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Intraoperative Quality Assessment in Vascular Surgery Using Transit Time Flow Measurement and Intraoperative Imaging Techniques

Graft patency is the predominant predictor of long-term survival after vascular surgery. In carotid endarterectomy (CEA), the risk of restenosis and embolization is increased if technical imperfections during the initial operation remain undetected. In AV access surgery, a non-maturing fistula due to low blood flow can require reintervention and prolonged use of a central dialysis catheter; if the flow is too high, there is a risk of hand ischemia and heart failure. Transit Time Flow Measurement (TTFM) in combination with intraoperative imaging offers a complete solution to approach functional and morphological quality assessment during vascular procedures.

A variety of intraoperative imaging and assessment techniques are available in modern operating rooms. However, there is no standardized method for assessing and evaluating vascular procedures. An intraoperative quality control is not performed routinely by most surgeons. Intraoperative angiography has been considered to be the gold standard during vascular procedures. However, a study performed by Pratesi et al (1) questions the routine use of intraoperative angiography as there was no significant difference between routine use of completion angiography and selective angiography. Debus et al (2) describe the limitations of intraoperative angiography this way: “Imaging is, however, supposed to be performed in two planes to detect occult stenosis or flaps, which causes additional radiation for the patient and therapist and can cause nephropathy. Additionally the ability of functional assessment is limited.”

Since its introduction, Transit Time Flow Measurement (TTFM) has been routinely used in vascular surgery for AV access surgery, CEA, and peripheral bypass surgery. Stranden et al (3) were of the first to document the ease of use, the very accurate measurements and the short learning curve. As the difference in transit times of the ultrasound beams is based only on moving elements in the blood vessel, the measurements are not influenced by the inner diameter of the vessel wall. This is especially relevant for atherosclerotic arteries. Stranden et al (3) describe the use of TTFM for detection of site branches acting as arteriovenous fistulae during in situ bypasses.

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 intraoperative TTFM, in order to avoid major surgical dissection. It is important to locate these residual fistulae since they may cause graft failure.

Intraoperative functional evaluation of a vascular reconstruction

During femorotibial bypass grafting, supplementary methods are necessary for intraoperative control. The primary aim is to obtain information on the immediate prognosis of the reconstruction. Several studies have shown that perioperative flow values have prognostic values (11,12,13). The risk of early postoperative occlusion is significantly increased if the basal blood flow after femoropopliteal reconstruction is less than 100 ml/min or the Papaverine-induced flow (intra-arterial injection of 40 mg Papaverine) is less than 200

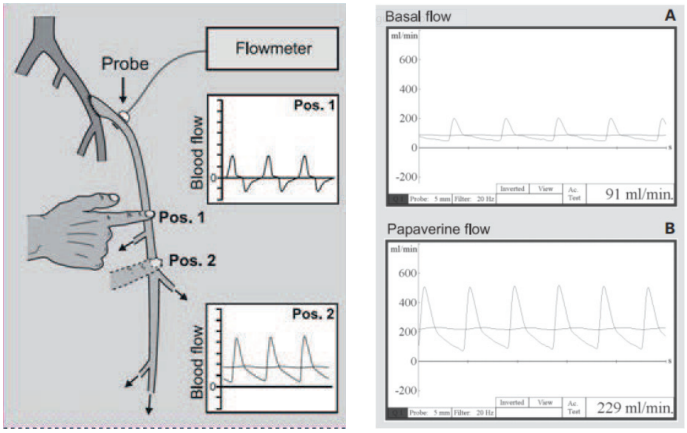

Figure 1 shows the procedure. The detection of arteriovenous connections has a qualitative aim; exact blood flow values are less relevant. A TTFM probe of appropriate size is placed around the vein, just below the proximal anastomosis. Pulsatile flow curves will immediately appear on the display.

ml/min (Fig. 2). The effect of Papaverine is reduced if the surgery is performed under epidural anesthesia, since basal flow is already increased. Obviously, blood flow values do not necessarily provide information about anatomical aberrations due to technical failure. In these cases intraoperative ultrasound imaging is performed in order to provide the surgeon with an anatomical evaluation as well.

Transit Time Flow Measurement in AV access surgery

Maturation of a newly constructed arteriovenous fistula is crucial for the prolonged use and complication rate for vascular access. In AV access surgery it is important that the resulting flow is not too high or too low. If the flow is too high, there is a risk of hand ischemia and heart failure. If the flow is too low the graft will not mature, resulting in the need for surgical reintervention at a new AV access location and prolonged use of a central dialysis catheter. During the fistula banding procedure, continuous intra-operative monitoring can be used to achieve the desired flow volume and improve the surgical outcome.

In a study by Saucy et al (5), 58 patients were monitored after radiocephalic arteriovenous fistula (RCAVF) creation and intraoperative blood flow measurement. The intraoperative blood flow in functioning RCAVFs was significantly higher compared to non-functioning RCAVFs (230 vs 98mL/ min; P = 0.007), as well as after one week (753 vs 228mL/min; P = 0.0008) and after four weeks

(915 vs 245mL/min, P <0.0001). Blood flow volume measurements with a cut-off value of 120mL/min had a sensitivity of 67%, specificity of 75% and positive predictive value of 91%. Saucy et al concluded that a blood flow <120mL was a good predictor of early failure in RCAVF. During the procedure, this cut-off value may be used to appropriately select which RCAVF should be investigated in the operation theatre in order to correct any abnormality in real time.

In a study conducted at the Queen Elizabeth Hospital in Berlin, Zanow et al (6) evaluated intraoperative monitoring of the access flow to evaluate the results of flow reduction in the management of high-flow arteriovenous access-related symptoms of distal ischemia and cardiac insufficiency. They concluded that the use of intraoperative flow measurement was an effective and durable technique allowing for the correction of distal ischemia and cardiac insufficiency in patients with high-flow autogenous access.

Transit Time Flow Measurement in vascular surgery has been evaluated by many vascular surgeons and described as a valuable and cost effective tool to predict the outcome of vascular procedures. (8,9,10)

A short learning curve and experience with different flow values for specific patient populations can guide and help vascular surgeons through operational procedures and enables them to execute necessary corrections while the patient is still in the operating room.

Transit Time Flow Measurement during carotid endarterectomy

In a prospective study with 100 consecutive patients undergoing carotid endarterectomy (CEA), Mätzsch et al (4) describe the routine use of TTFM for completion control. An 8 mm probe is placed around the common carotid artery (CCA) and the volume flow is measured. The external carotid artery (ECA) and the internal carotid artery (ICA) are briefly clamped in succession while the blood flow is measured in each vessel. Care is taken to clamp a location where the vessel is soft and free from arteriosclerotic plaque. This procedure is repeated immediately after restoration of the flow after CEA and after an observation period of 10 minutes. During the observation period, the flow is monitored using the trend analysis function with the probe in place around the CCA.

The flow in the CCA increased from 261 to 307 ml/min (mean increase 46 ml/min) after CEA and in the ICA from 121 to 221 (mean increase 100 ml/min). In the ECA it decreased from 175 to 162 (mean decrease 13 ml/min). A slightly increased flow in excess of these figures was seen immediately after restoration of flow following endarterectomy. In six of the 37 cases performed, TTFM had an impact on the surgical procedure: in three patients an unacceptable low or decreasing flow in the external carotid artery made further interventions necessary.
After correcting intimal flaps through separate incisions in the ECA, flow was normalized. In one case the flow in the ICA decreased during the observational period. An ongoing thrombus formation was corrected and the arteriotomy closed with a patch. In another case, where the trend analysis function was not used, the patient, who was operated under local anesthesia, developed neurological symptoms during the observation period. Repeated flow measurement revealed decreased flow and reintervention was undertaken with full recovery from the neurological symptoms. In the third case, results of the TTFM only led to extended diagnosis with Doppler velocity measurement and renewed flow registration.

Intraoperative imaging techniques in vascular surgery

Detecting the need to perform corrections intraoperatively has been described in a case report by Debus et al (14). A disobliteration of a femoral artery was performed in a 71-year-old male patient, also suffering from intermittent claudication. After completion, the surgeon routinely performed TTFM and found that the flow was only 11ml/min and the pulsatility index (PI), representing an indication of resistance, was almost 12. The surgeon used the intraoperative high-frequency EL probe (Medistim) to evaluate the area of interest and found a flap partially occluding the reconstruction. After correction the flow increased to normal range and PI was also considerably lower. This case clearly indicates the need for an easy-to-use complete quality control device, combining Transit Time Flow Measurement with intraoperative imaging.

Kniemeyer et al (7) conducted a continuous prospective study with 575 patients undergoing 620 carotid operations. Intraoperative duplex ultrasound examination was performed prior to wound closure: 9.5% had significant contralateral ICA stenoses and 6.7% ICA occlusion; 8.5% presented special lesions. An eversion thromboendarterectomy (TEA) was performed in 20.5% while 78.5% underwent conventional TEA, with patch plasty and graft interposition in 1%. Intraoperative quality control revealed unexpected lesions in 10%, which required immediate repair.

They concluded that the routine intraoperative duplex ultrasound examination of the carotid reconstruction allows early diagnosis and immediate correction of morphologic as well as hemodynamic lesions.

Competing with stent placement, a further reduction of the complications of carotid TEA seems to be possible and necessary.

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