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5 Re-exploration, Complications and Flap Salvage

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5.1 Introduction

Success rates of up to 95–99% have been reported for free flap surgery (FFS), with variation existing depending on whether the surgery is for breast, head and neck and lower limb reconstruction [1]. Elective DIEP flap failure rates have been quoted as low as 0.29%, while failure rates are reported as high as 6% in head and neck reconstruction and up to 9% in lower limb reconstruction [2, 3].

Despite often favourable outcomes, all surgeons who regularly undertake these procedures will at some point be faced with failing/failed flaps, which may not necessarily be attributed to poor technique. It is important to recognise evolving problems early and act accordingly to prevent flap loss and potential significant morbidity.

Adverse outcomes in FFS can present on a spectrum of severity and be categorised into complete flap loss, partial flap loss, failure to achieve desired outcome despite flap survival, donor site morbidity, medical complications and disappointed patients [1].

Beyond meticulous microsurgical technique, a number of other factors should be considered in aiming for a successful outcome. We discuss preoperative, perioperative and post-operative optimisation and management, together with an algorithm for surgical re-exploration and free flap salvage, and other associated complications.

5.2 Preoperative Assessment

This should serve to identify both potential technical challenges, relating to donor or recipient sites, and the fitness of the patient as a whole.

When selecting the appropriate donor site, one must consider volume and suitability of tissue, the functional and aesthetic result of the defect, available length of pedicle (and potential need for vein grafting) and vessel calibre, together with potential preoperative imaging. In terms of recipient site, key factors include the location of recipient vessels, potential for considerable size mismatch between vessels, previous irradiation, extent of zone of injury, need for adjuvant therapy and again the benefit of preoperative imaging [4]. This is of particular relevance in the head and neck, when often faced with an irradiated field, depleted recipient vessels and the need for interposition grafts to access the contralateral recipient site, all of which may contribute to high rates of failure [2]. Note, the correlation between free flap failure rates and use of vein grafts is controversial, with some reporting high success rates (>93%) when the need for a vein graft is identified in the preoperative planning phase [5]. Post-operative medical complications in FFS have been linked to high preoperative risk stratification tools such as the ASA (American Society of Anesthesiologists) and Charlson Comorbidity Index. However, the presence of pre-existing comorbidity does not increase the risk of surgical complications in patients undergoing FFS, and advanced age alone is also not a risk factor for surgical complications [4].

Where possible the patient should be optimised with regard to the following factors;

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Hypertension has been linked with anastomotic failure, while diabetes, although known to increase the risk of wound complications, has not been shown to affect flap survival in large clinical series. Obesity (BMI > 30) has been shown to be significantly related to total/partial flap loss and the development of complications in free flap breast surgery, with a systematic review by Shin et al. showing obesity to play a significant role in the development of complications in breast free flaps when compared to non-breast free flaps [6].

The development of post-operative alcohol withdrawal symptoms has been specifically shown to be associated with flap complications. The literature has suggested that patients should cease smoking at least 1 week prior to undergoing free flap surgery, as an association has been demonstrated with smoking and flap-related wound complications, such as flap necrosis, haematoma and fat necrosis [7].

5.3 Perioperative Management

Patient physiology undergoes a multitude of changes during various stages of free tissue transfer: at induction, tissue resection, flap harvest, reperfusion of the flap and emergence from anaesthesia. Inadvertent hypothermia (core temperature <36.5 °C) in the immediate preoperative period can result in coagulopathy and later wound healing problems. Prewarming patients 1 h prior to the induction of anaesthesia and the maintenance of an ambient theatre temperature of 24 °C has been shown to counteract the drop in core temperature resulting from induction of anaesthesia. Studies have suggested that preoperative fasting of patients results in very minor insensible fluid loss, and preoperative fluid loading is therefore not necessary in those with normal circulation. Prophylaxis against venous thromboembolism is required in patients undergoing FFS, by way of graduated compression stockings (started on admission), intermittent pneumatic compression (started prior to induction of anaesthesia) and daily administration of low molecular weight heparin.

A hyperdynamic circulation (high cardiac output, peripheral vasodilation and large pulse pressure) is ideal in maintaining microcirculatory perfusion in FFS [8]. Goal-directed fluid therapy using oesophageal Doppler monitoring is the gold standard, as hypervolaemic haemodilution has been associated with medical complications in the post-operative period [4]. Aggressive fluid resuscitation has been shown to be an independent positive predictor for post-operative complications and length of hospital stay [9]. Studies have suggested that intraoperative fluid administration should not exceed 6 mL/kg/h and that a normovolaemic haemodilution with a haematocrit of 30–40% is preferable [10].

The perioperative and post-operative use of vasopressors in FFS has been widely debated. Many surgeons are concerned that these agents may compromise the blood supply to the flap, though they may at times be necessary to counteract vasodilatation resulting from anaesthetic agents. Though contrary to existing belief, studies looking at the use of intraoperative vasopressors have shown that they do not affect flap outcome [10]. A large study by Nelson et al. looking at complications in >1000 breast free flaps showed that vasopressors did not significantly impact thrombotic events or increase risk of free flap loss [11], with similar findings mirrored in the head and neck literature [12–14]. Evidence suggests that the maintenance of blood pressure through the use of vasopressors may be a preferable technique to fluid overload [13]. If vasopressors are to be used, evidence suggests that dobutamine is preferable and can even promote flap perfusion [10].

5.4 Post-operative Monitoring

Change in the status of the flap, which may or may not indicate a failing flap, must be identified early and managed aggressively to ensure the success of potential salvage procedures. Most flaps that are successfully salvaged are identified within the first 24 h post-operatively. Monitoring is therefore an essential component of post-operative care. There is no world-wide consensus regarding the nature or timing of monitoring; indeed there is evidence of significant variation in monitoring protocols between individual centres [15].

Clinical observation is the prime method of monitoring a free flap, by assessment of temperature, turgor, colour, capillary refill time (CRT) and Doppler signal. Ideally the distal course of the pedicle should be marked perioperatively, to avoid both difficulty in locating it and confusion with the recipient vessel on hand-held Doppler examination (Fig. 5.1). If necessary, other potential manoeuvres include dermal scratch or pin prick, which are of particular use in patients with darker skin tone, in whom identification of congestion can be difficult until the late stages. While a number of alternative monitoring methods exist, such as implantable Doppler probes and spectroscopy, these have not shown increased usefulness, particularly when taking cost and invasiveness into account [16].

Pedicle thrombosis is the most common cause for flap compromise, with 80% of pedicle thrombosis occurring within 48 h of surgery [4]. Venous thrombosis often occurs in the first 24 h and is twice as common as arterial thrombosis, which often occurs in the second 24 h [4]. Note, late venous thrombosis, after Day 3, which is rare, should be managed as per acute thrombosis [17]. After thrombosis, haematoma is the next most likely cause of compromise.

We suggest free flap monitoring according to the British Association of Plastic, Reconstructive and Aesthetic Surgeons (BAPRAS) guidelines for the first 48 h (Table 5.1)

Fig. 5.1 Hand-held Doppler examination of an anterolateral thigh free flap

[18] and clinical assessment four times a day thereafter [19]. Clearly some of the recommendations documented in Table 5.1 are not possible with muscle flaps, which are discussed separately. It is important to audit the local centre's data regularly and adjust local monitoring guidelines accordingly, to ensure the highest possible rate of flap survival.

When faced with a pale flap, one should assume arterial insufficiency, which may be due to hypotension, vasospasm, thrombosis or external compression. It is however important to bear in mind that a pale flap, in a Caucasian patient, may well be healthy, with development of a pink/hyperaemic hue a potential sign of venous compromise. Often, fasciocutaneous flaps are hyperaemic in the immediate post-operative period but settle with time (Video 5.1). It is therefore good clinical practice for the surgeon to assess the flap on table, in recovery and on the ward, together with staff responsible for subsequent flap monitoring.

Clinical assessment of a pale flap may identify a prolonged CRT, decreased temperature, increased pallor and loss of tissue turgor. An audible Doppler signal and evidence of bleeding on scratch/prick may be absent, though one should be mindful of transmitted signal from the recipient vessel and the potential for signal from the pedicle, proximal to a thrombosed segment.

Venous insufficiency is more common than arterial, likely due to the low-flow system being more likely to succumb to stasis; however it is more likely to be detected [20]. It should be suspected with any evidence of congestion, which may be

Table 5.1 British Association of Plastic, Reconstructive and Aesthetic Surgeons flap monitoring guidelines [18]

Recommendation	Action	Rationale
Monitor flap every 30 min for 24 h Hourly thereafter	Document flap observations on the chart regularly to identify changes quickly.	Flap problems are the most common in the first 72 h after surgery (50% in 4 h, 80% in first 24 h, 95% in first 72 h). Venous compromise with flap congestion is three times more common in these early stages.
Flap temperature	Check with the back of your hand or finger and compare with skin on shoulder. Keep patient warm and cover flap with warm gamgee. Strips for comparing flap temperature with surrounding skin are available	A cold flap (>2 °C different) can indicate venous or arterial problems.
Flap Turgor	Press gently on flap to assess turgor.	A 'full', swollen, tense flap with increased turgor indicates a flap with venous compromise and / or a haematoma. An 'empty', flat flap with decreased turgor may indicate arterial compromise.
Flap Colour	View flap in good light to assess colour.	A purple, cyanotic, bluish or dusky flap is present with venous compromise. A pale, mottled flap indicates a flap with arterial compromise.
Flap Capillary Refill	Press on flap gently with your finger or a shaped instrument (e.g. the handle of a pair of scissors) for 5 s. Release the pressure and time the return of the pink colour.	Capillary refill should take about 2 s. In venous congestion it is brisk (<2 s). In arterial compromise it is sluggish (>2 s).
Flap Doppler signal	A mark may be made on the flap at the site of the dominant perforator or pedicle. The Doppler probe should be applied in this area. Alternatively implantable devices are available.	A triphasic pulsatile signal can be heard if the artery is working and a lower pitched more constant sound can be heard if the venous outflow is patent.

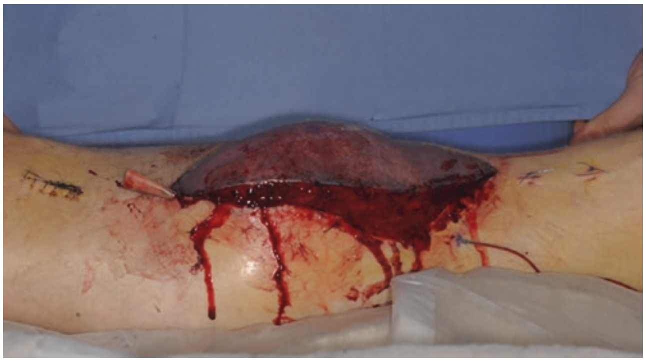

Fig. 5.2 An anterolateral thigh free flap at 48 h post-operatively, which has been congested for 12 h

Fig. 5.3 Healthy free gracilis muscle flap with adherent overlying skin graft

due to venous thrombosis, compromise of the pedicle by kinking or external compression, from adjacent tissues or haematoma. It may manifest in the early stages with a purplish hue, which becomes progressively darker, a brisk CRT and increasing tissue turgor and temperature. Excessive bleeding from the flap edges, potentially leading to haematoma, may alert the clinician to venous compromise of the flap (Fig. 5.2).

If any doubt exists, the patient should be taken back to theatre urgently for re-exploration, as delayed return to theatre has been shown to be associated with a significantly increased rate of flap failure [20]. Delayed flap compromise due to any cause, which occurs after discharge home, is unlikely to be salvageable [21].

5.4.1 Muscle Flap Monitoring

Some differences exist when considering the monitoring of muscle flaps, due to potentially less obvious clinical signs and as they are more susceptible to ischaemic damage. Different compositions of flap tolerate different ischaemia times, due to differing basal metabolic rates. Biochemical changes have been reported in normothermic muscle tissue (at around 34 °C) after 2 h and 15 min [22], due to a higher metabolic rate than skin flaps, which are thought to tolerate a secondary ischaemia time of 7.2 h [23] and bone flaps up to 25 h [24]. Given the difficulty in clinical assessment of muscle-only flaps and time taken from decision to explore, to exploration, one should adopt a lower threshold of concern than with other flap types [25].

Muscle flaps should be salmon pink and contractile, with any overlying graft found to be adherent (Fig. 5.3). Conventional clinical monitoring should be undertaken but is less reliable than in fasciocutaneous flaps. Any change in contractility, colour or turgor should act as a warning of an underlying problem (Fig. 5.4). Anecdotally, some centres delay grafting of muscle flaps, to facilitate monitoring.

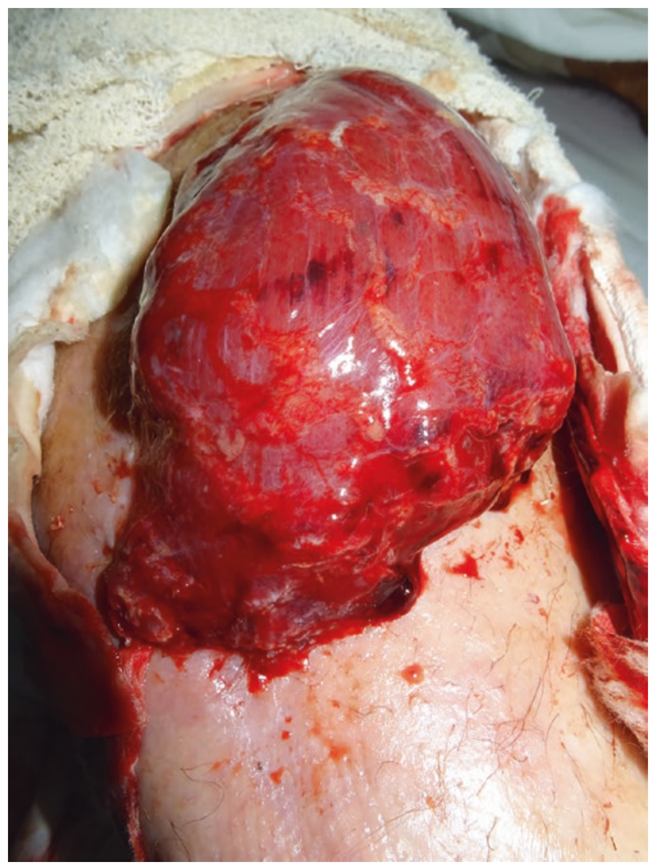

Fig. 5.4 A congested, swollen, free gracilis muscle flap with venous bleeding. Video 5.2 demonstrates a congested gracilis flap

Inclusion of a skin paddle may be considered, which will aid monitoring, expedite return to theatre and result in a higher salvage rate than their skin paddle-free counterparts [26]. Without a skin paddle, other, equally effective monitoring needs to be used.

A variety of alternative flap monitoring methods have been developed, with differing levels of efficacy, complexity and invasiveness, including implantable Doppler scanners, microdialysis and radionucleotide scanning. There is currently still no consensus as to which method should be the accepted standard [27]. More recently removable Dopplers have been incorporated in end-to-end anastomotic couplers, with no significant difference exhibited in free flap outcomes when compared to the longer-standing Cook-Swartz Doppler [28].

The non-invasive technique of hourly laser Doppler imaging with a commercially available camera, in addition to conventional clinical monitoring of the muscle flap, has been shown to detect vascular incompetence up to 17 h before clinical monitoring [29].

5.5 Flap Salvage

While preparing the patient for theatre, the following factors should be optimised:

- *Patient factors*
  - Normothermia
  - Haemodynamic stability (ideally without the use of vasopressors)

- *Flap factors*
  - Remove tight dressings.
  - Release tight sutures to ease tension on the flap while also decompressing any potential tense collection.
  - Position to avoid postural dependency of the flap.

These manoeuvres may buy time, but do not reduce the urgency for return to theatre.

5.5.1 Algorithm for Re-exploration of Flap

Intraoperatively, the following potential contributing factors must be assessed and addressed in a sequential systematic fashion, as per Chen [30].

5.5.1.1 Pedicle

Under the operating microscope, the entire course and position of the pedicle should be assessed, with great care and copious amounts of warm wash, to ensure there is no kinking or twisting. The position/inset of the flap should be checked, for tension or undue pressure on the pedicle. If concern exists, revision anastomoses with vein grafts should be considered to ensure the pedicle is without tension and with a favourable course.

5.5.1.2 Anastomoses

Working from proximal to distal (inflow to outflow), anastomoses should be examined for both patency and presence of thrombus. Patency may be assessed with the Acland flow test or by trimming a branch distal to the anastomosis to assess bleeding. To avoid undue trauma, the Acland flow test should not be performed repeatedly, while in irradiated vessels it should be carried out with extreme caution. If patent, the anastomoses should not be taken down; however, if any concern exists, a few sutures can be removed to examine the lumen. If localised thrombus is noted, the anastomosis should be taken down and thrombectomy performed, either by milking of the thrombus from the vessel and fishing out with vessel dilators or, if more extensive, by excision of the affected segment. Patency of the vascular circuit may be assessed by feeling for any resistance when flushing with heparinised saline.

There should be a low threshold for the use of vein grafts, to enable tension-free anastomoses between healthy vessels. If the thrombus is extensive and cannot be removed by simple measures and the affected segment cannot be excised, then thrombolytics should be considered, as discussed later. Vasospasm should be managed with vasodilators, such as lidocaine, verapamil or papaverine. Constricted segments may require adventitial excision. Supercharging, which is augmentation of either venous or arterial drainage by an additional distant (not intra-flap) anastomosis, should be borne in mind when attempting flap salvage.

5.5.1.3 Flap Inset

Once the pedicle and anastomoses have been evaluated and addressed, the flap should be re-inset, avoiding a tight inset, which may compress the pedicle. If too tight, a partial or delayed inset, with staples followed by secondary closure, should be considered.

5.5.1.4 Pharmacological Salvage

Thrombolytic drugs should be considered in the salvage of failing free flaps, though as yet no consensus has been reached regarding optimal agent and strategy [31]. Indications include intra-flap thrombus and cases of no-reflow. This is characterised by failure of tissue perfusion despite adequate arterial input and venous drainage, when systemic causes such as low arterial pressure and hypothermia-induced vasospasm have been ruled out [1]. At a cellular level, this is characterised by vascular endothelial cell swelling, intravascular aggregation of platelets and fluid leakage into the interstitial space. Pharmacological salvage should be considered, even in cases when venous thrombosis has been identified late, such as in cases of flap congestion of up to 12 h (Fig. 5.2) [32].

We advocate the use of tissue plasminogen activator (TPA), also known as alteplase, as a primary thrombolytic agent, as it is relatively clot selective and not antigenic and has minimal systemic side effects. It can be administered via an arterial side branch or through the original arterial anastomosis, with either a few sutures removed or completely taken down. A paediatric cannula is placed and an 8-0 suture placed around it to prevent leakage. The artery proximal to the site of infiltration should be clamped and the draining veins of the flap disconnected, to prevent systemic administration of the thrombolytic agent [32].

Our preferred recipe is for dilution of a 1 mg/mL preparation of TPA with 4 mL normal saline, to provide 5 mL with a concentration of 0.2 mg/mL. This 5 mL is infiltrated and alternated with 5 mL of heparinised saline, at a strength of 100 units/mL (5000 units heparin in 50 mL normal saline), infused over 5 min, and the cycle repeated [32]. In theory this cycle may be repeated ad infinitum; however there must come a point when there is no venous return, despite patient inflow and outflow and numerous cycles of thrombolysis, that the flap should be considered unsalvageable, likely due to the no-reflow phenomenon.

Prior to re-anastomosis of the successfully salvaged flap, the venous effluent should be allowed to drain for at least 10 min, once again to reduce the risk of systemic administration. At the time of clamp release, 5000 IU of heparin should be administered systemically (Figs. 5.5 and 5.6).

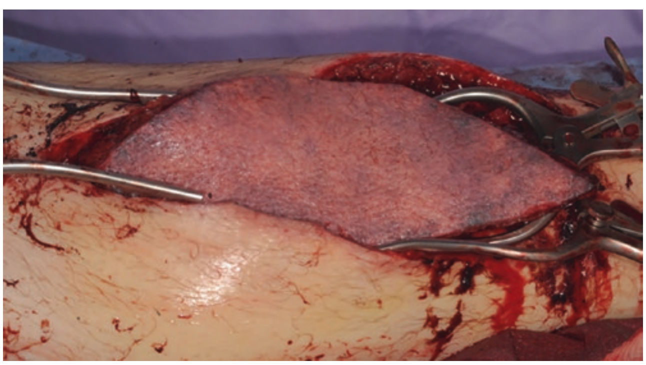

Fig. 5.5 Appearance of anterolateral thigh free flap immediately following successful administration of alteplase, prior to inset

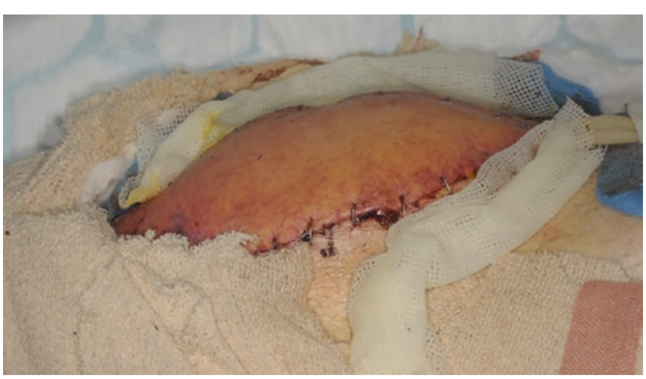

Fig. 5.6 Anterolateral thigh free flap, following successful pharmacological salvage, after 12 h of venous congestion

5.5.1.5 Hirudotherapy

Leeching, both live and chemical, is not a first-line therapy in free flap surgery, but is commonly used following digital replantation [33]. It may also be considered in cases of limited partial (distal) flap compromise or if flap salvage is medically or technically not possible. *Hirudo medicinalis* medicinal leeches may be applied in a cyclical manner, with appropriate antibiotic prophylaxis. Chemical leeching can be undertaken by way of multiple dermal punctures and the application of topical heparin. With both of these interventions, one must be mindful of the high likelihood for requiring blood transfusion [34].

5.5.1.6 Human Factors

Flap salvage procedures are stressful and the importance of having breaks and recruiting help from colleagues should not be underestimated. Taking a step back and approaching the situation with a fresh perspective, whether your own or a colleague's, is incredibly valuable.

5.6 Donor Site Morbidity

The success of FFS is, by most surgeons, based on flap survival, with minimal emphasis placed on donor site morbidity. As free survival rates improve, one cannot forget and must actively strive to reduce donor site morbidity. Problems with donor sites can be both troublesome for patients and hinder post-operative recovery. Potential donor site complications may be illustrated by looking at the radial forearm free flap (RFFF) and anterolateral thigh flap (ALT), both of which can be particularly problematic.

RFFF donor site complications are numerous. Most commonly, poor wound healing (>30%), including graft failure and unstable scar, results in long-term cosmetic and functional morbidity, such as reduced range of movement and grip strength post-operatively [35, 36]. Paraesthesia in the radial nerve distribution has also been documented. In cases of osteocutaneous RFFF, fractures of the radius are possible post-operatively [36]. Various techniques to reduce donor site morbidity and improve functional outcome have been suggested, such as full-thickness grafts in preference to split thickness skin grafts, suprafascial elevation of the flap and use of an ulnar-based transposition flap for donor site closure [35].

ALT donor sites have been reported, by Townley et al., to be complicated by reduced sensibility around the donor scar in 59% of patients, found to be correlated with the width of flap [37]. Muscle 'bulging' was reported by 12% of patients; however there were no clinical findings of discrete herniation [37]. Debate exists as to whether quadriceps function is affected post-ALT harvest, though even in cases of intramuscular perforator dissection, Townley et al. found no alteration in quadriceps function [37]. Other donor site complications

Fig. 5.7 Wound dehiscence of anterolateral thigh free flap donor site

from ALT free flap harvest may include pain, seroma, haematoma, wound infection, wound dehiscence and rarely compartment syndrome (Fig. 5.7). Avoidance of epidural use and avoiding the closure of donor site fascia could mitigate against potential compartment syndrome [35].

Potential donor site morbidity, particularly functional, should not be underestimated or disregarded. Every effort should be made to reduce any associated morbidity.

5.7 Summary

Any microsurgeon will inevitably be faced with the challenging scenario of a failing free flap. Every effort should be made to avoid this, through diligent preoperative and perioperative planning, though this will serve to reduce, rather than completely prevent, flap compromise. Careful post-operative monitoring should be undertaken to identify the failing flap early, at which point aggressive measures should be undertaken to attempt to salvage the flap. One should have an algorithm to ensure potential contributing factors are sought out and addressed in a systematic fashion. Above all, do not forget the patient, to which the flap is attached, and consider them foremost in all decision-making.

5.8 Selected Readings

- Bui DT, Cordeiro PG, Hu QY, Disa JJ, Pusic A, Mehrara BJ. Free flap reexploration: indications, treatment, and outcomes in 1193 free flaps. Plast Reconstr Surg. 2007;119(7):2092–100.

  A retrospective review of 1193 free flaps over a 9-year period, with a 98.8% success rate. Venous thrombosis could largely be salvaged (71% salvaged), while arterial thrombosis led to a worse outcome (40% salvaged). Time to re-exploration was found to be significantly correlated with rate of salvage.
- Gardiner MD, Nanchahal J. Strategies to ensure success of microvascular free tissue transfer. J Plast Reconstr Aesthet Surg. 2010;63(9):e665–73.

  A literature review examining the current evidence pertaining to preoperative optimisation of perioperative management of patients undergoing free tissue transfer.
- Winterton RI, Pinder RM, Morritt AN, Knight SL, Batchelor AG, Liddington MI, Kay SP. Long term study into surgical re-exploration of the 'free flap in difficulty'. J Plast Reconstr Aesthet Surg. 2010;63(7):1080–6.

  A prospective study of 2569 free flaps over a 23-year period. 13% of flaps were re-explored, of which 83% were successfully salvaged. They highlight two key areas to achieve favourable outcomes: firstly, a model of monitoring based primarily upon clinical examination, by experienced individuals, at its core and, secondly, nursing in a specialised post-operative environment, with the ability to return patients to theatre in an expeditious manner.
- Chen WF, Kung YP, Kang YC, Eid A, Tsao CK. Protocolisation and 'end' point of free-flap salvage. J Plast Reconstr Aesthet Surg. 2012;65(9):1272–5.

  A correspondence article summarising the standardised approach, and established endpoint, to flap salvage at Chang Gung Memorial Hospital.
- Griffin JR, Thornton JF. Microsurgery: free tissue transfer and replantation. SRPS. 2015;10(5):1–39.

  Includes a thorough overview of the mechanisms and pathophysiology relevant to free tissue transfer.
- Zoccali G, Molina A, Farhadi J. Is long-term post-operative monitoring of microsurgical flaps still necessary? J Plast Reconstr Aesthet Surg. 2017;70(8):996–1000.

  A literature review and case series, examining the correlation between time of complication onset and probability of flap salvage. As the first 48 hours are key, monitoring during this period is crucial; however beyond this time monitoring was not felt to affect the rate of flap salvage.
- Brouwers K, Kruit AS, Hummelink S, Ulrich DJO. Management of free flap salvage using thrombolytic drugs: a systematic review. J Plast Reconstr Aesthet Surg. 2020;73(10):1806–14.

  A systematic review examining the current evidence (a total of 27 studies and case reports) for pharmacological thrombolysis as a method of free flap salvage. Though deemed a useful adjunct, the level of evidence is low, and no consensus has been reached regarding their optimal use or of the benefit of one specific thrombolytic agent over another.

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