Archives of Plastic Surgery APS

COMMUNICATION

Avoiding complications in microsurgery and strategies for flap take-back

Hui Chai Fong[1], Lawrence Scott Levin[2]

[1]*Department of Plastic, Reconstructive and Aesthetic Surgery, Singapore General Hospital, Singapore;* [2]*Division of Plastic Surgery, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA, USA*

Correspondence: Hui Chai Fong
Department of Plastic, Reconstructive and Aesthetic Surgery, Singapore General Hospital, Outram Road, Singapore 169608, Singapore
Tel: +65-9478-7405, Fax: +65-6224-9221, E-mail: Fonghc@gmail.com

Received: December 20, 2018 • Revised: December 20, 2018 • Accepted: February 1, 2019
pISSN: 2234-6163 • eISSN: 2234-6171
https://doi.org/10.5999/aps.2019.00059 • Arch Plast Surg 2019;46:488-490

Introduction

The invention of the operating microscope, the introduction of the vessel triangulation technique, and the development of fine microinstruments and microsutures were seminal factors in the widespread adoption of reconstructive microsurgery. In the decades that followed, advances in our understanding and technology have ushered in a new frontier of microsurgery, revolutionizing soft tissue reconstruction. Where skin grafts or pedicled flaps of limited tissue types were once the mainstay of reconstruction, free tissue transfer of multiple tissue types has enabled dramatic improvements in aesthetic and functional results.

In the last 45 years since the first free flap, microsurgery has been a process in constant evolution. Success in microsurgery is not an end point, but the culmination of a series of steps that are taken toward achieving a particular objective. Over time and with experience, critical evaluation of each step yields better judgement and alternate, often better ways of doing things. The exercise of physical preparation (staying in "technical shape"), mental reflection, and continual refinement is the key to staying current and obtaining positive results. Indeed, the maxim "Preparation is the only shortcut that you need," shared many years ago by the esteemed Dr. Robert Acland, remains true today.

Rigorous training and sustained practice form the technical foundations of any competent microsurgeon. The learning curve for microsurgery, while steep, can be overcome at a basic level by sufficient practice on *ex vivo* simulation models and small animals. It has been demonstrated that an average of 25 rat femoral vein anastomoses was necessary to overcome the microsurgical learning curve, with patency rates increasing from 48% to 83.4% [1].

Patient selection is equally important; while there are no absolute contraindications to microsurgical reconstruction, expectations must be managed if compliance to postoperative restrictions and in particular, tobacco use, is likely to be an issue. Smokers should be counselled on the need for smoking cessation several weeks before and after surgery. Systemic comorbidities such as diabetes and cardiopulmonary conditions must be optimized prior to elective reconstruction to minimize patient morbidity. Great care is warranted when operating within an irradiated field, as these tissues tend to be more friable, with a tendency for vessel delamination during dissection.

The cornerstone of any successful procedure is obtaining informed consent from the patient and establishing robust lines of communication with his or her family. The reconstructive approach must be tailored to the goals and expectations of the patient.

If a proficient surgeon is operating on an optimized patient after obtaining informed consent, then the subsequent considerations are technical. Surgical considerations include the selection of recipient vessels, flap type, intraoperative positioning (or need for position changes), and postoperative care. If a two-team reconstructive approach is to be utilized, this should be discussed with the resecting team. The surgeon performing recipient vessel preparation must be well versed with the regional anatomy, with a plan for a backup vessel should the situation go awry. Postoperative care requirements, such as intensive care unit bookings, must be secured prior to the operation.

With the multitude of variables and uncertainties that accompany a complex reconstructive problem, a mental preoperative checklist is a useful tool to ensure that the entire team is on the same page. The reconstructive plan, comprising the first and second choice of flap, recipient vessel selection, sequence of harvest, patient positioning, and microscope location around the table must be discussed with all parties involved. The relevant staff should be briefed on the "how and where" of postoperative monitoring. A bed within the postoperative care area or a room with telemetry facilities for close monitoring of the patient and flap perfusion should be available. Nursing staff must be aware of the reconstruction performed, the location of the pedicle, and region-specific nursing requirements (e.g., jack-knife position nursing, non-weight-bearing status). Medical staff monitoring the flap must be aware of the baseline vascular perfusion of the flap, as well as the method and frequency of flap monitoring.

Execution

The need for adequate mental and physical rest for the surgeon cannot be overstated. If there are postoperative flaps in the hospital from the previous day, the possibility for take-back of an existing flap must be managed, and contingency plans (back-up consultant coverage) for these situations must be secured. Similarly, if the primary surgeon is on call, back-up cover for emergency cases should be arranged. After-work commitments on the day of surgery should be kept to a minimum or postponed.

A preoperative huddle with the anesthetist would not be complete without discussion of the need for invasive monitoring, analgesic infusion catheters, and blocks. The anesthetist should be mindful to avoid placing invasive lines or compressive cuffs in or around flap harvest sites. Postoperative analgesia must be optimized to reduce sympathetic drive and peripheral vasoconstriction.

A smooth procedure and a healthy, bleeding flap are good intraoperative prognosticators of success. A successful vessel anastomosis is contingent on good recipient vessel quality and preparation. This requires dissection outside the zone of injury and vessel cut-back to ends that are visibly healthy. A positive spurt test is indicative of sufficient inflow. The donor pedicle and recipient vessels should be mobilized generously from their surrounding connective tissue for tension free coaptation of vessel ends. If this is not possible, vein grafts should be used, particularly in the setting of traumatic wounds or scarred and irradiated recipient beds. It is always a good idea to harvest a skin paddle, even with buried flaps, for ease of postoperative flap monitoring.

Cutaneous inset can be performed primarily, so long as this is achievable without excessive tension. If there is any doubt, inset should be performed as a secondary procedure, 3–5 days postoperatively under local anesthesia in an ambulatory operating theater. Drains are placed under the flap, but situated well away from the pedicle to avoid inadvertent suction on and rupture of the vessels. Loose, ideally non-circumferential, dressings are applied, and the location of the pedicle is marked in bold over broad strips of surgical tape. If a flap is located over or adjacent to a joint, a plaster slab is helpful in immobilizing the reconstructed limb if an external fixator has not been used. Upon completion of the operation and transfer from the operating table, flap circulation should be assessed one final time before the patient leaves the operating room.

Following surgery, a prompt update to family members offers some reassurance and is good practice. A detailed handover in the recovery suite or ward helps to mitigate inadvertent mishaps due to external staff who may be unfamiliar with the postoperative peculiarities of microsurgical patients. It is our convention that flap monitoring, when done in the early hours of the morning (the "midnight run"), is conducted by the surgeon who performed the anastomosis.

Flap take-back

In spite of our best efforts, flap thrombosis can and will occur, usually at an inopportune time. A forewarning of flap thrombosis often presents itself as doubt. If there is anything less than absolute confidence in the assessment of flap viability, particularly in the setting of a complicated anastomosis, a personal assessment eliminates any ambivalence and allows for decisive measures to be taken. An error of commission, while undesirable, is a lesser wrong than an error of omission. When in doubt, the patient and flap should always be assessed by the primary surgeon.

With flap salvage, early recognition and timely intervention are critical to success. The urgency of the situation must be expediently conveyed to the ward team, operating room staff, and on-duty anesthesiologist. Nursing staff must be notified about the equipment to prepare, and the available operating microscope must be procured in anticipation of flap exploration. The highest salvage rates are achieved when return to the operating room occurs within 90 minutes of the first sign of pedicle thrombosis [2]. While isolated cases of salvage following late vascular compromise (postoperative day 11) have been reported, the majority of successful salvages occur within the first 12–24 hours postoperatively [3-5].

The patient must be counselled preoperatively on the possibility of total flap loss. He or she should also be advised that vein grafts may be required in the event of significant pedicle shortening. Pre-revision counselling should also include the possibility and risks of chemical thrombolysis and the operative plan in the event of recurrent thrombosis or failed salvage. The events that transpire and the salient points discussed must be duly documented in the medical record.

During the take-back, the vessels are approached carefully and methodically, ideally by the surgeon who performed the anastomosis. The lie of the pedicle is assessed for kinks or twisting to rule out extrinsic sources of compression. Sharp bends (e.g., redundant pedicle) or abrupt changes in contour of the vessel bed (e.g., irregular edge of the costal border) are identified. Any potentially compressive hematoma is carefully evacuated and the field generously irrigated with heparinized saline. The pedicle is gently palpated to assess for intraluminal thrombosis. If this has occurred, several techniques are useful for salvage: balloon thrombectomy, intravascular irrigation with heparin, anastomotic revision with vein grafting, and thrombolysis. Postoperative leech therapy for venous congestion has also been used with limited success.

If thrombosis is encountered, two or three anastomotic stitches are removed, and a manual milking technique is applied to dislodge the thrombus. If the pedicle distal to the anastomosis is uninvolved, a single-vessel clamp is applied across the healthy segment to prevent distal migration of the thrombus. Flushing the flap with warm heparin solution (5,000 IU in 200 mL of normal saline) can be used to dislodge clots. If these measures are not successful in re-establishing arterial and venous flow, mechanical thrombectomy can be performed with a 3-F Fogarty unicameral balloon.

The anastomosis is taken down and shortened by 2 mm on either end, before the balloon is advanced proximal and then distal to the anastomosis by 10–20 cm where possible. Ensuring that the tip of the catheter remains intraluminal, it is inflated with up to 0.2 mL of saline before the balloon is slowly and carefully withdrawn. Any existing thrombi are trawled out in this fashion until good flow from the artery and/or free outflow from the flap is observed. Special attention must be paid to avoid intimal injury at the point of vessel entry. Furthermore, the speed and extent of balloon inflation must be moderated, as over-inflation exerts significant shear forces on the vessel wall, causing endothelial injury. Patients should be kept on systemic anticoagulation in the postoperative week to avoid repeat thrombosis.

If venous outflow from the flap is insufficient despite successful thrombectomy, chemical thrombolysis can be used to relieve microcirculatory obstruction. Three agents are commonly used in microvascular surgery: streptokinase, urokinase and recombinant tissue plasminogen activator (rt-PA). rt-PA is produced by vascular endothelial cells and, like urokinase, is a direct activator of plasminogen, with a theoretical advantage of a reduced systemic bleeding rate compared with urokinase and streptokinase [6]. Infusion of the thrombolytic agent is confined to the flap circulation by taking down the venous anastomosis, or through a venotomy with atraumatic clamping of the proximal outflow, to allow free drainage of the effluent. A 2.5-mg dose of rt-PA is injected in an isolated fashion into the arterial side of the flap circulation. If brisk flow is not restored after 15 minutes, a second 2.5-mg dose may be administered [7]. Thrombolytic therapy, if successful, neither resolves the cause of thrombosis nor reduces the risk of recurrent thrombosis. Re-inset of the flap should be delayed when possible due to the high probability of postoperative swelling, and anticoagulant therapy in the form of a heparin infusion for 5 days with a target partial thromboplastin time 1.5 to 2 times that of normal is usually required. Normovolemic hemodilution should be maintained with a lactated Ringer's infusion (1.5 to 2 times the normal maintenance volume if medically permissible) to lower blood viscosity [8].

Every surgeon has experienced the consequences of a heroic effort that was unsuccessful. Complications do occur, and the importance of communicating this in the process of obtaining informed consent cannot be overstated. Ultimately, success in microsurgery is dependent on many factors. Preparation is key, and while an expanding armamentarium has improved flap salvage rates, the best outcomes are obtained by avoiding these situations in the first place. With complex surgery, a multitude of worries sit at the edge of every surgeons' bed. However, it is important to remember that the patient (not the surgeon) is the one in need of treatment and that it is our prerogative to stay calm, despite the storm, to secure a favorable outcome for them.

Notes

Conflict of interest
No potential conflict of interest relevant to this article was reported.

Author contribution
Conceptualization: Levin LS. Writing - original draft: Fong HC, Levin LS. Approval of final draft: all authors.

ORCID
Hui Chai Fong https://orcid.org/0000-0003-4130-3131

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