Postoperative monitoring of the free jejunal flap: use of colour duplex and systematic review of available techniques

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ABSTRACT

INTRODUCTION The free jejunal flap represents the gold standard for circumferential defects in upper digestive tract reconstruction. It is a technically demanding procedure with significant failure rates. Unrecognised failure leads to flap necrosis and potentially fatal sequelae, including sepsis and carotid artery bleed. Despite these catastrophic consequences, however, there remains no consensus on an optimum method for postoperative flap monitoring. Our unit has pioneered the use of external colour duplex ultrasound to monitor flap vascularity. We describe this technique and systematically review other published monitoring systems.

MATERIALS AND METHODS A patient underwent oesophageal reconstruction using a jejunal free flap. Monitoring commenced immediately via external application of a colour duplex probe over the flap's vascular pedicle to facilitate flow volume assessment. Further bi-daily assessments were successfully used to monitor the postoperative viability of the flap. The systematic review was conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

RESULTS Six alternative monitoring techniques were identified: exteriorised jejunal segment, implantable Doppler probe, watch window, microdialysis, microendoscopy and reflectance photoplethysmography.

DISCUSSION Exteriorised jejunal segment and implantable Doppler probe are most commonly described, yet both are associated with high false positive rates, which is particularly significant in a patient demographic facing increased general anaesthetic risk. Most other techniques remain experimental. External colour Doppler ultrasound provides the surgeon with immediate reassurance following the reconstruction, requires minimal training to use, and eliminates the need for revisional procedures.

CONCLUSION Our initial experience suggests that external colour Doppler ultrasound has exciting potential as an efficient and noninvasive technique for monitoring the free jejunal flap.

KEYWORDS

Jejunum – Free tissue flaps – Ultrasonography – Doppler – Duplex

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Introduction

The free jejunal flap has proved an invaluable technique for oropharyngeal and upper digestive tract reconstruction and represents the current gold standard for circumferential defects. It is a technically demanding procedure with significant failure rates.¹ The reasons for this are multifactorial and include poor baseline health of the patient and difficulty in accurate flap monitoring.

Unrecognised failure of the free jejunal flap will lead to flap necrosis, as well as potentially fatal sequelae including sepsis and carotid artery bleed. However, despite nearly six

decades of free jejunal transfer, there remains a lack of consensus on an optimum method for postoperative monitoring.²

Various techniques have garnered support in the literature. The implantable Doppler probe demonstrates a promisingly high sensitivity in detecting loss of flap perfusion, yet this is accompanied by a high false positive rate.³ Exteriorisation of a jejunal segment facilitates monitoring of flap viability via estimation of serosal colour, bleeding and temperature.⁴ Although a useful technique, it represents an additional step in a complex procedure and requires revisional surgery in patients likely to already have a poor medical baseline.

In our unit, we have used external colour duplex ultrasound to monitor the vascularity of internal jejunal free flaps and have found this to be an efficient, non-invasive technique. Here, we describe the use of colour duplex in monitoring the jejunal transfer and systematically review other published monitoring systems.

Materials and methods

Colour duplex monitoring

Assessment with colour duplex ultrasound is performed post-procedure by the operating surgeon to provide immediate reassurance regarding the reconstruction. Nurse-led postoperative flap monitoring then commences as per protocol. In our unit, this involves hourly flap observations (colour, capillary refill, texture and temperature) for the first two days, then four hourly for the next five days. To augment nurse-led monitoring, bi-daily physician-led assessment with colour duplex ultrasound is performed concurrently for the first seven days. A mini-probe is used to demonstrate vascular in and outflow volumes alongside standard clinical assessment of the patient. If any concerns are raised during nurse-led monitoring, the frequency of physician-led assessment is increased accordingly (hourly if necessary).

Search strategy

The search strategy was developed based on standard principles for systematic review and in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.⁵ With the exception of animal or in vitro studies, all relevant study designs were considered to be eligible for inclusion, with no minimum specified follow-up period and no patient population exclusion criteria. We conducted a search of the Cochrane Database and a systematic search of Medline. Search terms included 'jejun*', 'flap*', 'monitor*'. Two authors independently reviewed abstracts identified by the search and excluded reports not meeting selection criteria and those for which full texts were not accessible. The full texts were analysed to establish the relevance, type of study, participants and outcome measures and key findings were extracted.

Case history

A 48-year-old woman was diagnosed with squamous cell carcinoma of the proximal oesophagus (T4N2M0). Chemoradiotherapy was unsuitable due to infiltration of the carcinoma into the posterior wall of the proximal trachea. The patient therefore underwent curative surgery. Total laryngopharyngectomy and bilateral selective neck dissection was completed by the ear, nose and throat surgical team. The free jejunal segment was raised by the general surgical team. Reconstruction of the oesophagus using the jejunal free flap was then performed by the plastic surgery team, with end-to-end microvascular anastomoses performed between donor vessels and the superior thyroid artery and middle thyroid vein (Fig 1).

Assessment with colour duplex ultrasound was performed immediately post-procedure by the operating surgeon

Figure 1 Oesophageal reconstruction using a jejunal free flap

(Fig 2). Nurse-led flap monitoring commenced subsequently in accordance with protocol. Concurrently, bi-daily physician-led assessment with colour duplex ultrasound was performed for the first seven days. A mini-probe was successfully used to demonstrate vascular in and outflow volumes of the free jejunal flap (Fig 3). There were no complications; gastrograffin swallow (18 days postoperatively) and barium swallow (3 months postoperatively) confirmed the anastomosis to be intact without early stricturing.

Article inclusion

Forty-one abstracts were identified for inclusion. Primary review limited this to 17 articles for secondary review; 23 abstracts were excluded from primary review because they were not directly relevant to the aims of this study. Of the 23 articles identified for secondary review, 6 papers were excluded because they were not relevant on full text review, existed only as abstracts for oral presentation or work was unavailable in English. Therefore, 17 papers were suitable for final inclusion in this systematic review (Fig 4).

Results

Seven papers were identified relating specifically to the use of an exteriorised jejunum segment.^{4,6-11} Two papers described the use of an implantable Doppler probe¹²⁻¹⁵ and

Figure 2 External application of the Doppler probe over the flap's vascular pedicle

Figure 3 The Doppler probe demonstrates the flap's vascular in and outflow volumes

two papers reported the watch window technique.^{14–15} Microdialysis,¹⁶ microendoscopy¹⁷ and reflectance photoplethysmography¹⁸ were described by one paper each.

Discussion

The free jejunal flap is not monitored only to attempt salvage in the event of flap failure; the flap can only tolerate a short period of ischaemia meaning attempted salvage is often futile.¹⁹ More importantly, monitoring facilitates early recognition of the potentially fatal consequences of flap failure, including necrosis, sepsis and carotid blowout. Furthermore, many surgeons find monitoring to be particularly beneficial in providing reassurance following the reconstruction which is often exceptionally complex and technically demanding.

Creech and Miller define the ideal free flap monitoring device as 'harmless to patient and flap, rapidly responsive, accurate, reliable, and applicable to all types of flap. Furthermore, it should be equipped with a simple display so that even relatively inexperienced personnel can alert the development of circulatory impairments'.²⁰ It is perhaps remarkable that six decades since the first microsurgical transfer of a jejunal segment,²¹ there remains no monitoring device universally considered to meet all these criteria.

External colour duplex ultrasound

We report the use of a mini-colour Doppler probe externally over the flap's vascular pedicle to demonstrate vascular in and outflow volumes (Fig 4). This can be performed immediately post-procedure to reassure the surgeon regarding the construction. From here onwards, a colour duplex is kept at the bedside, allowing vascular in and outflow volumes to be assessed twice daily by the surgical team.

This monitoring technique does not seek to replace the fundamentals of clinical assessment of free flaps postoperatively. Instead, it is used as an adjunct to augment routine nurse-led postoperative flap monitoring, which in our unit involves hourly flap observations (colour, capillary refill, texture and temperature) for the first two days, then four-hourly for the next five days. Bi-daily physician-led assessment (with scope to increase frequency of assessment based on clinical need) is a realistic aim and is in accordance with Patel's multi-institutional review, which found no significant difference in outcomes for free flaps of the head and neck when comparing those receiving 4-hourly, 8-hourly or 12-hourly physician-led reviews.²²

External colour duplex ultrasound represents a simple and non-invasive technique for monitoring vascular flow

and patency. External use of the ultrasound ensures there is no risk of interference with the flap and eliminates the need for revisional procedures. Further, monitoring can be performed swiftly by even the most junior members of the surgical team. The disadvantages are the failure to provide continuous feedback and relatively limited information given about the status of the flap.

Use of an exteriorised flap segment, implantable Doppler probe or a watch window remain the most proven monitoring techniques based on larger-scale case series. We have used this technique as an alternative to the senior author's usual practice of not monitoring the flap directly in the postoperative period and report no problems with our first experience. However, longer-term data with more reconstructions will be required to facilitate more comprehensive analysis of external colour Doppler ultrasound's sensitivity and specificity.

Exteriorised flap segment

Exteriorisation of a segment of jejunum is a common monitoring method. A segment of the jejunum on its mesentery is brought outside the neck and later excised. Numerous case series describe the use of this technique. In 1992, Bradford first described 17 flaps monitored in this way, with no flap loss recorded.⁷ Dionyssopoulos reports a case series of 20 patients in which the sentinel segment guided re-exploration of a potentially failing flap in six cases. Of these six cases, four flaps indeed demonstrated arterial insufficiency, but two were normal intraoperatively.⁶ Cho *et al.*'s larger study of 109 buried flaps (of which six were jejunal) illustrated a false-positive rate of 36% for all

exteriorised flap segments, although there were no false positives in the jejunal cohort.⁴ One case report of a false-negative sentinel segment exists, reporting a dissociation between the blood flow in the functional jejunal flap and the exteriorised monitoring segment. This provided false reassurance that the flap was healthy, when in reality the monitoring segment was healthy but the true flap was congested owing to an obstructed vein.¹¹

False-positive findings in the exteriorised segment have led to unnecessary operations in numerous documented cases;^{4,6} this is particularly pertinent in a patient population with significant morbidity likely to face increased risk from general anaesthesia. However, only one case of a false-negative finding has been reported, which suggests that the exteriorised segment is effective in identifying threatened flaps.¹¹

Implantable Doppler probe

The implantable Doppler probe was introduced by Swartz.²⁵ The probe is connected to a unit in proximity to the vascular pedicle and can be removed once monitoring is complete by gentle traction. It offers continuous monitoring in all types of flaps and produces clear and definitive readings due to the flow of the vein being reflected as an all or none phenomenon and enabling monitoring to be carried out by even the most junior personnel. In a study of 20 cases, the implantable Doppler probe had a 100% sensitivity rate in detecting loss of flap perfusion.⁵

In the same study, however, the implantable Doppler probe suffered from a false-positive rate of 88%, culminating in a positive predictive value of just 13%.⁵ This was secondary to probe dislodgement and the senior author has also found the probe to be cumbersome and difficult to secure in place. As a result of the high proportion of false positives, many patients underwent unnecessary surgical exploration. This is again of particular significance in a complex patient population likely to face increased risk from general anaesthesia.

Watch window

The search identified two case series reporting the use of a watch window.¹⁴⁻¹⁵ This technique involves creating an external window overlying the flap through which the flap can be observed. The window is constructed by creating an opening, suturing jejunal serosa up to this opening and covering it with a thin split thickness graft. A 14-patient case series reported identification of arterial insufficiency in two flaps, both of which were returned to theatre.¹⁴ One flap was subsequently lost with replacement required while the other flap was successfully rescued with removal of the thrombosis. In neither of the published series is late flap loss reported secondary to unidentified ischaemia.¹⁴⁻¹⁵

Microdialysis

One unit has explored a rare form of monitoring.¹⁶ Microdialysis describes the analysis of a dialysate from within the flap itself. A catheter is inserted into the flap intraoperatively, through which fluid is passed and dialysate removed. Impending ischaemia can be identified by low

glucose concentrations. In a single case series, 14 patients with jejunal flaps were monitored with both exteriorised segments and microdialysis simultaneously. In two flaps, low glucose concentrations were used to justify surgical re-exploration even though both cases had exteriorised segments which did not clearly appear to be ischaemic. Arterial insufficiency was confirmed in theatre. Neither flap was lost and no flaps were explored unnecessarily. Retrospective analysis identified the glucose to lactate ratio to be a more sensitive indicator for flap ischaemia than the glucose level itself.¹⁶

Microendoscopy

A single case report demonstrated the technical feasibility of microendoscopic examination of capillaries on the surface of the flap.¹⁷ Microendoscopy allows direct visualisation of capillaries which demonstrate a pulsatility. This suggests active flow into the flap and was used initially in theatre to clarify the patency of the anastomosis and later to facilitate postoperative monitoring. No postoperative complications were reported in relation to the single flap.¹⁷

Reflectance photoplethysmography

A pilot study illustrated the potential for use of a reflectance photoplethysmographic (PPG) sensor and processing system with the capability of real-time estimation of both perfusion and arterial oxygen saturation levels in free jejunal flaps.¹⁸ A prototype dual-wavelength PPG sensor was developed which was sufficiently narrow in width to be accommodated into the jejunal flap. In a patient undergoing total laryngopharyngectomy and reconstruction with a free jejunal flap, the PPG sensor was placed in the distal end of the jejunal flap prior to removal of the arterial clamp in order to capture flap reperfusion. Following reperfusion, good quality PPG signals (an indicator of good perfusion) were successfully obtained intraoperatively. Further, preliminary oxygen saturation levels from the PPG sensor were in broad agreement with the commercial finger pulse oximeter.¹⁸ This novel technique has exciting potential in the monitoring of free jejunal flaps, providing the advantage of offering greater information on the viability of the flap by estimating arterial oxygen saturation levels alongside perfusion. Clinical trials are in progress to evaluate the technology further, with an emphasis on investigation of its role in postoperative flap perfusion monitoring.

Conclusions

There are a number of techniques available for monitoring the jejunal free flap. None has a particularly strong evidence base; as far as we are aware, no evidence higher than level 4 (Oxford Centre for Evidence-Based Medicine) exists.²⁴ Sentinel segments are commonly used and generally safe, although have led to unnecessary operations.^{4,6} The watch window is less common and less popular; most likely because it leaves an unsightly lesion in the neck and renders the deep spaces of the neck more vulnerable to invasive infection.¹⁴⁻¹⁵ The implantable Doppler probe has

many advantages over these surgical techniques. It is minimally invasive and provides continuous feedback which can be easily assessed. However, the probes are expensive and retain a foreign body within the patient close to the vascular pedicle. In common with exteriorised jejunal segments, they also have a high false positive rate.⁵ The significance of this must be emphasised, leading as it does to unnecessary surgery in high-risk patients.

Three novel experimental techniques are of interest. Microendoscopy has limited application currently, particularly as it is invasive and demands specialist training to be used effectively.¹⁷ Microdialysis is in its infancy but has exciting potential. It could be used to detect early signs of flap failure prior to any physically detectable signs even emerging in external flaps.¹⁶ Similarly, although in the prototype stage, reflectance photoplethysmography may have the capability of real-time estimation of both flap perfusion and arterial oxygen saturation levels.¹⁸ This would facilitate establishment of a more comprehensive picture of flap viability.

Minimal data exist on the cost effectiveness of each technique; however, it is reasonable to suggest that in the long term, external colour Doppler ultrasound represents one of the cheapest options based on the materials required. The Implantable Doppler currently retails at 600 Canadian dollars (Can\$500 for the probe and Can\$100 for the extension cable),²⁵ while Setälä estimates the use of microdialysis in flap monitoring incurs an additional cost of €535 per patient.²⁶ The watch window technique demands the use of multiple sterile plastic membranes (changed hourly for the first 24 hours then 2 hourly for the next 4 days),¹⁴ while surgical removal of a sentinel segment requires operative equipment and local anaesthesia. A colour duplex ultrasound machine retails at approximately £6000, but would already be readily available in intensive care units (where patients would be managed postoperatively) at all centres performing free jejunal flap procedures. Rudimentary training on the use of the mini colour Doppler probe is necessary but this is unlikely to significantly exceed training costs required for alternative monitoring systems; for example, the primary surgeon would require training to perform microdialysis and subsequent dialysate analysis or intraoperative creation of watch windows and exteriorised flap segments. As no published data exist comparing training costs for each monitoring technique, more comprehensive financial analysis is certainly needed. However, when solely considering materials required, external colour Doppler ultrasound is likely to represent a cost-effective option in the long term.

In summary, external colour Doppler ultrasound is a simple technique for monitoring vascular flow and patency. It provides the surgeon with immediate reassurance following the reconstruction which is often exceptionally complex and technically demanding. There is no implant or interference with the flap and no need for revisional surgical procedures. The principal disadvantages of the technique are its failure to provide constant feedback and relatively limited information given about the status of the flap. Of all of the available monitoring techniques for

buried flaps, not one will be appropriate for all patients. We have used external colour Doppler ultrasound successfully and have found it to be a useful non-invasive option that is worthy of consideration in many patients.

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