

The Benefit of Flowmetry in Peripheral Vascular Surgery

Prof. Einar Stranden* Ph.D. and Prof. Andries Kroese M.D., Ph.D.
Departments of Vascular Diagnosis and Research and Vascular Surgery
Aker Hospital, University of Oslo, Norway

The benefit of measuring blood flow in conjunction with peripheral vascular surgery has been recognised for several decades. Generally three modalities have been used to measure flow in a blood vessel, based on the following principles: electromagnetic, ultrasound Doppler and transit time. They can all be applied during peripheral vascular procedures in order to evaluate the results of the operation. This information may assist the surgeon in choosing the appropriate intra-operative course and thus ensure an optimal immediate and long-term outcome.

Although much scientific documentation was obtained from studies with electromagnetic flowmetry during the Seventies, the conclusions about the benefit of intra-operative flow measurements in general are still quintessential. From our own experience with all three principles, we find the transit time flowmeter superior for several reasons¹:

- The CardioMed Flowmeter in particular is very easy to use and allows for rapid volume flow measurement, which is important for keeping operation time to a minimum.
- The probe is easily applied on the vessel, and one size fits a range of vessel diameters. After the transducer has been plugged into the flowmeter, pulsatile and mean flow curves immediately appear on the display and mean flow values are also shown numerically. No zero-line calibration is needed.
- Measurements are very accurate. The difference in transit times of the ultrasound beams is based only on moving elements in the blood vessel. Thus measurements are not influenced by the inner diameter of the vessel wall. This is especially relevant for atherosclerotic arteries.
- The validation of transit time flowmetry has been thoroughly tested^{2,3}.

The following applications are the most common:

I. THE DETECTION OF BRANCHES OF THE SAPHENOUS VEIN ACTING AS ARTERIOVENOUS FISTULAE DURING "IN-SITU" BYPASS SURGERY

After the proximal and distal anastomoses have been made, vessel clamps are removed and blood flow through the bypass is established. Major tributaries of the vein can be visually identified and ligated without difficulty. However, smaller branches often have to be detected by other means, mainly intra-operative flowmetry, in order to avoid major surgical dissection. It is important to locate these residual fistulae since they may cause graft failure⁴.

PROCEDURE (Fig. 1)

The detection of arterio-venous connections has a qualitative aim; exact blood flow values are less relevant. A CardioMed probe of appropriate size is placed around the vein, just below the proximal anastomosis. Either sterile saline or ultrasound gel is used to maintain acoustic coupling between the probe and measuring site. Pulsatile flow curves will immediately appear on the display (Fig.2).

Manually or by means of an atraumatic clamp the vein is occluded successively at different sites along its course, from the transducer to the distal anastomosis.

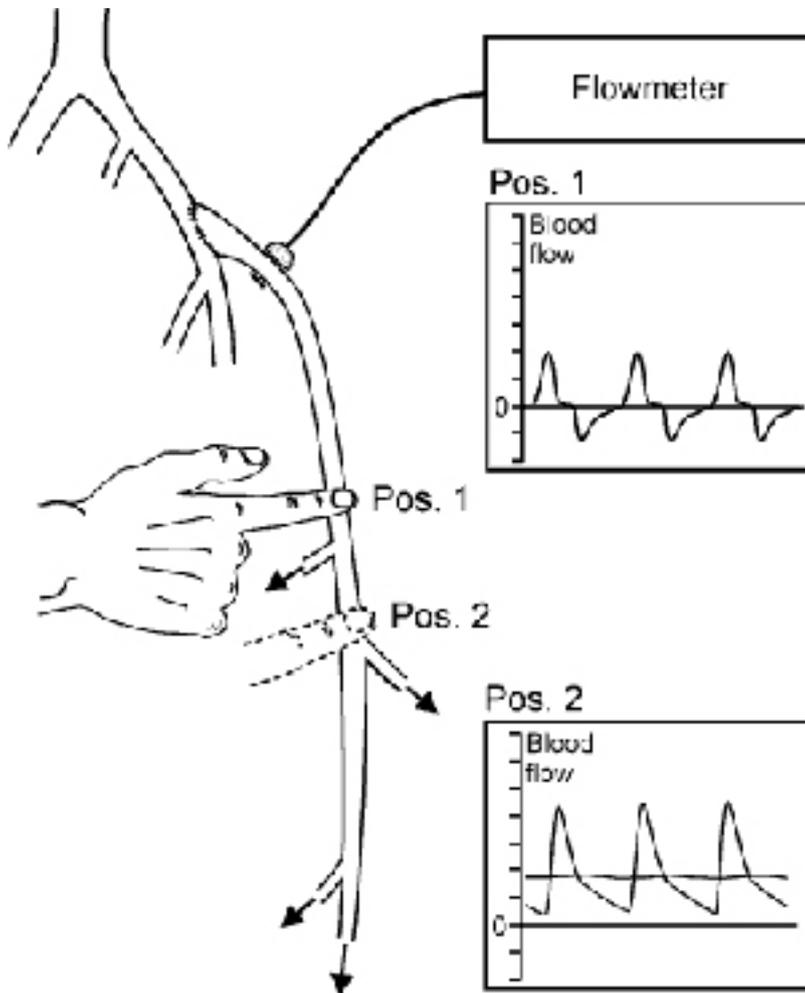


Figure 1. Procedure for detection of side-branches during "in-situ" bypass surgery.

Reverberating flow profile, indicating no net blood flow (Fig. 1, position 1), is found when there is no leakage flow between transducer and the compression site. If flow is detected during clamping, we can expect to find an open side branch proximal to the site of clamping (Fig. 1, position 2), which can subsequently be ligated.

II. INTRA-OPERATIVE FUNCTIONAL EVALUATION OF A VASCULAR RECONSTRUCTION

As distal femorotibial bypass grafting has become more common, supplementary methods are necessary for intra-operative control. The primary aim is to obtain information on the immediate result of the reconstruction. Dedichen⁵ found that the risk of early post-operative occlusion was significantly increased if the basal blood flow after femoro-popliteal reconstruction was less than 100 ml/min. or the papaverine-induced flow (intra-arterial injection of 40 mg papaverine) was less than 200 ml/min. The effect of papaverine is reduced if the surgery is performed under epidural anaesthesia, since basal flow is already increased.

Obviously, blood flow values will not necessarily provide information about anatomical aberrations due to technical failure. Ideally, intra-operative arteriography is performed in order to supply the surgeon with an anatomical evaluation as well¹.

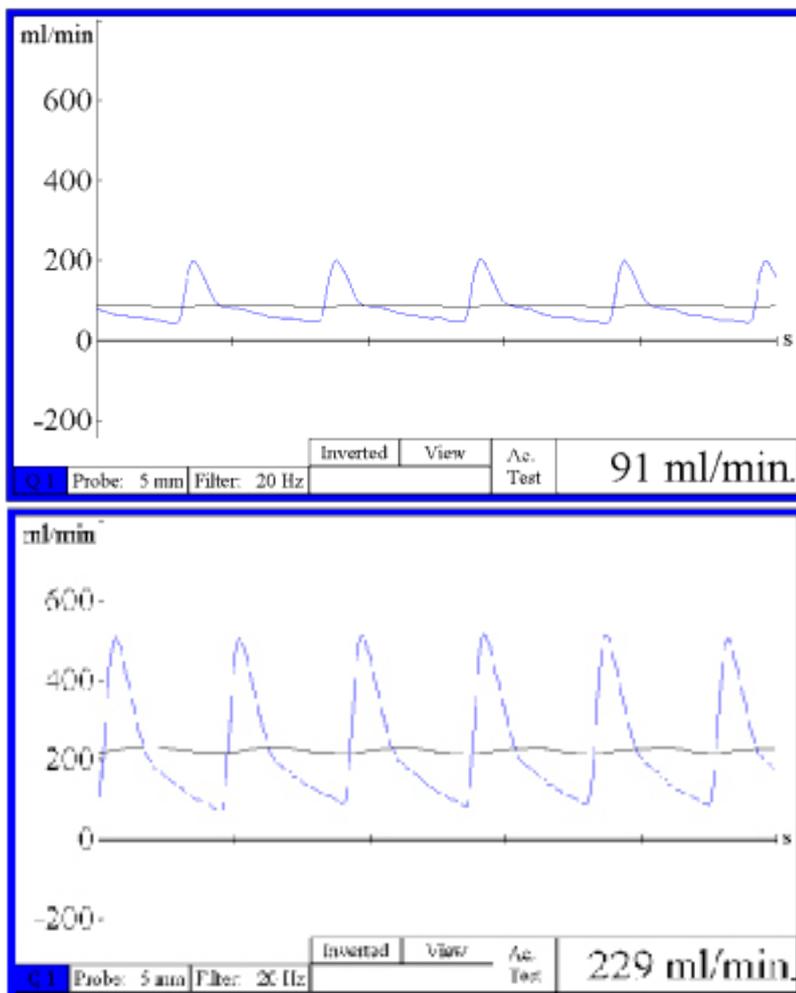


Figure 2. Mean and pulsatile blood flow curves in a successful femoropopliteal bypass. Upper panel: basal flow. Lower panel: Following i.a. injection of papaverine.

III. INTRA-OPERATIVE MEASUREMENT OF PERIPHERAL RESISTANCE

Following femorodistal bypass surgery, both limb salvage rate and graft patency are dependent upon outflow resistance. Pre-operative arteriographic visualisation of these vessels does not inform us on whether their functional capacity is adequate to keep a distal bypass open. Peripheral resistance is defined as mean arterial pressure divided by mean arterial flow, and is often expressed in Peripheral Resistance Units (PRU), $\text{mmHg} \times \text{min} \times \text{ml}^{-1}$.

Ascer et al.^{6,7} and Beard et al.⁸ have shown that intra-operative measurements of distal resistance are predictive in terms of the outcome of femorodistal bypass surgery. Some authors have defined a sharp cut-off limit above which femorodistal grafts are prone to reocclude. Ascer found that an outflow resistance greater than 1.2 PRU was uniformly associated with graft failure within the first 30 post-operative days⁷. Consequently, some authors refrain from performing bypass surgery in the lower limb if the peripheral resistance is above a certain level⁹.

The CardioMed TraCe System is an integrated unit for continuous recording of peripheral vascular resistance based on pressure and flow data.

CONCLUSION

Angiography is one of the cornerstones in the intra-operative evaluation of patients with arterial occlusive disease, and in many centres is regarded as part of the minimum facilities in the management of these patients¹⁰. Other techniques for evaluating vascular function will emerge, and some will fade out. However, two basic functional tests are most likely to persist: flowmetry and intra-arterial pressure measurements. Of the flowmeters, transit time technology is chosen because of its accuracy and ease of handling. Intra-operative measurement of outflow resistance may be important in delineating between revascularization or primary amputation, provided more reliable data concerning cut-off values are presented.

References

1. Strandén E and Myhre HO. Intra-operative Diagnostics in Critical Limb Ischaemia. *Critical Ischaemia* 1994; 4(2): 44-52.
2. Laustsen J, Pedersen EM, Terp K et al. Validation of a new transit time ultrasound flowmeter in man. *Eur J Vasc Endovasc Surg* 1996;12: 91-96.
3. Lundell A, Bergquist D, Mattsson E. et al. Volume blood flow measurements with a transit time flowmeter: an in vivo and in vitro variability and validation study. *Clin Physiol*. 1993; 13: 547- 557.
4. Donaldson MC, Mannick JA, Whittemore AD. Causes of primary graft failure after in situ saphenous vein bypass grafting. *J Vasc Surg* 1992; 15: 113-120.
5. Dedichen H. The papaverine test for blood flow potential of ilio-femoral arteries. *Acta Chir Scand* 1976; 142: 107-113.
6. Ascer E, Veith FJ, White-Flores SA, Morin L et al. Intra-operative outflow resistance as a predictor of late patency of femoropopliteal and infrapopliteal arterial bypasses. *J Vasc Surg* 1986; 4: 820-827.
7. Beard JD, Scott DIA, Skidmore R et al. Operative assessment of femorodistal bypass grafts using a new Doppler flowmeter. *Br J Surg* 1989; 76: 925-928.
8. Parvin SD, Evans DH and Bell PRF. Peripheral resistance measurement in the assessment of severe peripheral vascular disease. *Br J Surg* 1985; 72: 751-753.
9. Myhre HO, Kordt KF and Strandén E. Pre- and perioperative angiography and clinical physiological measurements. *Acta Chir Scand* 1987; 538: 132-138.

*Please address all correspondence to: E. Strandén, Dept. of Vascular Diagnosis and Research, Aker Hospital, University of Oslo, N-0514 Oslo, Norway.

Correspondence related to the Flowmeter should be forwarded to: Medi-Stim ASA, Marketing Dept., PB 4744 Nydalen, N-0421 Oslo, Norway, or by using e-mail: medistim@medistim.com.