Practical free flap monitoring techniques in head and neck surgery

A myriad of techniques varying in complexity and sophistication for monitoring flaps have been described but systematic clinical assessment is regarded as the most reliable monitoring tool. This article reviews the contemporary clinical methods in monitoring free flaps.

Over the past three decades, free tissue transfer has evolved into a reliable tool for immediate reconstruction following ablative surgery for head and neck tumours. Multiple large series studies have documented overall flap success rates of over 95% (Truelson, 1996; Urken et al, 1998). However, salvage rates of free tissue transfers after vascular thrombosis or insufficiency have not increased to the same extent. The consequences of losing a free flap are, at best, a prolonged hospital stay and delayed recovery and, at worst, significant patient morbidity and even mortality. Timely re-exploration and re-anastomosis can salvage most failing free flaps, warranting close monitoring of each and every flap.

A typical head and neck oncology operation involves resection of malignant tissue, neck dissection and reconstruction of the resultant defect. The surgery on average takes 8–12 hours to perform and the patient is kept in the intensive care unit for the immediate postoperative care. Costs have been estimated at £20–30 000 for a head and neck operation involving free tissue transfer (Berger et al, 1995; McCrory and Magnuson, 2002). These costs would increase significantly in the event of flap failure necessitating further reconstructive surgery.

The first part of this review will discuss specific areas of general care of head and neck patients in an intensive care unit and the latter half will focus on clinical techniques and practices in monitoring free flaps.

General intensive care unit care of free flap patients

The improvement in free flap survival rates has in part been attributed to improved postoperative care, usually in an intensive care unit. The benefits of postoperative admission to the intensive care unit include:

- Airway support and management
- Cardiopulmonary support and monitoring
- Optimal sedation and adequate analgesia control
- Monitoring of free flaps
- Optimal nurse to patient ratio.

These benefits of intensive care unit admission are not mutually exclusive and the physiological status of the patient has a major influence on the viability of the transferred tissues. In other words, oxygen delivery to the flap and its survival depends on a combination of satisfactory control of blood pressure, blood oxygen levels and blood flow (Macdonald, 1985; Truelson, 1996; McCrory and Magnuson, 2002). Standard intensive care unit protocols and practices should achieve these goals and their detailed description is beyond the scope of this review. A number of potential problems deserve a specific mention.

Positioning of the patient in the intensive care unit

The patient should be nursed at approximately 30–40° head-up position. This will improve ventilation and thus oxygenation by reducing ventilation–perfusion mismatch (Vitacca et al, 1996; Vilke et al, 2000), and aids venous drainage from the flap. Keeping the patient's head in a neutral position or slightly turned to the side of the anastomosis reduces any tension on the microvascular anastomosis (Janz and Heller, 2006). For the same reason, extreme movement of the neck should be avoided during the early postoperative period.

Blood pressure control

The goal is to maintain a near-normal blood pressure, guided by continuous invasive blood pressure monitoring. The authors aim for a mean arterial pressure of 80–90 mmHg. Preservation of a good perfusion pressure with wide pulse pressure is essential for regional autoregulation of blood flow and flap survival (Sigurdsson, 1995; Adams and Charlton, 2003). Adequate sedation, good analgesia and appropriate fluid management are all important factors in blood pressure control.

Uncontrolled hypertension may cause direct damage or formation of a thrombus in the vascular anastomosis. Beta blockers can potentially lead to flap vasoconstriction and are best avoided until further information is available (Adams and Charlton, 2003).

Hypotension is usually secondary to hypovolaemia or vasodilation. It should be treated with fluid replacement as guided by the central venous pressure (Sigurdsson,

Mr Kaveh Shakib *is Specialist Registrar in Maxillofacial Surgery, St Bartholomew's Hospital, London EC1A 7BE,* **Mr Laurence Newman** *is Consultant Maxillofacial Surgeon, Queen Victoria Hospital, East Grinstead and* **Mr Nicholas Kalavrezos** *is Consultant Maxillofacial Surgeon, University College London Hospital, London*

Correspondence to: Mr K Shakib

1995; Sigurdsson and Thomson, 1995; Adams and Charlton, 2003; Al-Benna and Grob, 2006). The use and choice of inotropes is still open to debate and these are best avoided in hypovolaemic patients (Adams and Charlton, 2003). Dobutamine is often considered the inotrope of choice, but systemic phenylephrine increases the mean arterial blood pressure with no adverse effect on the free flap blood flow (Adams and Charlton, 2003).

Haematocrit

Isovolaemic haemodilution to a haematocrit of 30% improves flow by reducing viscosity, thereby reducing reperfusion injury in muscle and increasing the number of patent capillaries, which decreases tissue necrosis (Macdonald, 1985; Truelson, 1996). From experience this haematocrit is established by keeping haemoglobin levels in the 8–10 g/dl range. Further reductions in haematocrit do not provide much more advantage because the curve of viscosity *vs* haematocrit flattens off markedly below 30%, and therefore serves only to reduce the oxygen-carrying capacity and thus oxygen delivery (*Figure 1*).

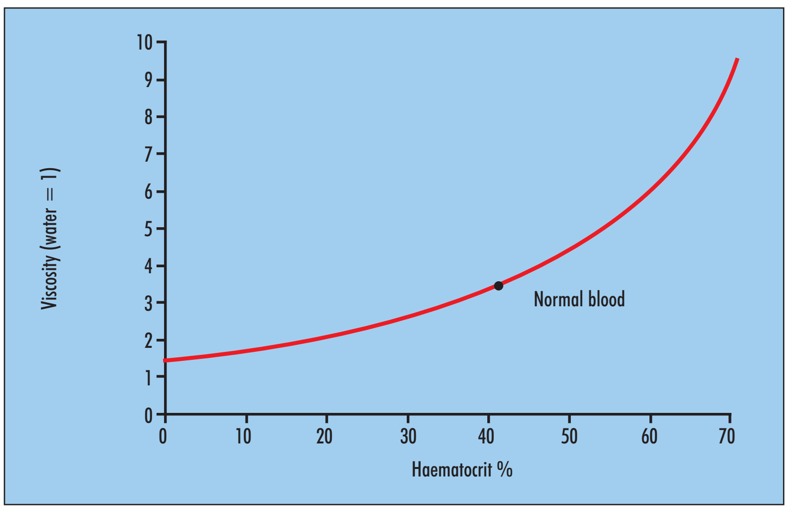
Monitoring of free flaps

The flap is closely monitored in the early postoperative period to detect any signs of vascular compromise so that a clinical decision to surgically re-explore the anastomosis can be made without delay. The success rate of flap salvage is inversely related to the period of onset of flap ischaemia and its clinical recognition (Neligan, 1993; Machens et al, 1994; Gapany, 1996; Truelson, 1996; Brown et al, 2003; Jallali et al, 2005; Whitaker et al, 2005). Once tissue ischaemia occurs, there is a finite amount of time after which the microvasculature is irreversibly damaged and the 'no re-flow' phenomenon takes place (Machens et al, 1994; Gapany, 1996; Carroll and Esclamado, 2000; Khalil et al, 2006).

Flap failure occurs primarily as a result of:

- Venous congestion – this is the most common cause of flap failure (Jallali, 2005). An increased risk has been noted between 24 and 72 hours postoperatively (Machens et al, 1994; Gapany, 1996)
- Arterial occlusion – an increased risk has been noted in the first 24 hours postoperatively (Machens et al, 1994; Gapany, 1996; Sekido et al, 2005).

Figure 1. Effect of haematocrit on viscosity. Adapted from Guyton (1981).



Important attributes of an ideal monitor of free flap viability should include (Berger et al, 1995; Sekido et al, 2005; Whitaker, 2005):

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

Many techniques have been described for monitoring flaps, varying in complexity and sophistication (Bradford, 1996; Brown, et al, 2003; Jallali et al, 2005; Whitaker et al, 2005). However, there are only limited reports comparing the success of different flap monitoring techniques, with no randomized trials. Most units rely on simple clinical observation of the transferred tissue (Bradford, 1996; Truelson, 1996; Brown et al, 2003, Jallali et al 2005; Whitaker et al, 2005).

Clinical observations

Clinical assessment is an indirect measurement of perfusion of the flap and is considered the most reliable monitoring tool (Berger et al, 1995; Bradford, 1996; Brown et al, 2003; Jallali et al, 2005; Whitaker et al, 2005). It is non-invasive, repeatable and economical. However, it is subjective and labour intensive, and depends on the expertise of the observer and ambient lighting. Interpretation of the clinical findings can be difficult, even for the most experienced observer (Neligan, 1993; Jallali et al, 2005; Whitaker et al, 2005; Khalil et al, 2006).

A change in the status of the flap normally requires a return to the operating room to try to salvage the flap by correcting the problems with the vein or artery (Neumeister, 2006). Clinical tests assess the:

- Colour of the flap
- Flap turgor or consistency
- Surface temperature
- Capillary refill time
- Doppler flowmetry.

Colour of the flap skin

In principle the colour of the flap should be similar to the general skin colour of the patient (Neumeister, 2006). Paleness may indicate an arterial occlusion, particularly if associated with poor capillary refill (Bradford, 1996). However, it should be stressed that most flaps, especially intra-orally, will appear a little pale when compared to normal oral mucosa. A 'blue flap' is a congested flap and signifies venous obstruction (Bradford, 1996). This is the most frequent cause of flap failure (Machens et al, 1994; Gapany, 1996; Sekido et al, 2005). Assessment of colour changes in flaps with dark skin, for example in Afro-Caribbean patients, can be more difficult.

Although venous compromise of a free flap may manifest suddenly as an abrupt colour change, it is usually an insidious process lasting 1–2 hours, causing clinical uncertainty and frustration. A digital photo of the flap immediately postoperatively may provide an invaluable baseline against which to measure any changes in colour of the flap (Neumeister, 2006).

Flap turgor

A flap should feel soft to the touch (Berger et al, 1995; Sekido et al, 2005). Any oedema or tension may suggest formation of haematoma deep to the flap or indicate kinking of the vascular pedicle, and can be a late sign of impending flap failure (Sekido et al, 2005).

Surface temperature

A healthy flap should be of a similar temperature to that of the surrounding normal tissue and a cool free flap may indicate arterial insufficiency (Khouri and Shaw, 1992; Sekido et al, 2005). Surface temperature measurement is one of the oldest and simplest methods of postoperative monitoring of free flaps (Khouri and Shaw, 1992), but the sensitivity of this observation, especially for intra-oral flaps, has been questioned (Berger et al, 1995; Busic and Das-Gupta, 2004; Sekido et al, 2005). It is argued that the flap usually assumes the core temperature of the oral cavity and is influenced by factors such as ambient temperature, tracheostomy mist or heat from an overhead light (Sekido et al, 2005). In addition, by the time the temperature has fallen, the flap will have suffered sufficient vascular damage to render it virtually unsalvageable (Busic and Das-Gupta, 2004).

Capillary refill time

This is assessed by applying gentle pressure on the flap for 3 seconds. A refill time of 3–5 seconds should be considered normal (Bradford, 1996; Hitchinson and Williams, 2000; Sekido et al, 2005). No blanching or a very quick refill (i.e. less than 3 seconds) may indicate early venous congestion (Bradford, 1996; Hitchinson and Williams, 2000; Sekido et al, 2005). A prolonged refill (i.e. more than 6 seconds) or no refill may indicate an arterial occlusion (Bradford, 1996; Hitchinson and Williams, 2000; Sekido et al, 2005). Bruising of the flap from repeated application of a spatula for measurement of capillary refill time, with no detrimental effect on flap survival, has been experienced by the authors and reported by others (Cotter and Devine, 2005) (*Table 1*).

Doppler flowmetry

Surface pulse Doppler assessment is a simple, rapid, and non-invasive method of objectively monitoring blood flow, which is commonly used (Bradford, 1996; Sekido et al, 2005). The probe is placed on the skin overlying the pedicle and the characteristic arterial noise and sound of venous outflow is heard. The primary limitation of this method is a high false-positive rate because the Doppler signal of adjacent vessels is mistaken for that of the pedicle. This can lead to a false sense of security, particularly when there is no exterior segment of the flap to monitor directly (Bradford, 1996; Sekido et al, 2005).

Implantable Doppler probes have the benefit of continuous feedback of venous and arterial Doppler signal, eliminating the need for active localization and detection of a Doppler signal. A more rapid detection rate of vascular compromise has been reported using this tool (Guillemaud et al, 2008). The major drawback of this technique is the cost of the monitoring apparatus and the single use probes. In some centres their use is limited to deeply implanted or osseous flaps where clinical monitoring is not possible. The first author's unit has routinely used the Cook-Swartz Doppler Flow Monitoring System (Cook Vascular Inc, Vandergrift, Pennsylvania, USA) since 2006 with a favourable response from the nursing and medical personnel monitoring the flaps.

Needle stick test

A needle stick or scratching the skin surface of the flap can help to assess the flap circulation (Bradford, 1996). If there is no bleeding, the problem is inflow. Rapid exit of dark red blood indicates venous congestion (Bradford, 1996). This test risks damaging the vascular pedicle and causing generalized bruising and is not typically included in routine published protocols. If indicated, i.e. if there is uncertainty with other findings, then it should be performed away from the pedicle.

Monitoring frequency

The optimum frequency of clinical assessment of the flap is not clear. The British Association of Head and Neck Oncology Nurses recommends the following flap assessment in routine cases (Hitchinson and Williams, 2000):

- Every 15 minutes for the first 6 hours
- Every 30 minutes for the next 18 hours
- Hourly for the next 48 hours
- Reassess individually according to ongoing clinical needs.

Others recommend hourly postoperative assessment by nursing personnel for 48 hours, and then 2-hourly, with medical personnel performing the same assessment every 4 hours for the first 48 hours and then 8-hourly

Table 1. Significance of clinical observations

Observations	Normal	Arterial insufficiency	Venous congestion
Colour	Usual skin tone	Pale	Blue or mottled
Turgidity	Soft	Flaccid	Turgid
Temperature	Warm	Cold	Cold
Capillary refill	2–3 seconds	Absent or sluggish (>6 seconds)	Brisk (<3 seconds)

(Bradford, 1996; Devine et al, 2001). A more simple protocol recommends hourly monitoring for the first 72 hours (Devine et al, 2001; Sekido et al, 2005). There is little evidence to support continued regular flap monitoring after the first 3 days.

Although there are no data to support specific observational timings there is a general consensus that frequent and regular monitoring in the early postoperative phase allows for early detection and increased salvage and survival rate of the flap.

Flap observations charts

Observation and measurement of colour, capillary refill time, temperature, consistency of texture and Doppler signal are recorded on a 'flap chart' (*Figure 2*). This provides an instant visual record of any change in the underlying trend. Owing to the subjectivity of such observations, nursing observers should agree on baseline flap observations at the shift changeover against which any observed changes in colour, capillary refill time, consistency and temperature can be measured (Devine et al, 2001).

The future of routine free flap monitoring

Many monitoring techniques have been described but none has yet become widely accepted. The techniques can be broadly divided into two groups: monitoring of tissue perfusion and direct imaging of blood vessels. A detailed look at these techniques is beyond the scope of this review.

Conclusions

The first 72 hours after free flap reconstruction is the critical period where flap monitoring can lead to avoidance and redress of flap compromise. A myriad of different techniques for flap monitoring have been described. Systematic and detailed clinical monitoring of the free flap is currently the most reliable tool. The success rate of flap salvage is inversely related to the period of onset of flap ischaemia and its clinical recognition. Venous congestion is the most common cause of flap failure typically detected 24–72 hours postoperatively. Arterial occlusion occurs mostly in the first 24 hours postoperatively. There is little evidence to support continued regular flap monitoring after the first 3 days. BJHM

KEY POINTS

- The improvement in free flap success rates is in large been attributed to improved postoperative care and early diagnosis and revision of a thrombosed anastomosis.
- The first 72 hours after free flap reconstruction is the critical period where flap monitoring can lead to avoidance and redress of flap compromise.
- Clinical assessment is the most reliable method of monitoring free flaps.
- Venous congestion is the most common cause of flap failure typically detected 24–72 hours postoperatively.
- Arterial occlusion occurs mostly in the first 24 hours postoperatively.
- There is limited evidence to support continued regular flap monitoring after the first 3 days.

Conflict of interest: none.

Adams J, Charlton P (2003) Anaesthesia for microvascular free tissue transfer. *BJA – CEPD Reviews* **3**(2): 33–7

Al-Benna S, Grob M (2006) Primary hypotension: a contraindication to free tissue transfer? *Plast Reconstr Surg* **117**(7): 2509

Berger A, Machens HG, Mailaender P (1995) Approaches to postoperative blood flow monitoring after free tissue transfer. Which is the best? *Int Angiol* **14**(3): 288–96

Bradford CR (1996) Flap monitoring. *Facial Plast Surg* **12**(1): 19–21

Brown JS, Devine JC, Magennis P, Sillifant P, Rogers SN, Vaughan ED (2003) Factors that influence the outcome of salvage in free tissue transfer. *Br J Oral Maxillofac Surg* **41**(1): 16–20

Busic V, Das-Gupta R (2004) Temperature monitoring in free flap surgery. *Br J Plast Surg* **57**(6): 588

Carroll WR, Esclamado RM (2000) Ischemia/reperfusion injury in microvascular surgery. *Head Neck* **22**(7): 700–13

Cotter CJ, Devine JC (2005) Spatula bruises and monitoring of free flaps. *Br J Oral Maxillofac Surg* **43**(4): 343–4

Devine JC, Potter LA, Magennis P, Brown JS, Vaughan ED (2001) Flap monitoring after head and neck reconstruction: evaluating an observation protocol. *J Wound Care* **10**(1): 525–9

Gapany M (1996) Failing flap. *Facial Plast Surg* **12**(1): 23–7

Guillemaud JP, Seikaly H, Cote D, Allen H, Harris JR (2008) The implantable Cook-Swartz Doppler probe for postoperative monitoring in head and neck free flap reconstruction. *Arch Otolaryngol Head Neck Surg* **134**(7): 729–34

Guyton AC (1981) *Textbook of Medical Physiology.* 6th edn. W. B. Saunders &Co, Philadelphia: 207

Hitchinson CR, Williams KD (2000) *Postoperative free flap monitoring: clinical guidelines.* British Association of Head and Neck Oncology Nurses, Bristol

Jallali N, Ridha H, Butler PE (2005) Postoperative monitoring of free flaps in UK plastic surgery units. *Microsurgery* **25**(6): 469–72

Janz BA, Heller L (2006) Principles of Microsurgery. http://emedicine.medscape.com/article/1284724-overview (accessed 6 August 2009)

Khalil AA, Aziz FA, Hall JC (2006) Reperfusion injury. *Plast Reconstr Surg* **117**(3): 1024–33

Khouri RK, Shaw WW (1992) Monitoring of free flaps with surface-temperature recordings: is it reliable? *Plast Reconstr Surg* **89**(3): 495–9; discussion 500–2

Macdonald DJ (1985) Anaesthesia for microvascular surgery. A physiological approach. *Br J Anaesth* **57**(9): 904–12

Machens HG, Mailaender P, Rieck B, Berger A (1994) Techniques of postoperative blood flow monitoring after free tissue transfer: *Microsurgery* **15**(11): 778–86

McCrory AL, Magnuson JS (2002) Free tissue transfer versus pedicled flap in head and neck reconstruction. *Laryngoscope* **112**(12): 2161–5

Neligan PC (1993) Monitoring techniques for the detection of flow failure in the postoperative period. *Microsurgery* **14**(3): 162–4

Neumeister MW (2006) Free flap monitoring: keeping it simple and reliable. *Plast Reconstr Surg* **117**(3): 1073–4

Sekido M, Yamamoto Y, Sugihara T (2005) Arterial blood flow changes after free tissue transfer in head and neck reconstruction. *Plast Reconstr Surg* **115**(6): 1547–52

Sigurdsson GH (1995) Perioperative fluid management in microvascular surgery. *J Reconstr Microsurg* **11**(1): 57–65

Sigurdsson GH, Thomson D (1995) Anaesthesia and microvascular surgery: clinical practice and research. *Eur J Anaesthesiol* **12**: 101–22

Spiegel JH, Polat JK (2007) Microvascular flap reconstruction by otolaryngologists: prevalence, postoperative care, and monitoring techniques. *Laryngoscope* **117**(3): 485–90

Truelson JM (1996) Perioperative patient management of free flaps. *Facial Plast Surg* **12**(1): 13–18

Urken ML, Buchbinder D, Constantino PD et al (1998) Oromandibular reconstruction using microvascular composite flaps. *Arch Otolaryngol Head Neck Surg* **124:** 46–55

Vilke GM, Chan TC, Neuman T, Clausen JL (2000) Spirometry in normal subjects in sitting, prone, and supine positions. *Respir Care* **45**(4): 407–10

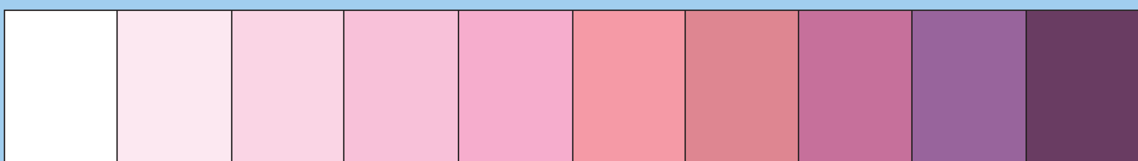
Vitacca M, Clini E, Spassini W, Scaglia L, Negrini P, Quadri A (1996) Does the supine position worsen respiratory function in elderly subjects? *Gerontology* **42**(1): 46–53

Whitaker IS, Karoo ROS, Oliver DW, Ganchi PA, Gulati V, Malata CM (2005) Current techniques in the post-operative monitoring of microvascular free-tissue transfers. *Eur J Plast Surg* **27:** 315–21

Name:		Consultant:	
Hospital:		Donor site:	
D.O.B.		Flap type:	

Date																													
Time																													

Colour																													
1																													
2																													
3																													
4																													
5																													
6																													
7																													
8																													
9																													
10																													



1	2	3	4	5	6	7	8	9	10

Temperature																													
Cold																													
Cool																													
Warm																													
Hot																													

Capillary refill																													
No blanch																													
<3 secs																													
3 secs																													
> 3 secs																													
No refill																													

Texture																													
Spongy																													
Soft																													
Firm																													
Hard																													

Figure 2. An example of a flap observation chart.