit lessens the amount of acoustic gel needed and minimizes its effect on the measurement.

- Choose a range of Flowprobe sizes to cover variability in vessel diameter between subjects so that the 75% vessel fit rule is followed.
- Use Nanoprobes for a close fit on small vessels (< 700 microns) to maintain acoustic coupling more easily.
- Certain Flowprobes have been designed with increased sensitivity to minimize the effects of acoustic mismatch. These include V-Series Flowprobes for small vessels (<700 micron diameter). V-Series Probes are larger bodied and may be used instead of Nanoprobes as vessel length and surgical space allows being careful to follow vessel placement guidelines for V-Series Probes.

ADVANTAGE OF CHRONIC IMPLANTS

Many of the sources of error listed here are associated with acute use of ultrasonic Flowprobes and can be effectively eliminated when the Probes are implanted for long term measurements and chronic protocols. No coupling gel is required unless measurements are taken during the intraoperative procedure. Within 3 - 5 days during an animal's

SILICONE WRAP

Precut silicone sheeting is applied during Probe implantation, after the Probe's sliding cover plate is closed around the vessel and before the Probe is sutured in place.

Wrap the silicone around the Probe so that both suturing ends of the Probe bracket assembly stick through the small rectangular cutouts in the sheet. The ends of the sheeting are then sutured together to hold the wrap around the Probe (Fig. 2).

The Probe may then be secured in place using its regular suturing points (the two suture holes in the Probe bracket assembly, and a suture around the Probe cable. Alternately, one may suture the silicone wrap to surrounding tissues, or to the artery wall, if appropriate.

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Optimizing Conditions cont.

surgical recovery, the air spaces are filled with fibrous connective tissue. This tissue is a good acoustic conductant and also serves to center the vessel in the most sensitive position of the Probe. As in acute applications, the vessel should be stripped of fatty tissue prior to Flowprobe implantation and preventative measures should be taken to keep fat from infiltrating into the acoustic pathway over time. In species or vessel sites predisposed to fatty tissue deposits, a thin sheet of silicone wrapped around the outside of the Probe and sutured to adjacent tissues at the time of implant will keep the Probe fat free and also aid in stabilization (see sidebar on second page).

In a chronic experimental design, the cardiovascular system will also be freed from intraoperative stresses. Conscious measurements may be made without cardiovascular influences from anesthesia. Under these stable acoustic and physiologic conditions, our customers have pushed the measurement capabilities of Transonic® Flowprobes to record low flow states in difficult applications such as bile flow in the cystic and common bile ducts in a dog model, and esophageal (amniotic fluid) flow in fetal lamb swallowing.

SCIENTIFIC PROTOCOL

While the ease of use of Transonic® precalibrated Flowprobes have earned plug and play status, the rigors of scientific protocol should not be ignored. Transonic®specifies its Probes for ± 10%-15% absolute accuracy (see specification tables for individual Probe series). Careful attention to the above considerations will ensure that measurements reliably meet these standards. Absolute accuracy may be further enhanced by in situ calibration of the Flowprobes to validate the measurement under their specific conditions of use.

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