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The Cook-Swartz venous Doppler probe for the post-operative monitoring of free tissue transfers in the United Kingdom: a preliminary report

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Summary Accurate assessment of the perfusion of free tissue transfers has always been a challenge for surgeons undertaking microvascular reconstructive procedures. The complexities of flap microcirculation are often difficult to assess despite all the subjective and objective examination techniques available today, particularly when the free tissue transfer is buried, and not visible for monitoring. The Cook-Swartz venous Doppler system is a technique for monitoring venous flow in free tissue transfer consisting of an implantable, removable, 20 MHz ultrasonic probe around the venous pedicle and a battery operated portable monitor. We perceive it as a quick and easy to use system, which in our study was well received by both medical and nursing staff. It can be used in conjunction with other monitoring techniques and we found it of value following revascularisation, during inset and in post-operative monitoring of free flaps particularly when operating outside our base hospital. We believe our initial experiences, on 24 patients, with the device, supports the use of a Cook-Swartz probe as an adjunct to traditional clinical monitoring techniques. We have had no technical difficulties with its application, use and removal, so far and we plan to continue with its use when it becomes available outside of a clinical trial.

Accurate assessment of the perfusion of free tissue transfers has always been a challenge for surgeons undertaking microvascular reconstructive procedures. The complexities of flap microcirculation are often difficult to assess despite all the subjective and objective examination techniques available today, particularly when the free tissue transfer is buried, and not visible for monitoring. The high success rate of microvascular free tissue transfers is partly due to monitoring of flap circulation post-operatively. Recent advances in technology and improvements in surgical technique

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have led to reported success rates between 95 and 98%.[1] The main methods of post-operative monitoring used in the United Kingdom at present are clinical tests:[2] colour, capillary refill, bleeding time, turgor and skin temperature. Adjunctive monitoring techniques are routinely used by the majority of units, with the most widely used being the hand held Doppler. This can be useful for visible flaps, but when the transplanted tissue is buried, other methods are necessary.

Routine monitoring of free flaps is often undertaken by nursing staff on the ward. Often junior medical staffs have little experience of such monitoring. The ideal technique of monitoring would be straightforward and any data collected for the post-operative monitoring of these free flaps should be unambiguous and easily interpretable, satisfying the criteria proposed by Creech and Miller in 1975.[3]

- Simple and harmless to the patient and free flap.
- Rapid, repeatable, reliable, recordable and rapidly responsive.
- Accurate and inexpensive.
- Objective and applicable to all kinds of flaps.
- Equipped with a simple display and an alarm that could alert relatively inexperienced personnel to the development of circulatory impairment.

The Cook-Swartz venous Doppler monitoring system

The Cook–Swartz venous Doppler monitoring system is a technique for monitoring venous flow in free tissue transfer. It consists of an implantable probe with a removable, 20 MHz ultrasonic Doppler crystal and a suturable cuff to secure it around the vessel adventitia of the venous pedicle, and a battery operated or line powered portable monitor. The cuff consists of a small 8×5 mm^2 thin silicone sheet which is wrapped around the vessel and the overlying ends either sutured or clipped. This probe's proximal end exits as a thin wire through the wound and is connected to an intermediate extension cable that is sutured to the patient through the use of specially designed retention tabs. The intermediate cable plugs into a transportable monitor at the patient bedside, which is battery or mains operated. The electrode slides free from the cuff when pulled externally at 5-10 days post-operatively depending on the length of monitoring required. The electrode is designed to separate from the cuff, when a tension of 50 grammes is applied. By 5 days the cuff is sufficiently adherent to the vessel and the vessel adherent to the surrounding tissue, allowing safe traction and removal of the electrode.

The probe allows direct vessel monitoring of a microvascular anastomosis at a specific site along a designated vessel. It is possible to listen to the signal in the donor vessels whilst selecting a vessel for anastomosis. It is possible to use multiple probes if several venous anastomoses are carried out.

Patients and methods

After obtaining ethical committee approval, we obtained 24 implantable probes and a monitor. Our study was carried out over a 9 months period from December 2002. In our unit, we perform approximately 70 free tissue transfers per year. The cases for which we used the probe were selected on the basis of geographic location of the hospital, type of flap, technical difficulty and availability of the system. It was not used for digital replants or toe to hand transfer. We used the probe in 12 cases at an orthopaedic hospital within the city where nursing staff have less experience with free flaps and also in cases where direct monitoring is more difficult including vascularised bone, muscle flaps and cutaneous flaps in nonCaucasian skin (rectus abdominus musculo-cutaneous flap). The case mix by flap type is shown in Fig. 1. All wires were removed on the ward by gentle traction at the bedside. The first case in which the probe was used demonstrates the technique and is briefly presented.

Case illustration

TP was a 52-year-old man undergoing reconstruction of his left distal radius and accompanying soft tissue defect with an osseocutaneous free fibula flap with custom made wrist fusion plate. This was a combined case with the orthopaedic surgeons, performed in an orthopaedic hospital separate to our base hospital. The background condition was an infected nonunion of a complex wrist injury 3 months following a roll-over road traffic accident. He had already undergone free latissimus dorsi and serratus anterior combined free tissue transfer for both volar and dorsal wrist defects. The flap was harvested in the standard fashion and inset into the defect. Arterial anastomosis was performed in the anatomical snuff box to the radial artery perfused by recurrent flow through the palmar arches from the ulnar artery. The single venae commitantes was anastomosed to the cephalic vein. The flap vein was

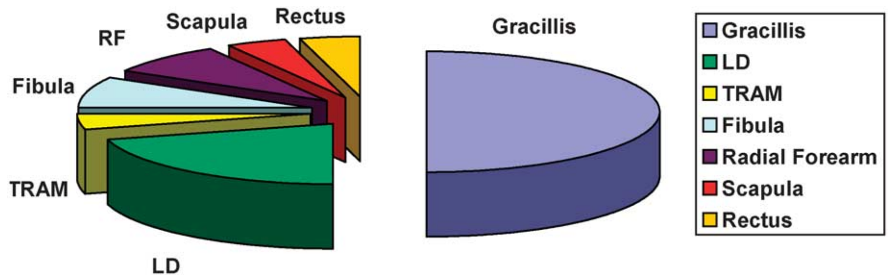

Figure 1 Free tissue transfer by type.

rather long and could not be shortened because the perforating vein from the cutaneous pedicle would have been sacrificed. Revascularisation of the flap was straightforward and the venous Doppler probe was placed on the cephalic vein downstream of the anastomosis. As the skin closure neared completion the venous Doppler signal was lost and the flap re-explored. A kink was found in the venous pedicle and a clot had propagated to the venous anastomosis. The anastomosis was revised, the pedicle inset without kinking and the wound re-closed with continuous monitoring.

There was little change in the colour of the skin paddle during this period of venous occlusion and we feel that significant delay would have occurred in detection of the problem by clinical findings alone if we had not had the venous Doppler probe.

The patient subsequently made an un-eventful recovery with flap survival. Fig. 2 shows the probe and monitoring system, Fig. 3 the probe about to be placed on the vessel, Fig. 4 the probe in situ and Fig. 5 the kink in the venous pedicle discovered when the vessels were explored. In this way it is possible to listen to both anastomosis.

Results

Of the 24 free tissue transfers included in this study there were no flap losses, one flap was revised on the table and a second on the third post-operative day. This failing flap was discovered by the operating surgeon after the venous Doppler machine had been switched off during the previous 12 h and not used. When switched back on, the venous Doppler confirmed there was no venous signal and the patient was returned to theatre and the gracilis flap salvaged after revising both venous and arterial anastomosis. It was not clear at the time of flap revision whether this had been due to an initial problem with inflow or outflow. A third case did not have Doppler monitoring because the wire exiting from the wound was cut as the dressings were trimmed and a replacement was not available. There were no complications with removal of the wire, which was removed at between 7 and 14 days post-operatively. We noticed that the venous signal could be heard to vary with respiration, reduce in intensity on limb elevation, and can be stopped by asking the patient

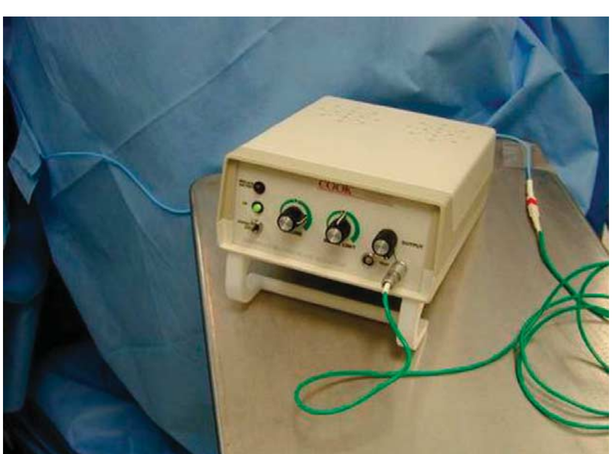

Figure 2 Cook–Swartz venous Doppler monitor.

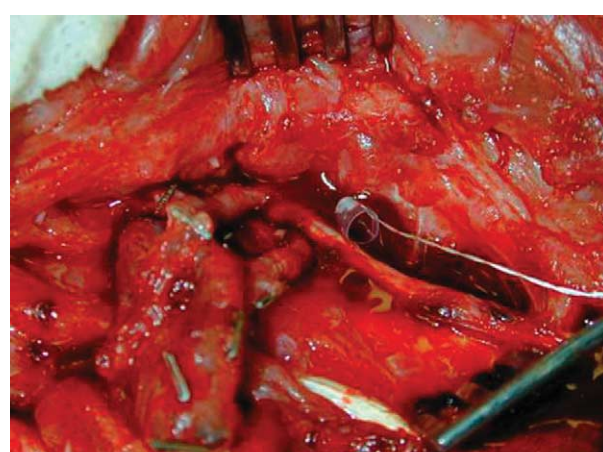

Figure 3 Cook–Swartz venous probe placed ready for attachment to venous pedicle.

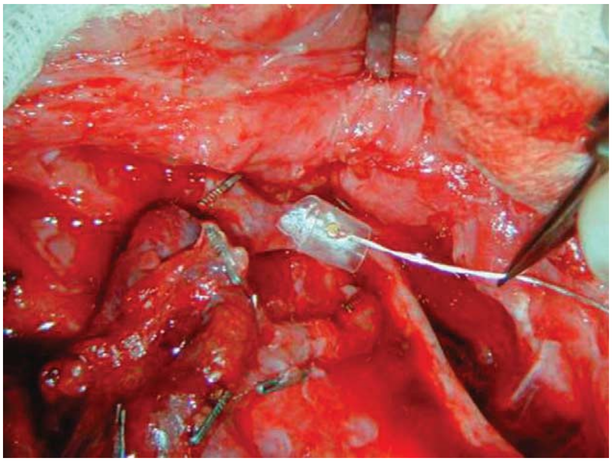

Figure 4 Cook–Swartz venous Doppler probe in situ.

to perform a valsalva manoeuvre. These variations in Doppler signal gradually diminish within 24–48 h to a more steady state.

Discussion

Free tissue transfers are often complex procedures with inherent risks involved. Any device that has the potential to minimise the potential morbidity from this procedure including flap loss must be welcomed as long if it does not expose the patient to additional risk.

Initial experimental work with the implantable Doppler probes showed that there were un-necessary re-explorations (false positives 3%) and venous thrombosis that was not detected (false negative 5%) when the probe was placed only on the arterial pedicle. Significant delay of up to 5 h was found between a problem with venous outflow to loss of the arterial signal in large muscle flaps.[4] This is also a drawback of external monitoring with the hand held Doppler of the arterial pedicle in muscle and cutaneous flaps. These findings were corroborated in Swartz's paper[5] when he found that arterial probes immediately detected an arterial occlusion but continued to record pulsation for up to 6 h after venous occlusion. By contrast venous probes detected a venous problem immediately and an arterial problem on average 6 min after arterial occlusion. This study included 103 episodes of venous monitoring in which 16 of 16 episodes of venous occlusion were noted and 12 flaps salvaged.

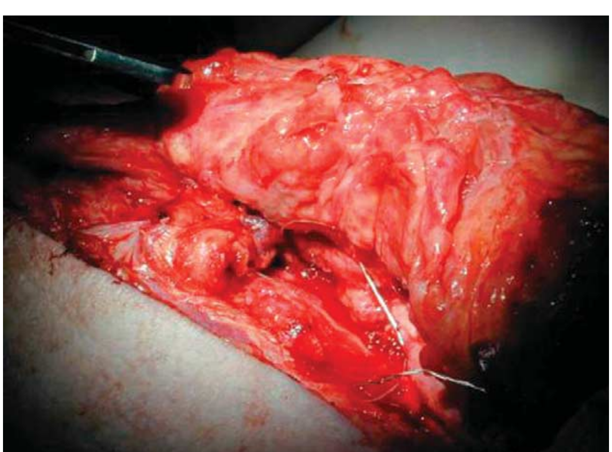

Figure 5 Kink in the venous pedicle at re-exploration of the flap after removal of the probe.

Other studies in the United States have shown that the implantable venous Doppler is effective,[6-8] with increased success and operative salvage rates. The Cook–Swartz monitoring system has Food and Drug Administration approval but has not yet been approved for use in the European Union outside of a clinical trial. This approval is now pending and the device will become available for general use in the UK and mainland Europe.

Advanced technology and precise surgical technique have led to high reported success rates of free flaps of between 95 and 98%.[1] NonTRAM free flaps, buried flaps, and flaps when vein grafts are used have lower reported success rates, and in these cases along with those in which detection of venous congestion is particularly difficult (i.e. darkly pigmented skin) the implantable Doppler could be of significant use. We certainly found it of use in our free TRAM on an Afro-Caribbean female, where clinical monitoring of the flap was problematic. It is also of particular use in the post-operative monitoring of free flaps when operating outside our base hospital, where the staff are inexperienced in clinical monitoring.

The Cook–Swartz system can be used in conjunction with other monitoring techniques and the probe allows direct vessel monitoring of microvascular anastomoses at a specific site along a designated vessel. The absence of the monitor's audible signal alerts the medical staff that a potential problem with perfusion exists.

We have found listening to the low background rumble of the venous flow be very re-assuring during the inset of the flap and transfer of the patient from the operating theatres. The intraoperative venous signal can highlight initial technical problems such as complete or partial kinking of the venous pedicle. We have also found it of help when listening to the arterial anastomosis before securing the cuff to the vein. If two venous anastomoses were needed in a particular case, multiple Doppler probes could be used as the monitor has two channels that can be used simultaneously.

The use of this system adds less than 10 min to the procedure. Whilst with any procedure there is a learning curve, we have found it straightforward to use from the first case. It has been used by a number of different surgeons in our unit during this study without technical difficulties with its application or use. Although, we have had no problems with removal of the wire so far, we have taken to suturing the cuff to an adjacent structure in the line of pull to add a further safeguard.

The main potential drawback of the technique is the cost. Each disposable probe costs in the region of £300 and the monitoring box £2000. Considering the cost of return to theatre and revision, morbidity of flap loss and consequences for the patient, however, venous Doppler monitoring can be justified in particularly the more high risk settings as aforementioned and those in our nonbase hospital.

Overall, the system was well received by both medical and nursing staff, and whilst our study has been a case controlled study with small number compared to all our free tissue transfers, we have found the technique to be very reliable and clinically useful. It would take a very large unit to be able to undertake a prospective randomised trial of this technique when failure rates are generally less than 5%. We believe our initial experiences with the device support the use of a Cook–Swartz probe as an adjunct to traditional simple clinical tests and we plan to continue with its use when it becomes available outside of a clinical trial.

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