

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

4,800

Open access books available

122,000

International authors and editors

135M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Getting Out of a Tight Spot in Breast Reconstruction — Salvage and Saving Techniques for DIEP, SIEA, and Lymphatic Flaps

Rebecca Studinger

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/56642>

1. Introduction

In performing perforator flaps, there are several obstacles that can arise that can limit your success. In this chapter, I will discuss some of the common problems that can occur with flaps. These can be difficult to navigate and are not always clearly illustrated in books or journal articles. However, some of the ways to successfully address these issues have been through experience and through advice from other experts.

1.1. Patient selection

When evaluating patients for perforator flap reconstruction, there are certain things to keep in mind. In the forefront is the assumption that most patients are candidates, but their overall health must be evaluated. A large population of patients with breast cancer are medically stable and the ones that are seeking tissue reconstruction usually fall into this category. Multiple factors should be explored to aid in the selection of a microsurgical flap patient. (Table 1)

The patient's overall health should be taken into evaluation. A younger population of breast cancer patients is often seeking reconstruction with perforator flaps. Usually, there are no other medical problems present. If this is the case, then nutritional, exercise level, and lifestyle habits can help optimize outcomes. Those that maintain healthy eating with a balanced diet often heal more quickly with fewer wound complications. Exercise can help prepare a patient for the rigors of a surgical recovery. It is helpful to determine if the patient's lifestyle habits or work/home situation can accommodate the time and postoperative restrictions that may apply. A patient who is thriving is more likely to do well postoperatively.

Patient Selection	
<ul style="list-style-type: none"> • Overall health • Age • Conditions for anesthesia <ul style="list-style-type: none"> • Cardiac <ul style="list-style-type: none"> • Cardiac function permits surgery (i.e. ejection fraction) • Able to tolerate high fluid volumes • Able to maintain blood pressure without the use of intraoperative pressors • Lung <ul style="list-style-type: none"> • Able to ventilate/intubate easily • No presence of pulmonary process that would inhibit large fluid volumes • Conditions for flap <ul style="list-style-type: none"> • Absence of clotting disorders • Atherosclerotic disease • IV access issues • Smoking <ul style="list-style-type: none"> • Absence of tobacco use for 3 months prior • Absence of nicotine use for 3 months prior 	<ul style="list-style-type: none"> • Psychology <ul style="list-style-type: none"> • Grieving process/increased susceptibility to illness • Ability to follow direction • Home situation • Resilience vs. overwhelmed or overanxious • Patience/Understands may be a multistep process • Other relative risk factors <ul style="list-style-type: none"> • Diabetes • Hypertension • Obesity • Radiation • Chemotherapy timing • History of multiple infections

Table 1. Factors to be addressed in patient selection for breast reconstruction with free flaps.

The age of a patient may or may not play a large factor into surgical decision making. A person of advanced age may not be able to tolerate a flap reconstruction due to other medical issues. Some surgeons will have a mandatory cutoff of age, for example 65 years, in order to streamline the screening process. There are always exceptions to this rule, and plenty examples can be made of patients who are older than 65, being in better health than some 35 year olds. Age is a relative factor in patient selection.

There are anesthetic conditions that should be evaluated prior to surgery. These mainly include cardiac and lung functions. Patients should have preoperative cardiac clearance prior to surgery. Occasionally young patients with breast cancer have had cardiotoxic chemotherapy, and will not tolerate microsurgery. In having clearance assessed, a patient who may be a candidate for other procedures may not necessarily be one for a flap, knowing that fluid loading is the mainstay of cardiac output in microsurgery and not vasoconstricting inotropes. This is not always clear to physicians who are providing cardiac clearance, so a discussion with them or their primary care physician can be vital in understanding this situation. [1, 2]

Pulmonary screening questions can be useful to determine if a patient is able to oxygenate well, has a good intubation history, and is able to handle fluid volumes. Maintaining oxygen

saturation post procedure increases the viability of the flap. Adequate pulmonary excursion is helpful for relief of postoperative atelectasis and prevention of pneumonia. It is helpful to have a smooth extubation after a case finishes to decrease pressure spikes and possible bleeding. Patients with a history of a difficult airway can alert you to possible complications in wake up. Patients who have a diminished pulmonary function may run into difficulties with large fluid volumes leading to postoperative flap or patient compromise.

Bleeding and clotting disorders are helpful to know in patient selection. Both abnormalities can affect the success of the flap. Based on the degree of severity, both can be accommodated for with the aid of a hematologist. If there is a family or personal history of either of these conditions, then a preoperative consultation should be obtained. Laboratory tests such as CBC, PTT, INR, fibrinogen levels for bleeding and protein S and protein C, antithrombin III, Factor V leidin, prothrombin 20210A, antiphospholipid Ab, and homocysteine levels can be checked to diagnose a hypercoaguable state. (Table 2) [3]

Coagulation Disorders

- Coagulation-promoting conditions
 - Procoagulantafibrinogenemia/dysfibrinogenemia
 - Protein C deficiency
 - Protein S deficiency
 - Antithrombin III deficiency
 - Factor V Leiden deficiency
 - Activated protein C resistance (aPCR)
 - DIC
 - Coagulation-impeding conditions
 - Anticoagulant afibrinogenemia/dysfibrinogenemia
 - Factor V deficiency
 - Factor VII deficiency
 - Factor X deficiency
 - Factor XI deficiency
 - Factor XII deficiency
 - Factor XIII deficiency
 - Hemophilia A
 - Hemophilia B
-

Table 2. Coagulation disorders to keep in mind prior to flap performance. (3)

Diseased blood vessels with atherosclerosis and calcifications can make anastomoses of the vessels difficult. It can also be a cause for a later failure with occlusion of the anastomosis. A strong history of vascular disease may be an indication to not perform the surgery. A personal or strong family history of coronary arterial disease may be a reason to select axillary vessels rather than the internal mammary arteries.

A poor peripheral vascular supply does not immediately indicate poor internal vessels. The presence of poor peripheral vessels in the breast cancer population can sometimes be explained by exposure to chemotherapy or multiple venipunctures. If the patient still has a chemotherapy port in place, this can be useful for emergency access throughout the patient's hospital stay. Other central vascular access routes can be predetermined if peripheral access is a known problem.

Tobacco use has been shown to increase complications in microsurgical flap procedures. For breast reconstruction, smoking has been shown to increase donor site complications as well as increased complications in mastectomy skin flaps during immediate reconstruction. Cessation of smoking with a delayed reconstruction has been shown to help decrease these complications. Differences in anastomotic failure have not been shown to be significant. Tobacco cessation at least 4 weeks prior to surgery has been shown to help decrease the risk. Those with an extensive history of smoking are more likely to have complications (10 pack year or greater). Nicotine tests (urine cotinine tests) can be performed to assess if the patient has stopped smoking. These are easy to perform in the office. If the patient is taking nicotine supplements, it can create a positive result. [4, 5, 6, 7]

The psychological/emotional state of the patient should also be assessed. This can be done rather informally in the office by observing the patient's affect, interactions and response to questions. If there is strong concern that the patient is in a state of severe depression or other illness, a psychiatric evaluation should be performed.

The diagnosis of breast cancer comes with a grieving period for patients. This may happen immediately or delayed. When people are in a state of bereavement, their immune system can be compromised, lending them to a poor healing condition. [8, 9, 10] The patient's ability to understand and cope with a possible surgical complication can be crucial to the success of the flap. Their ability to follow direction, anxiety level, and possible resilience needs to be gauged. Breast reconstruction is a multistep process which some patients can find overwhelming.

Oftentimes patients are in a state of emotional flux, grieving about a recent cancer diagnosis or the loss of a breast. This is sometimes seen as a good opportunity to do reconstruction with a tissue transfer to decrease psychological stress. I have found, however, that patients who have gone through the entire cancer process tend to do remarkably well, if not better overall, than their immediate reconstruction cohorts. This is not always the case of course and there are many different views on immediate reconstruction versus delayed, but I have moved from a position of immediate is always less traumatic to now screening my patients when they come in initially to see how emotionally fit they seem to be.

A lot of times delayed reconstruction patients are more compliant and will already have a good support system in place partly due to having the experience from prior mastectomy surgery and treatment for cancer. When doing immediate reconstruction, it can sometimes be difficult to find out about home life and the patient's current psychological state. Some studies show that patients in a state of grieving have a vulnerability to physical illness and this can sometimes predict poor adjustment post surgically. If the patient is incredibly overwhelmed already and appears to be unable to handle any more stress than they are already in, I would recom-

mend starting with a tissue expander reconstruction. The potential for a loss of a flap or post op complications with a tissue reconstruction might be too much for them to bear. A study by Metcalfe et al. looked at the psychosocial functioning of women up to one year later with no significant difference between those with immediate, delayed or no reconstruction. [11]

For other health complications such as diabetes, as long as the condition is under control there should be minimal complications. Complications associated with diabetes can be related to wound healing. It can also be associated with poor vascularity. Hypertension can also be an indication of damaged vessels, depending on the length and severity of the hypertension. Postoperative pressure management and prevention of bleeding can be challenging in this situation.

Patients who are overweight can be candidates for flap reconstruction. In fact, Garvey et al. found that obese patients do better with tissue reconstruction than they do with implant reconstruction. [12] That being said, obese patients are prone to more complications and failure with flap reconstructions than an ideal weight population. [13] Sometimes patients who are larger have larger vessels to work with as well which can help with anastomoses.

Prior radiation is usually a reason to perform a free flap reconstruction. For breast cancer patients, this may be more of an issue with skin availability rather than the availability of recipient vessels, especially if they are internal mammary arteries. Patients that need postoperative radiation and desire immediate reconstruction may benefit more from tissue expander reconstruction until the radiation is finished, and then they can bridge to tissue reconstruction. This preserves the reconstructed tissue from radiation damage, and allows for reconstruction throughout the process. Implants do not necessarily work well with radiation, and so fully expanded breast skin prior to radiation may increase complications as the skin changes.

Patients with a history of tissue expander and implant reconstruction with multiple infections may have difficult recipient vessels dissections as well. This can be an important part of preoperative planning, in order to come up with a backup plan for recipient vessels.

2. Preoperative imaging

Currently, the trend has moved to preoperative imaging to aid in the planning of perforator flap reconstruction. MRI, CTA, Lymphoscintigraphy study, ultrasound, doppler and nuclear medicine are all very useful in helping to determine if a patient will be a good candidate. MRI can image on several planes with no radiation. CTA's have clear images which are excellent for evaluating the body in vessel reconstruction. Nuclear medicine helps with functional tracing of lymphatics. MRI can give functional with additional structural and physical characteristics of lymphatics. [14-19]

The use of preoperative imaging has become a mainstay for many practitioners of perforator flaps. Initially, a handheld Doppler to mark out the perforator signals was a useful way to help assess the presence of a perforator. However, the location of a perforator signal and the location of the actual perforator could vary immensely, and therefore, the limitation to finding the

perforator of choice. The trend toward preoperative imaging has helped in intraoperative planning, patient selection and execution of the flap.

2.1. MRI

MRI studies have been very useful as an adjunct in perforator flap imaging. The main advantage is to provide imaging of the vessels and muscular course while limiting the patient's exposure to radiation. In comparison to CT scans, the images are not always as clear. Also, some patients have a harder time with the test itself than a CT scan test for them. Motion artifact can be a factor in the final views. I have had a few cases where the vessels were not present in the DIEP system but were read as and reviewed by myself and the radiologist as being present with motion artifact crossing the view. In actuality, the vessels really were transected from a previous surgery at the point that looked like artifact only to be weakly reconstituted at a later point. This caused a change in operative plan on the table that in retrospect was easily seen. I have had other examples of times when a dominant vessel was damaged or did not show well in this type of study either due to the motion artifact or the slight lack of clarity of the images. (Figure 1.)

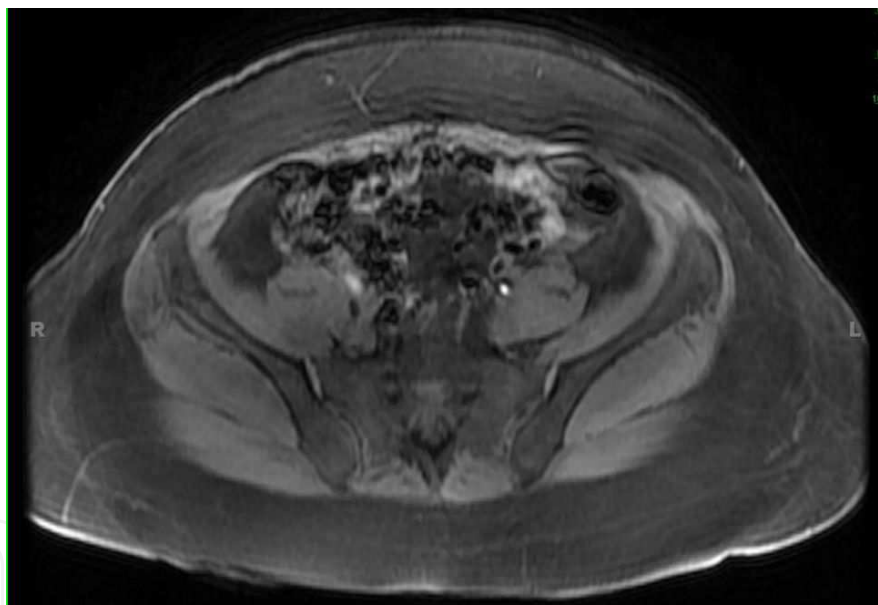


Figure 1. MRI axial view illustrating a perforator vessel of the right abdominal wall.

2.2. CT scan

A CT angiogram of the vessels can be very helpful as well. It has the imaging capabilities to have clear imaging of the position and course of the vessels. It does expose the patient to radiation. IV contrast dye allergy is more likely than gadolinium sensitivity. This can be premedicated for, if the patient's reaction is not too severe. This scan I have found easy to read. The vessels show up clearly. The angiogram part which is usually a reconstruction image at our institution can sometimes make the vessels look a little more im-

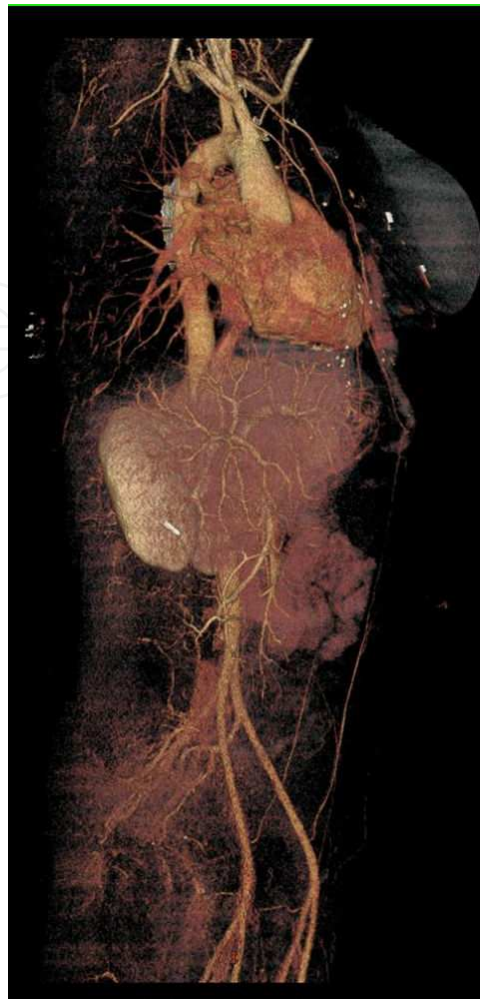


Figure 2. A 3D reconstruction from a CT angiogram illustrates the location of the DIEP vessels as well as the IMA vessels.

pressive than they are, especially if they are quite small. This is apparently due to the layering technique that is present in the reconstruction process of the images. So in order to get an immediate overview of the vessels of the chest and the abdomen, a quick swing through a regular axial series is helpful to get an idea of the strength of the vessels. Then, once viewed, the angiogram reconstruction is invaluable for the muscle path or other anatomical travel that it does. As far as imaging the vessels in the chest, I prefer the coronal view to help with vessel placement near the sternum. Again, I will assess the vessels at the axial view first without the reconstruction images and then go to the coronal view. I have found that the axial reconstructions of the chest vessels are somewhat difficult to get a good read, due to the almost 3d view of the curved ribcage. (Figure 2.)

2.3. Lymphoscintigraphy

A nuclear medicine lymphoscintigraphy study is very helpful to determine the function of the lymphatics in all the extremities. Performed by injecting a tracer isotope in the web

spaces of the hands and feet, the uptake of the isotope into the lymph nodes is tracked and followed. This provides a map of which areas are functioning well. This is useful to see if there is another injury to a set of lymph nodes elsewhere which would restrict the harvesting of the nodes in that area. It is to be expected that the area in question would not function well. This test can be a confirmation of that, although it does not always correlate with the physical severity that is noticed clinically, and the images can over and underrepresent the clinical picture. (Figure 3.)

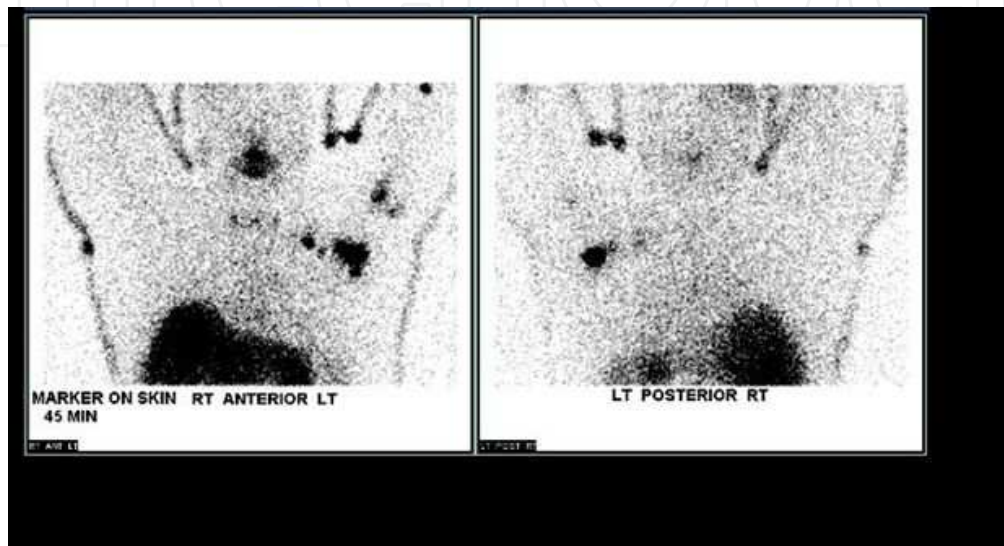


Figure 3. A lymphoscintigraphy study illustrates the absence of lymphatic activity in the right axilla due to prior lymph node dissection and scarring. The left shows evidence of lymphatic activity.

A CT scan and MRI can both be useful for lymph node imaging. They can each show the path and anatomical locations of the lymphatics. With certain software technology, MRI can give a good functional lymphatic result without the use of injections which is very helpful. (Figure 4.)

2.4. Evaluating the Imaging

Preoperative imaging of the chest, abdomen and pelvis gives the most information for operative planning. Whether it is done by MRI or CT, the ability to see the vessel placement in relation to physical structures and landmarks can increase the efficiency of intraoperative vessels selection and completion of the procedure. A systematic review of the study is helpful.

Initially, looking at the recipient vessels in the chest is a good place to start. A coronal view shows the internal mammary arteries in relation to the sternal edge and rib spaces. Thoraco-dorsal vessels, branches and their relationship to the dissection area are seen in this view. Axial views help to show perforator vessels in the breast tissue that can be preserved during an immediate reconstruction. The internal mammary veins are also easier to see in this view. Frequently on the left side of the chest the veins are smaller than may be helpful. This can also

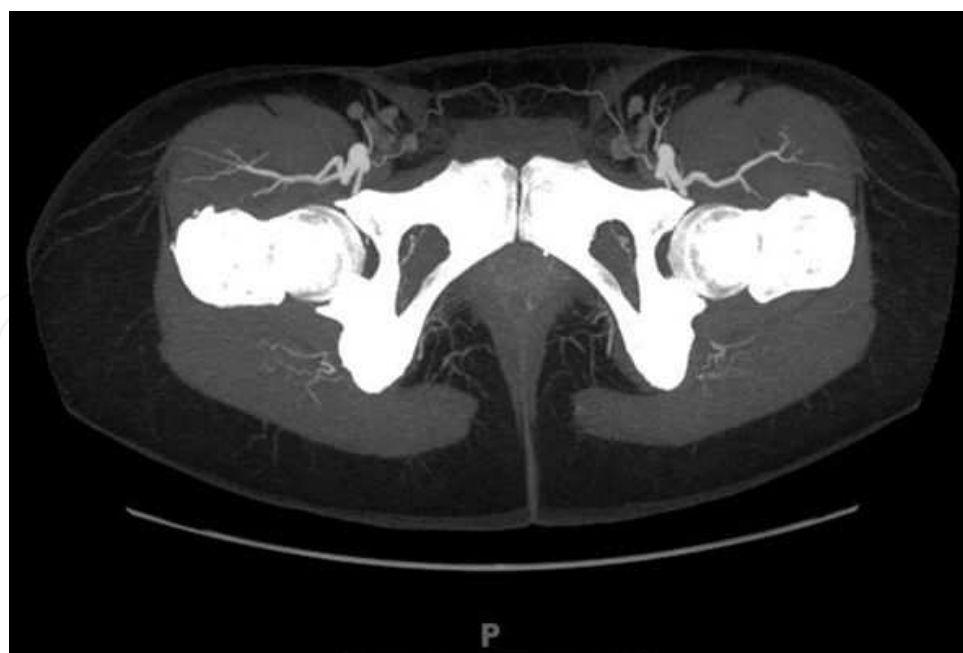


Figure 4. CT scan showing the lymph nodes and vessels present in the groin area.

help to show continuity of the vessels in the axilla, and the amount of axillary compression due to scarring in a delayed case. (Figure 5.)



Figure 5. The axillary vessels are seen clearly on the left side of the patient. On the patient's right (left side of image), the CT shows the compression of the axilla due to scarring from prior lymph node removal and scarring.

After evaluating the chest vessels, the abdominal vessels are visualized in a similar fashion. Coronal views can show branching of the deep inferior epigastric vessels. This is helpful in

planning for double pedicled or stacked flaps. Also the perforators and superficial vessels can be viewed in relationship to each other to help select DIEP or SIEA flaps. (Figure 6.)



Figure 6. In this view, the deep inferior epigastric and superficial inferior epigastrics are visualized. The internal mammary vessels are also seen. The superficial and deep vessels can be compared to evaluate which are more appropriate in size to use.

Axial views of the abdomen are viewed approximately 4 cm above the abdomen, all the way down to the bottom of the pelvis. Looking for the perforators along the way, the vascular branching is traced superiorly and inferiorly to see which direction the branches are going. Once the vessels are identified, then the pathways are traced through or around the muscles, and a comparison is made to the superficial system to see what appears to be dominant. At this time, the caliber of the vessel is compared to the recipient vessels seen in the chest. (Figure 7.)

If a lymphatic flap is going to be included, then the functionality of the lymph nodes are visualized. The donor sites must be functioning without any evidence of delay or diminished signal. This is seen with the lymphoscintigraphy study. Anatomically, a CT or MRI study can show the location of the lymphatics. This can help plan the flap in relation to final placement. (Figure 8.)



Figure 7. The perforator vessels are marked with arrows. These are located near the umbilicus. Using this view, and scrolling up and down, the vessels can be traced throughout their course to the pedicles. This can help in planning to select the lateral or medial vessels based on the size of the perforators, presence of a vein as well as minimal disruption to the muscle.



Figure 8. This CT angiogram illustrates both the lymph nodes located at the groin area as well as the vascularity that is associated with the nodes. This can be used in flap planning for the area and proposed vascular planning.

3. Approaching the DIEP flap

The design of this flap is going to be based on two factors: where the blood supply is located, and the amount of tissue needed to recreate the defect. Using preoperative imaging, the vessel location of the flap is easier to determine. Adjustments to the positioning of the flap will be made accordingly. In general, a design not unlike an abdominoplasty procedure is selected for the superior, lateral and inferior incisions. Check with the patient in an upright position if it seems as if the tissue can be closed by pinching the skin together. If you need more tissue, then have the patient bend forward slightly and then mark the area where the skin edges can be closed from this point on. Remember, if this is the case, you will need to have an OR table that will flex the patient into this position, and to check the functionality of the table prior to the start of the case if this is the design that you are committed to.

One way to calculate the amount of tissue to remove is to measure the contralateral breast if present, or the current breast if going to be removed, and determine how much skin is needed and how much of the fat is needed to balance the two breasts. If doing bilateral reconstructions, and there is no premeasured size, then an approximation can be made with a measuring tape, but curving it in the air to assess the size. The skin quality of the chest tissue can be checked as well. If doing an immediate reconstruction, it can be difficult to predict how much of the skin tissue will be left or how strong it will be depending on the breast tissue itself and general surgeon's mastectomy technique. Once the skin flexibility is determined, an approximate second measurement can be made of possible additional fat that can be harvested beyond the skin envelope. This may result in a contour deficit of the abdomen but may allow the skin to be initially closed with a revision to help the scar later. (Figure 9.)

Once the approximate size of the area is determined, then the radiographic study of choice can illustrate where the vessels are positioned relative to the umbilicus. Usually they are at the level of the umbilicus or slightly below. In this instance, the flap design can be made superiorly to just above the umbilicus, allowing for a moderate inferior scar. If the vessels are located further below the umbilicus, or if they appear to be a superficially dominant system, a change to an SIEA plan can be made, or a shift of the flap design lower in the abdomen can be made to yet lower the abdominal scar, for a more cosmetic postoperative look. If the vessels are at the superior edge of the umbilicus or higher, then the flap can be shifted cephalad, depending on how much further up the vessels are. In this instance, the inferior flap will also be shifted closer to the umbilicus, making it more difficult to disguise postoperatively in abdomen revealing clothing. (Figure 10.)

Laterally, the flap design can be made with the patient's habitus in mind, allowing the natural folds of the skin to help design the lateral edges. A point to remember, oftentimes a distant lateral edge will not be adequately supplied by the DIEP vessels, and so will be removed to prevent necrosis at inset. Because of this, I do not plan for long lateral extensions, unless doing so is purposeful for the flap, is based on the vascular supply placement, or is a way to prevent lateral scar deformities or "dog ears."

There are several ways to approach elevating the flap. One such way is to start at the umbilicus and separate it from the surrounding tissues using a 15 blade scalpel (or surgeon's choice).

Preoperative Markings for Flap Design

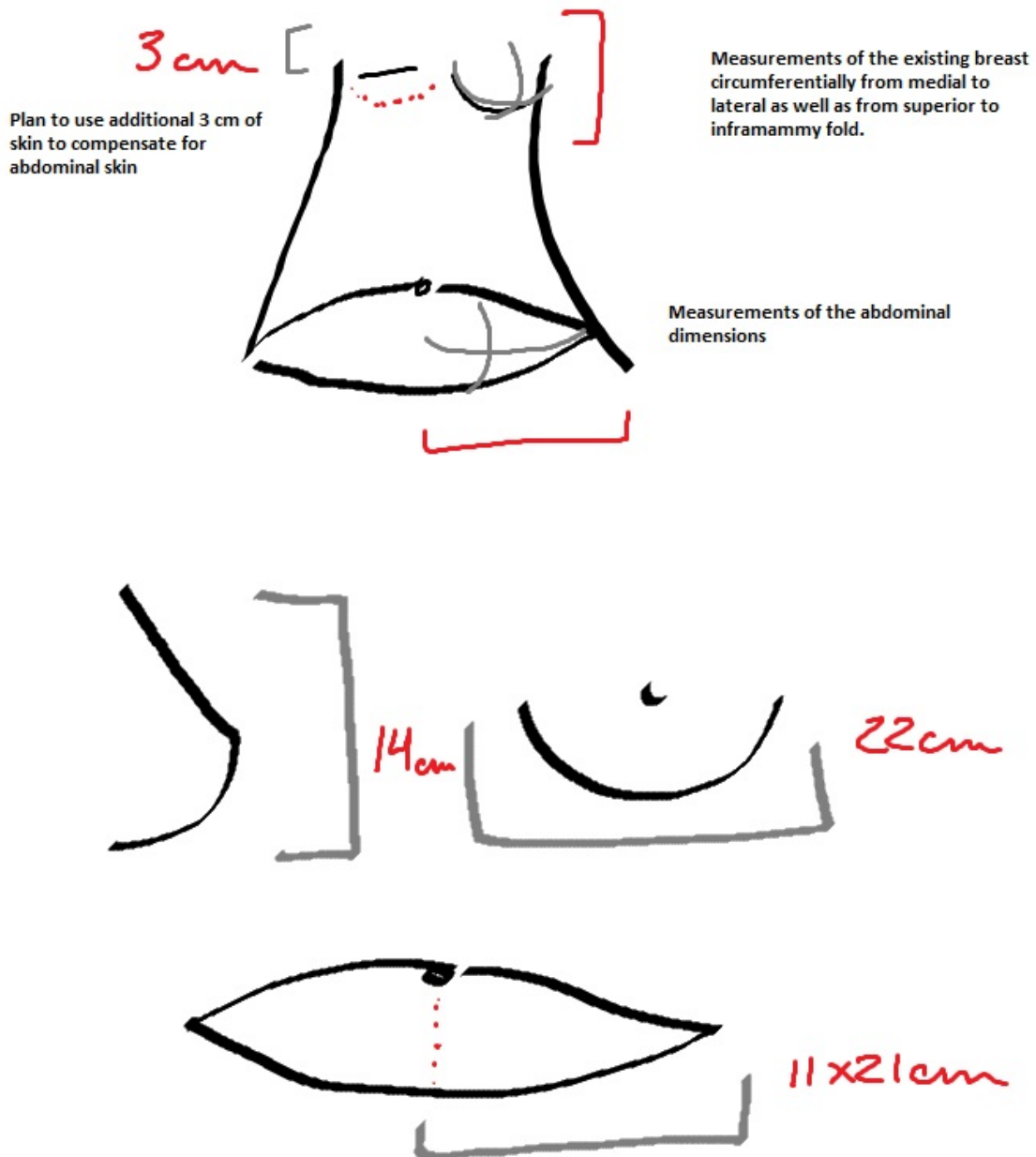


Figure 9. Planning of the flap measurements can be made by measuring the width and height of the existing breast tissue if it is present. This can help to determine if more or less skin needs to be taken. This is particularly useful if the patient has an incredible excess of tissue, and the flap is designed to be smaller, or can help to illustrate sizing to a patient if there may not be enough tissue to match the opposite side.

Flap placement based on preoperative imaging

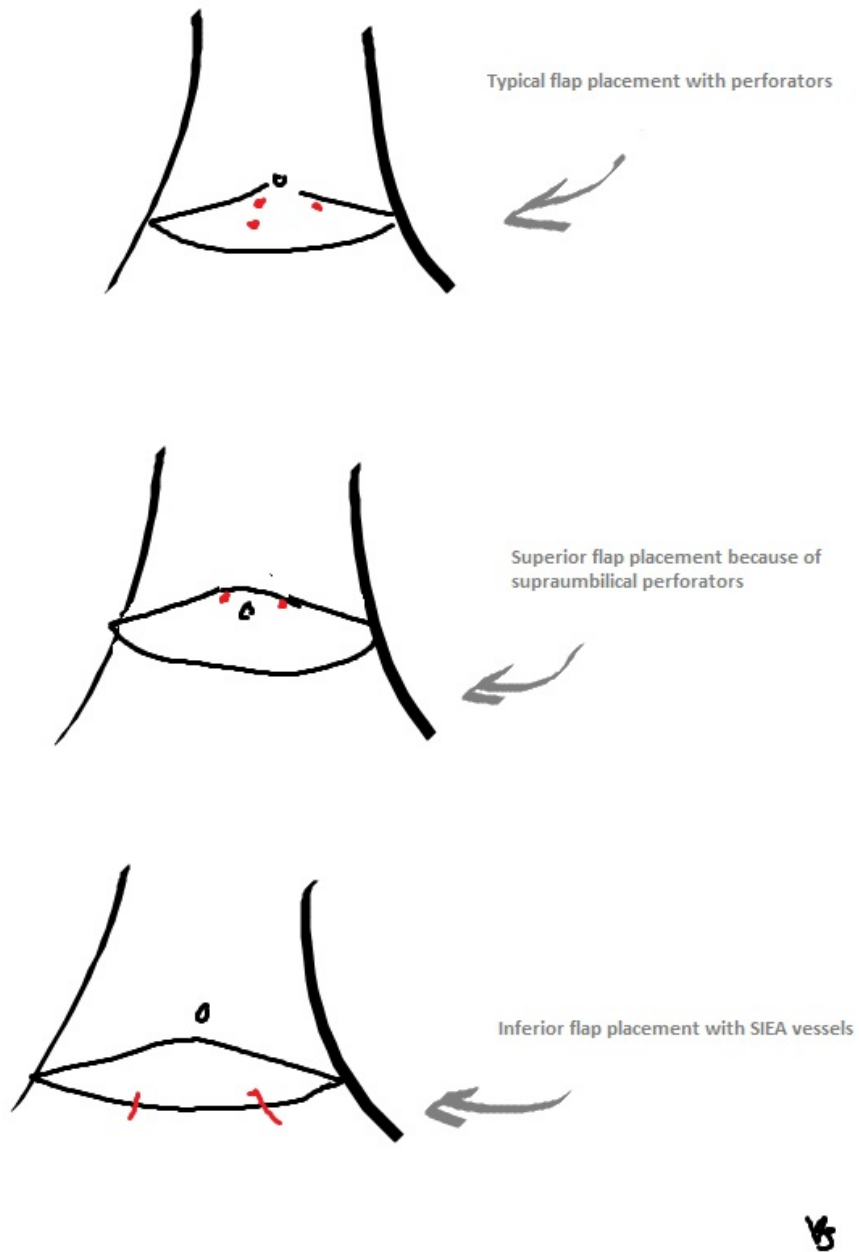


Figure 10. Placement of the flap design can be tailored to the presumed location of the perforator vessels. This can be determined by preoperative imaging. This can be especially useful if the vessels are located at the edges of the initial flap design. Changing the location of the flap to center it more around the vessels can improve the survival of the flap

Once the umbilicus has been freed, then the markings are incised with a scalpel blade. Prior to incision, another helpful technique is to draw marks perpendicular to the incisions, and then

put tacking staples at these areas both superiorly and inferiorly to help match the abdominal skin edges together, and prevent dog ear deformities.

Once these are incised, then electrocautery dissection is used to dissect the subcutaneous tissues down to the fascia superiorly and inferiorly. If the plan is to include more subcutaneous tissue than skin, dissect down to the scarpas layer in a perpendicular fashion from the skin. Once below the fascial layer, then the dissection can bevel out to include more tissue. It can be done directly under the skin as well, but it makes for a more difficult final closure of the abdomen with a greater risk of contour deformity and widened scar. The additional fat harvest is usually performed in a superior fashion. Laterally, the initial dissection is not always done to the depth of the fascia often because the fascia is not located as far laterally as your incision may start. In this instance, a dissection of a presumed equal depth to that of the main abdomen is performed, leaving subcutaneous tissue underneath the dissection until the actual fascial location is reached.

Inferiorly, the dissection can be done a little differently to maximize success. The superficial inferior epigastric arterial and venous systems are located in this area. Initial dissection with a scalpel can be performed in this area to get through the dermal layers. Once this is finished, then bipolar cautery with microhemostat dissection can be performed to locate the superficial vein(s), and the artery with venous commitantes. There are several ways to do this. One method of locating these vessels is to use the electrocautery on cut mode, and gently push the tissue over to see if there is something located near it, and then cauterize those areas which have nothing, or use it with microsurgical or fine tipped hemostats to lift the tissue and then cauterize. Usually there will be a vein located towards midline which is fairly sizeable. This is usually visualized on the preoperative scans, and so the location and depth can be approximated by these. Usually more laterally, the arterial system can be located. Even further laterally a second venous system is often noted and travels towards the midline. In order of depth, most commonly I have found that the more medial the vessel is located, the less deeply it lies. (Figure 11.)

These vessels are important in this dissection because they can: help you in times of venous congestion to provide a second or third draining vein; can convert your flap from a DIEP to a SIEA if the artery appears to be suitable; and give you some information about the perforator occasionally by the size of the vessels (veins especially) versus the size of the perforators. (Figure 12.)

The vessels in this area have a tendency to spasm often and early. It is very helpful to use a vessel loop around the vessels as soon as they are found in order to keep them safe during dissection. Usually the best view that you will have of them is the first view. If you think you saw a large shadow for a vein or a system and then it disappears, leave that particular area and come back to it. Even veins that are 3 mm in diameter I have seen collapse to look like a fibrous attachment. They can often stay in this state, and until you follow them down a little to areas undissected, can look inconsequential. Papaverine can be useful to help them relax, but time is usually best.

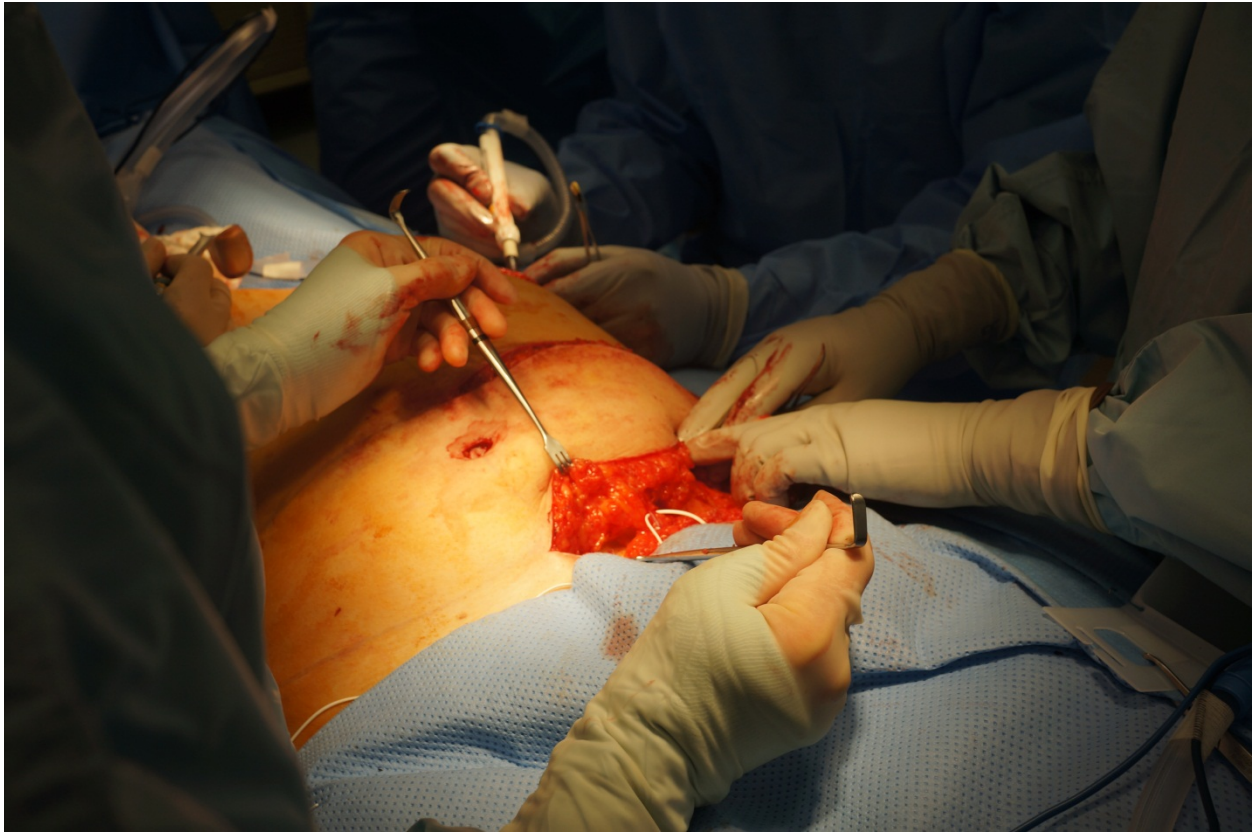


Figure 11. Initial dissection of the superficial vessels. Inferior dissection is done on the flap to find the more medial superficial vein, as well as a possibly useful superficial artery. It is helpful to use a vessel loop under the vessel when it is first found, as these vessels have a tendency to go into a hard spasm, making it very difficult to see and very easy to injure.

Once the vessels have been found and isolated, then the rest of the inferior area of subcutaneous tissues can be further dissected using electrocautery or bipolar cautery, ensuring that the vessels that are isolated are not damaged. At this point, if the arterial system does not seem adequate for an SIEA flap, then dissection of the veins, usually the more medial one can be performed. This is done by gently dissecting around the vessel, using small clips (i.e. gem clips) to clip the branches. Branches can also be tied. Bipolar cautery can also be used with caution to perform this portion of the dissection. The risks with that are getting too close to the main vessel and having thermal injury to the portion of the vessel that you would use, having the bipolar “meld” to a small branch and in removing it, avulsing the branch off the main portion of the vessel damaging it and shortening the usable length or creating more work for you to repair it and possibly creating a stricture by doing so. Once a sufficient length has been obtained, and this varies too as far as how much of a sense that you have that you would need to use it in the future, then it is clipped or tied and divided and reflected back towards the flap. Another way to dissect is to go until the vein starts to dive down, and then transect it after it has curved. Usually at this point you will need a little retraction of the subcutaneous tissue that you did not dissect with a small retractor such as an army navy or Richardson retractor, senn retractor a lone star (a silastic tube with a curved hook, sharp or dull).



Figure 12. Dissecting the superficial vessels. Using fine blunt dissection, and bipolar cautery to help, the superficial inferior epigastric vessels are evaluated for a SIEA flap potential, or use of an accessory vein if necessary for additional drainage.

Once the subcutaneous tissues have been dissected to the fascia on all edges of the flap, then the flap can be raised to locate the perforators. One of the ways to do this is to go from lateral to medial. This can be done while sitting down, having an assistant on the opposite side of the table. The assistant will support the flap up and away from you as you start to raise it. This can be done with electrocautery. I will usually use the cut mode for this with a setting of 30/30. The cut mode of cautery tends to give a cleaner separation from the fascia making it easier to see. Most dissections have a “clean” suprafascial layer to it. This makes the visualization of the perforators easier. Others have fatty tissue or scar tissue that makes an adherent or “sticky” plane to dissect. In these instances, then the dissection is done much more slowly in order not to damage anything. You may run into perforating vessels long before you reach the rectus muscle. Unless there is a clear indication from preoperative imaging that these travel superficially under the fascia and then join the DIEP system, they will not usually be adequate for use. These can be cauterized or clipped on the way to the perforators. (Figure 13.)

If it is unclear as to where the rectus muscles are located, electrocautery stimulation of the muscles can be performed to see where they are. This is done by gently and quickly stimulating the fascia with the cautery. The fascia can remain intact during this test if it is done quickly. If the direction of contraction is vertical, then the rectus muscle is below, if diagonal, then you are in the territory of the obliques. Once in the rectus muscle territory, a safe dissection mode is to switch to bipolar cautery and hemostat dissection to find the perforators.

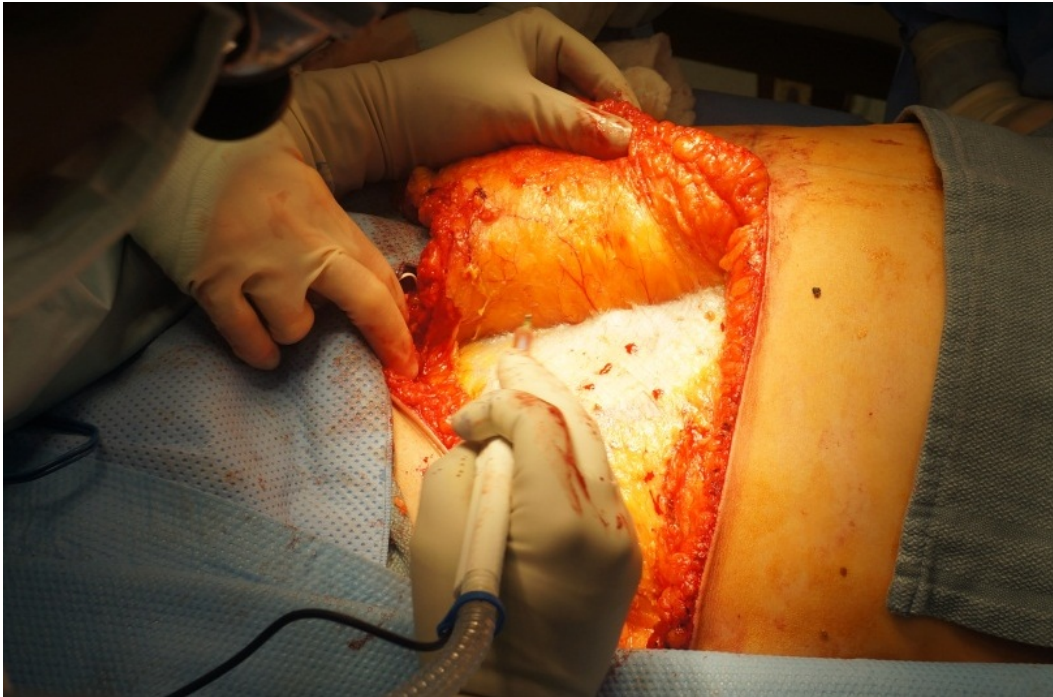


Figure 13. Dissecting the abdominal flap from laterally to medially using cautery. The perforator branches initially can look like branches of a tree. Once this is seen, then careful dissection can lead to the “trunk” of the perforator branches.

As you are lifting the flap away from yourself, small vessels will usually start to appear, as if the tops of a tree. As you continue medially, these start to condense into thicker branches or a single trunk. At this point a perforator is usually underneath. Another way to see one is by looking for “shadowing” underneath the tissues, it will usually be the vein. A third way is to notice a small opening in the fascia. Usually the perforators are located in small oval gaps in the fascia and sometimes the edges of these gaps will be visible before the vessels are.

There are lateral and medial row perforators, meaning that some will be closer to the umbilicus and some will be closer to the obliques. Once you locate the lateral perforators, you can use a vessel loop to go around them, and then start the dissection from medial to lateral, or superiorly to inferiorly or inferiorly to superiorly. This is to locate the medial perforators. Once these are located, then the planned vessels based on studies are confirmed or an alternative is chosen. If there is a question about the actual flow provided by these vessels, Doppler skin signals can be used to assess which is supplying the overlying skin. Vessel clamps can also be used to determine if one has better flow or venous return than another. Another technique is to use a fluorescein injection and monitor the flow to determine the dominant perforator. Oftentimes, the grouping that has a larger vein and a similar artery size is the one to choose. Radiographic studies can also determine the selection by viewing the pattern of distribution into the subcutaneous tissues that each has, as well as its subfascial course.

The majority of the main selected perforators are around the level of the umbilicus. These can be medial or lateral. There are also areas where a grouping of vessels with a larger nerve are located. These can initially look to be ideal, but on further inspection will be fairly useless for

a vascular supply. Two locations where these are commonly found are just on the superior medial aspect of the umbilicus and midway through the flap between the umbilicus and pubis, often located between the medial and lateral row. Another temptation can be to select multiple medial perforators in a row to use. The lateral row often can be coordinated with more than one perforator as the branches follow a linear path through the rectus muscle. Medially, the perforators can cross through the muscle at several points resulting in transection of the muscle transversely in order to connect the systems.

Once selected, then the dissection to release the perforator is performed. If you have an assistant who is holding the flap for you, they must be extremely careful to make sure that they are not pulling the flap in such a way to avulse or create a stretch injury to the perforator vessels at this time. Separation of the vessels from the fascia can be done by directly going to the fascia that is surrounding the pedicle and using blunt/fine tipped scissors (i.e. Wescott) splitting the fascia further cephalad and caudad to follow the path of the perforators. Another way to do this is to start indirectly by scoring the fascia with a scalpel superiorly and inferiorly to the pedicle, catching the edge of the fascial opening or going slightly lateral or medial to it. Once this is incised or scored, then scissor dissection can open the fascia up at a little distance inferiorly to the perforator. At this point, usually the vessels are not directly underneath the fascia (although radiographs do help to see this), and the fascia can be gently split and retracted until the perforators are visualized. This can be a helpful way to avoid cutting into a branch or the actual vessel at your initial dissection. (Figure 14.)

Once the perforator has been visualized under the fascia, then it is dissected down to the deep inferior epigastric artery and veins. This is done with microhemostat dissection and bipolar cautery to dissect the tissue freely from the vessels. Branches can be tied or clipped and divided. Careful attention is paid to crossing nerve branches in order to spare them during the dissection. During the dissection of the branches through the muscle, it is important to keep the bipolar tips clean, otherwise they can stick to the cauterized tissue, and especially if it is a small branch of the vessels, can cause tearing and damage to them. We use lubricant on the bipolar tips to keep them from sticking.

Occasionally it is not clear what branch of the perforator vessel is going to the deep vessels. If this is the case, then dissection through the muscle to find the pedicle can be performed and then the dissection work its way cephalad towards the perforator. Once this has been done, then the branches can sometimes be easier to separate from the main branch point. Do not assume that if a perforator branch initially goes medially or laterally that it is not going in the right direction. It can often travel from side to side and then dive down. It is possible to transect what looks like a branch, only to have nothing left underneath at all. Superior to the perforator, there is often a continuation of the vessel. Occasionally the deep vessels will terminate at the perforator but this is less often the case. Finding the vessels that are travelling superiorly and are not curving back to join the pedicle, these can then be clipped or tied and then divided. Harmonic scalpel is also useful for this purpose. Once these are divided, then it can free the perforator to see branch points as well. This can be a useful maneuver to aid in dissection, as well as one of safety to prevent the perforator from getting tethered and injured by stretch during dissection.

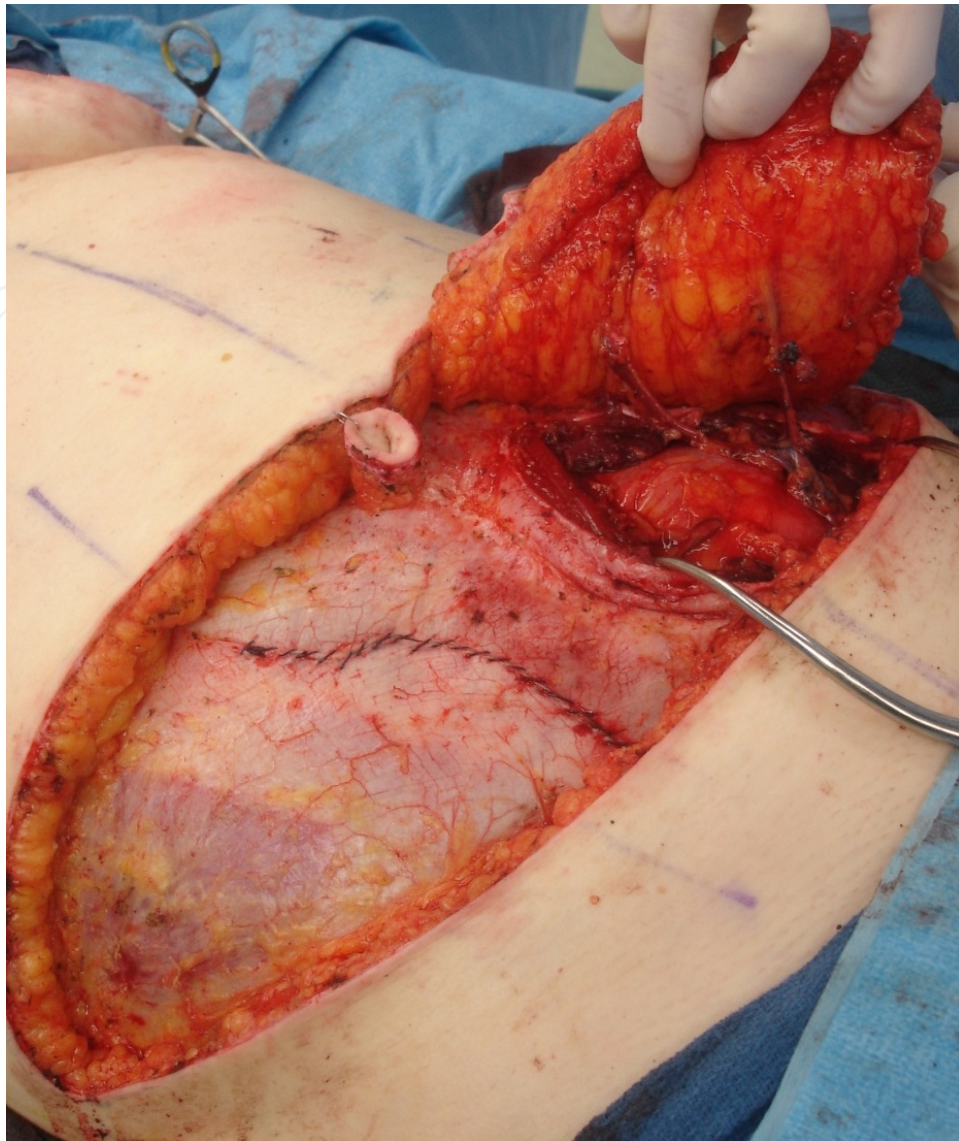


Figure 14. Two perforator branch points can be helpful for flow if they are in the same dissection plane. Retraction in the plane can help to visualize the pedicles.

A place where the radiological studies can come in helpful is in viewing the course of the vessels. This is viewed by scrolling through the cuts of the vessel in question. This has helped on more than one occasion where a vessel appears to be a main branch off the pedicle, but is actually travelling through the muscle and is hidden. If a muscle sparing TRAM technique was to be employed in this situation, then the vessels would be transected and the flap would not be viable. (Figure 15)

If the perforator is traveling through an inscription point, it can be a short course to the pedicle, but it is often difficult to dissect because of the fibrous nature of the structural attachments in the area. It is best to go slowly in this dissection, being aware that the tethering effect seen at this area can cause the vessels to appear smaller than they are, making it less clear as to where they are travelling. Sometimes it is only after they are released that their full size is appreciated.

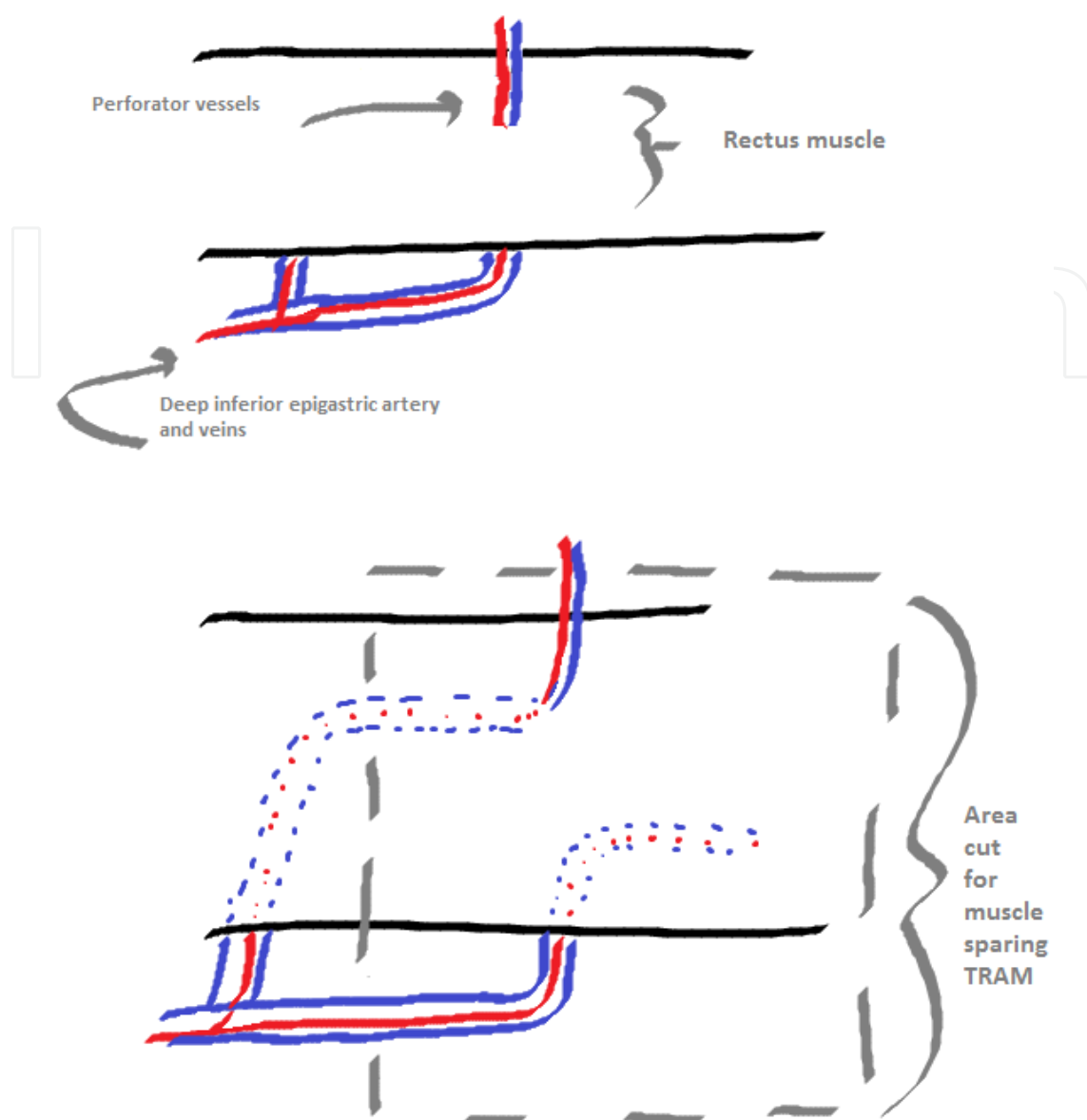


Figure 15. Diagram image of external physical perforator and pedicle branch image which can be misleading. Treating this as a muscle sparing opportunity can lead to a total transection of the actual communication between the perforator and pedicle. Prior imaging can be useful if it shows the intramuscular course clearly, as well as fully dissecting the vessels out as the ultimate test.

Loupes are often used in the dissection of the vessels. The most common I have seen is 2.5x for the dissection of the abdominal vessels, and 6x for the IMA dissections. Other surgeons do not use loupes at all. The benefit to using loupe magnification is in seeing small branches or tethering material that can rip or damage the vessel inadvertently during the dissection or can help to show a path that the vessel is taking. A different source of damage can occur, though, in the inadvertent neglect of other factors in dissection by the inability to see them through the loupes. An example of this would be tethering or pulling and damaging the perforator because that portion of it is not in the loupe dissection window. This is when not using the loupes or

looking around them is better. If this is difficult to do, then a good assistant who can watch the dissection plane can alert you to impending mistakes or injury. Another way to proceed is to routinely check over the edge of the loupes before making another adjustment in the placement of the vessel.

Once the initial dissection of the perforator is done, then dissection of the pedicle is done in a similar fashion. Branches are secured and divided. Nerves are dissected free from the pedicle in order to preserve them. One of the ways to do this is to gently dissect these off with hemostats, clipping small branching vessels. If they are tightly associated, gently hydrodissect them off the vessels using heparinized lactated Ringers solution on a 22 gauge angiocatheter with a 10 cc syringe. This can show you the actual branches if there are any, versus fibrous attachments which can be transected with scissors.

After the attachments have been released, then an inspection of the vessels to assess the caliber and length of the pedicle is made. If they seem to match the recipient vessels and it seems like there is enough room to maneuver then your dissection is done. Separating the vessels from each other at the area that will be divided can be useful at this point to save time when at the recipient site, create more length. If you are at a main branching point for the pedicle, and allow you to see branch points that are evident when the vessels are inflated, but may not be obvious when empty. You can decide to procure extra length by dividing the branches and dissect further down the pedicle, or you can preserve the remaining vessels' direct blood supply route to the muscle.

Branch points can be useful if you preserve them sufficiently. There is no need to randomly take long branches of vessels to incorporate with the pedicle. A risk of doing so is to have a large blind end of the vessel which can clot and then propagate that clot towards the main flow area, and then occlude it. However, if you are planning on doing a large flap, a branch point, particularly the dividing branch of the main pedicle trunks can be an anastomotic recipient for the pedicle vessels of the other half of the abdomen.

Once the vessels have been fully freed from the surrounding tissues, then the Doppler signals on the skin can be confirmed and marked with marking pen (which can often fade or smear away) or a marking suture such as a 5-0 prolene. This will help to find the vessels signals once the flap is inset. If the flap appears to be perfused well (i.e. good skin tone, no sign of congestion, positive capillary refill, and bleeding around the edges), but there is no skin Doppler signal, then an implantable Doppler may be useful post anastomosis to help monitor the flap.

The pedicle can be marked with methylene blue or a marking pen for aid in orientation. One side is marked while the other is left plain. This can help to keep the vessel from being twisted while it is deflated and harder to see. Another way to do this is to clip the branches on one side of the pedicle and tie the branches on the other, leaving a physical reminder of the sides. Usually a marker dipped in methylene blue is sufficient, quick to apply and long lasting.

There are different ways to approach dividing the vessels. One way is to clip and divide the artery first, allowing the veins to drain and then clip and divide them. Another is to terminally clip the smaller of the two veins, and then clip the artery and main vein, leaving those two vessel ends open. A third is to clip across all three at once with a large vascular clip and divide

them, leaving all edges free to drain. At this time, it is helpful to keep track of the ischemic time by having the time recorded when the vessel flow was stopped.

At this point, the flap can be gently removed, watching that the pedicle and perforators are not caught on a nerve or any unnoticed attachment. The flap can be weighed and then placed onto the recipient site. The weight can be useful, especially in cases of bilateral reconstructions, or immediate reconstructions when a size match is anticipated. Once at the recipient site the flap is secured with sutures, or staples or a combination of the like to allow full attention to be paid to the anastomosis and prevent avulsion of the vessels with a shift in the flap placement.

4. SIEA

There are similar dissection points for the SIEA with a couple of differences. The dissection of the flap can be shifted inferiorly a couple of centimeters if this makes a difference in final closure. Shifting the flap too inferiorly can result in a shorter pedicle length. The initial dissection can be done similarly to that of a DIEP flap. Once the inferior portion of the dissection is performed, then the vessels are carefully dissected to find the arterial and venous systems.

The venous systems are located medially and laterally usually. The medial vein can be fairly close to the midline or up to a third of the length of the flap away. The arterial system can be located close to the medial vein or much further laterally. Once the vessels are located, a similar method of isolating the vessels with vessel loops can be performed. The main goal in the assessment of the vessels at this point is the arterial flow. A couple of points can be made here. The artery should be clearly visible at this point. This can be deceiving because it will usually be surrounded by two veins. The veins can vary from being small and unusable on either side of the artery, to being large and mimicking the artery itself with a small hair of an artery causing a signal and maybe a small pulsation in one of them. A nice rule of thumb is to have the artery be at least 1 mm in diameter at the initial dissection point, visibly pulsatile and/or palpably pulsatile. If the artery is tethered by tissue or branch attachments it may not initially pulsate visibly until these are removed. Also, it may be difficult to distinguish the surgeon's own digital pulse from the pulsations of the patient's vessel.

As dissection proceeds further, the artery should increase in apparent size and strength. The veins are often quite large and sometimes will join with each other if you have the patience to continue to dissect toward each other. This can be useful for drainage purposes especially if a lateral vein is the dominant drainage vein for half of the flap and the medial for the other half. As the dissection gets closer to the fascia, there is often increased branching of the artery. This can be confusing as the branches can look equally as dominant and the directions can look similarly logical as far as the next dissection area. In this instance proceed with caution and try a different angle to view the posterior side of the dissection. Another trial is to gently clamp the branch that appears to be the main trunk and see if the pulsations decrease markedly and/or the signals change. If not, then this branch can be divided and dissection continues usually with a branch underneath.

Once at the fascial level, the artery and veins may be of sufficient length and size. Dissection to remove the rest of the connecting tissues and branches is performed. Keeping a vessel loop around the lowest portion of the dissected vessels can help keep you out of trouble at this point. If the vessels do not appear to be large enough (and the artery can often be a 1mm or 1.5 mm at the largest), then the fascia can be split (to be repaired after), and the vessels can be carefully followed further down. Usually, there is not a large gain in distance at this point but there may be a small gain in size. Branch points often will abound in this area which may be useful but may also get in the way because of their proximity to the future anastomotic site.

Prior to the final dissection to length of the SIEA vessels, dissection of the flap off of the fascia is performed to free it up and to do a final assessment of the choice of flap. If there is a possible perforator choice that seems better, then gentle clamping of each of the vessel sets with visualizing of the flap and Doppler monitoring can help determine which of the two has an advantage.

The arterial recipient vessel for the SIEA flap may need to be much smaller than a DIEP vessel recipient. These recipient vessels can be selected ahead of time by using perforators, branch points, axillary vessels or the IMA more caudad on the ribcage. This will help with a final size match and flow.

5. Lymphatic flap

If performing a combined flap of lymph nodes and SIEA or DIEP flap breast reconstruction, preoperative planning for which abdominal side to transfer should be made. The lymphatic flap design is created in order to keep the lymphatics harvested above the inguinal ligament. The most medial lymph nodes are left in place to help prevent donor site lymphedema.

The dissection is performed sharply at the inferior edge of the breast reconstruction flap. Vessels are clipped if not being used, or dissected out to length if going to be the main donor vessels. The lymphatics can be located underneath the superficial inferior epigastric vessels. Once the vessels have been found, then dissection for the lymph nodes are performed below the Scarpa's fascial layer and down to the abdominal fascia. Once the dissection has been performed to the inferior aspect of the flap, then the rest of the flap can be raised by dissecting from the lateral portion of the flap to the inferiormedial portion of it until the flap is free.

If the flap will be resting for a while before harvesting, be cautious of stuffing the lymphatics back into the pocket and having the vessels kink as you can get hidden vascular congestion of the flap until you extract it again. Careful handling of the lymph nodes is important to keep them functional. Avoiding electrocautery appears to help the lymphatic channels to reconnect with the recipient lymphatics by preventing the sealing of the edges of them.

5.1. Postoperative plan

The postoperative management of the free flap patient can be as important as the surgery itself in the final success of the flap. There are several acceptable ways to manage the flaps. Deciding

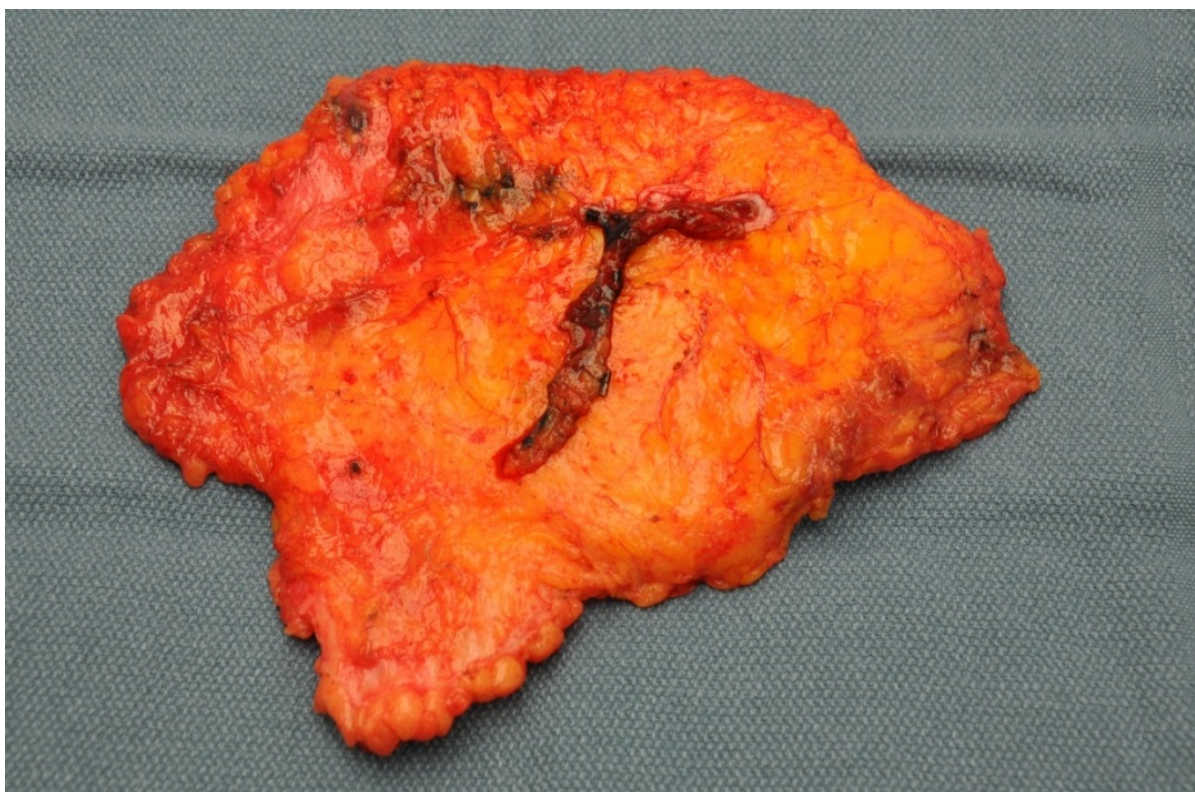


Figure 16. Subcutaneous view of DIEP flap with lymphatic composite flap.

on a plan, and being flexible with it when necessary will lead to better outcomes. As part of the plan, the support staff who help to monitor the flap are just as vital as the protocol, if not more so, as they are who will alert you to the changes that can be fixed by going to the operating room.

Initially the patient will be in the post anesthesia care unit. It is important that the nurses there know what you are looking for in flap evaluation. Clinical evaluation points should be addressed every hour immediately postoperatively. Some evaluation parameters can include the patient's vital signs, the temperature of the flap, Doppler signals on the surface of the flap, internal Doppler signals, firmness of the flap and capillary refill. Once the parameters are established, having a flow sheet for the nurses to record their findings can illustrate trends of the flap. If trends are changing, then the surgeon should be alerted as to the next course of action.

Once the patient has been recovered, the patient is moved to the floor. This can be an ICU setting or a regular floor. If in the intensive care unit, the flaps can be monitored every hour. On the floor, every hour checks may be more difficult to do over a prolonged period of time. In the ICU, the patients are less likely to be able to be ambulatory. If other patients in the unit are unstable, then it is possible that the flap patient will get less monitoring for a period of time. On the floor, the patient is more likely to be able to ambulate more quickly. Also, patients are usually more comfortable in a less intensive setting.

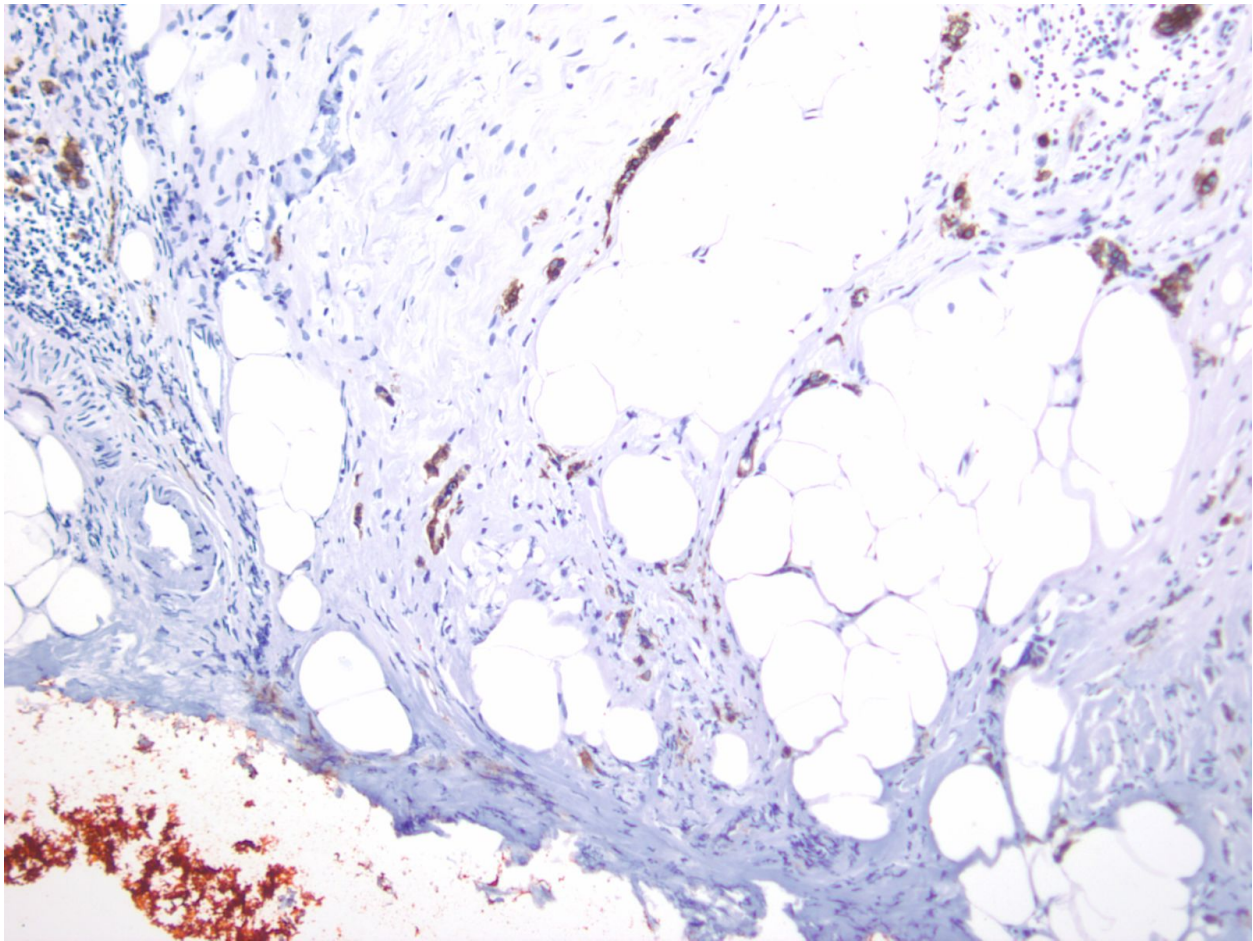


Figure 17. Microscopic image of cauterized tissue at the inferior portion of the slide, as compared to the normal cell structures of the more superiorly based cells. It illustrates how in order to create new connections between cells, keeping cautery damage away from these surfaces can maximize the cells' chances for this.

The simplest postoperative plan that I have seen and which has been just as effective as more elaborate plans is to have the patient evaluated every hour for 4 hours in recovery, and then they go to a regular floor with q 2 hours for the remaining 8 hours of the first 12 hours postoperatively, and then q 4 hours evaluations until the end of their stay. There is no warm room or overheating of the patient. The patient is heplocked on postoperative day 1. They are given a regular diet, with no additional anticoagulants. The labs are not checked, and the patient is expected to ambulate and void on their own. The patient is monitored for two more days and as long as they are doing well, they are discharged home, possibly with or without drains. That being said, it depends on the comfort of the surgeon, and the reliability of the staff that they work with, which may dictate what postoperative protocol they fill comfortable with.

Postoperative monitoring variables which are simple are often the best. Temperature monitoring using temperature strips can indicate changes in flow of the flap. Softness of the flap can indicate changes in congestion, capillary refill indicates congestion vs arterial inflow loss. Skin Doppler signals can help find a diminishing signal. Several methods to evaluate flaps are utilized, some more technologically advanced than others. [21]

Whatever method is chosen, communication with the staff is key. Early detection of problems with early intervention will have better postoperative salvage. Communication with nursing staff has evolved through time, now including phone technologies. [20]

5.2. Troubleshooting the flap

Occasionally, there will be a change in the flap that requires some intervention, operative or nonoperative. This possibility should be discussed with the patient preoperatively in order to give them a sense of what they will be asked to do. If they have an understanding about this, then they are much more likely to stay calm and follow directions.

The monitoring techniques that are employed will give you information on what course of action to follow next. Often, intraoperative and immediate postoperative incidents can help you start your plan. If the patient had a rough wake up in the operating room, is vomiting postoperatively, or has sustained high blood pressure in recovery, then a change in signal may be because a hematoma is accumulating from a disruption of a vessels and the flap will need to be opened to reverse a failure due to the compressive nature of the process. Oftentimes, the signs will be a change in flap temperature (cooler), firmness (firmer), quicker capillary refill (congestion), or change in color (pink to purple indicating congestion). If the arterial signal becomes lessened or is lost, then the anastomosis may be closed by a clot. Initial changes can be addressed by a release of pressure at the bedside, and if they are resolved, a small drain can be placed to help ensure further drainage if necessary and to monitor the flow, or an operative exploration can be performed to stop any further bleeding if it seems to be an active process.

If the patient is wild in recovery, and thrashes quite a bit, or just changes position often, with a pedicle that is either quite long or quite short, then a change in the flap can indicate that the vessels have become kinked or twisted due to movement, or that the flap itself has shifted position, resulting in tension of a vessel which may be resolved with repositioning and support of the flap.

Generally speaking, most issues with the flap will be from venous congestion. This could be because the flap is dependent on a superficial vein for additional drainage, or the vein is easily kinked before it has healed into place. These issues can be treated with direct and indirect interventions such as positioning, temperature therapy, leeches, direct venous drainage, and operative anastomosis. (Figure 18.)

It can sometimes be difficult to know when it is a time to intervene with a flap and when it is time to let the flap continue to adjust.

If in the operating room the flap is normal skin colored/pale, moderate temp, possibly cool, possibly warm, if the capillary refill is absent, or 3 seconds or more, flap is soft, skin tissue may be firm or soft, and Doppler sounds are fine on the flap skin, then everything should be fine. If the Doppler signal is staying strong or stronger, hearing sounds on more areas than just the initial areas, capillary refill is showing up and still 3 seconds or more, the temperature is getting warmer or feels the same as the rest of the skin, then the flap is still doing well

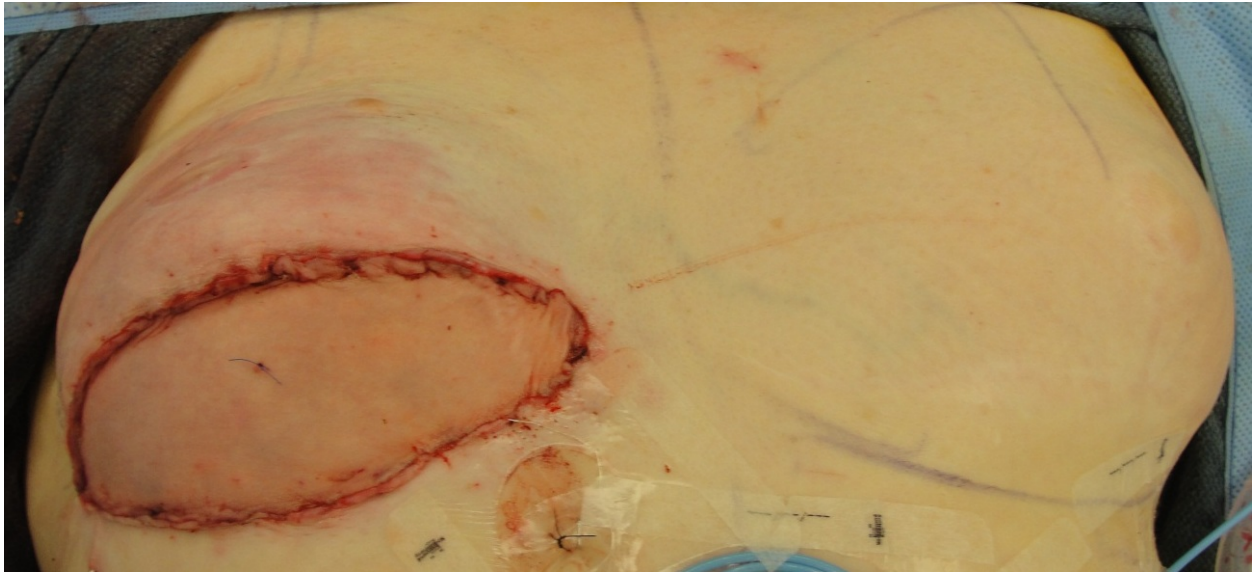


Figure 18. An illustration of venous congestion in a flap, the most common cause of flap failure. Congestion can manifest in varying colors of pink to purple hues. Distinguishing between hyperemia and congestion can be done by the speed of capillary refill. Capillary times of 3 seconds or greater usually indicates adequate drainage even in the presence of hyperemic coloration. Capillary refill that is 2 seconds or less, or is becoming quicker even in the presence of very mild coloration or almost normal skin tone can indicate that a precipitous congestion process will follow.

If the capillary refill was quicker and now getting slower, skin color is pink but capillary refill is slow (just around wake up or initial hook up), observe for a little while, while closing or in the or for 30 minutes or so. If it is not improving but the capillary refill is still slow, then it is generally ok to wake and go to recovery especially if the Doppler sounds are strong or improving, temperature is improving, and capillary refill time is getting longer. Then in recovery, the initial color should start to improve. This color change can happen to a single flap, to both flaps of a bilateral reconstruction, or to just one of the two flaps in a bilateral reconstruction, even if the vessels sizes seem similar. One of the things to check to help determine the patient's skin reactivity is to look at other areas of the body. Check the patient's native skin on the upper chest area, (neckline flushing), and check for refill, oftentimes is quick as well, or look at the incision lines to see if handling the tissues of the abdomen is causing a similar reaction to gauge if this is unique to the flap and requires a re-exploration or if you can wait on it.

If the capillary refill is quick and seems to be getting quicker, (1-2 seconds), open the incisions and observe, if it resolves then too much pressure with closure is possible. Repositioning the flap can be helpful, or reducing the size of the flap, loosely closing the skin for a delayed closure, or doing further dissection of the pocket to allow for more room may be necessary. If after opening the incision there is still a problem, take the flap out of the inset and observe the flow and flap color changes/Doppler signals with the anastomosis intact. If the flow improves then it is a positioning issue.

If the superficial veins are dilated, and the tissue looks congested (purple), then open the superficial vein and let it drain, if the anastomotic vein looks functional. Make sure to check

the anastomosis and position of vein to make sure it is flowing and not twisted. Undo the vein if that doesn't work, let the native vein drain a little to return it to its regular positioning if it was twisted. You can open the costal cartilage above the space if the vein path is not easily seen to make sure there is no tethering or hidden twisting. If additional drainage is necessary, you can anastomose the accessory vein of the comitants, if there is a second IMV available or a branch of the first, or anastomose the second vein into a branch of the first.

The superficial venous system can be used to drain into a branch of the main pedicle. You can anastomose it to the IMV, anastomose it to another branch or vein found in the field, or drain it with a catheter. If the superficial vein is long enough to reach the original anastomosis or a branch then it is easy to anastomose to aid in drainage. If it won't reach around the edge of the flap, then you can dissect the vein back into the flap for a distance and then split the flap underneath it, i.e the fat and scarpa's fascia, to allow the vessel to reach the IMV or the original pedicle. Make sure you open scarpa's fascia to keep it from tethering at this point. More easily done with couplers, this can be attached to a branch point along the way in case you need it.

Arterial insufficiency can present as loss of signal, paleness of the flap and loss of tone. The treatment for this is returning to the operating room to inspect and repair the vessel, possibly using thrombolytics as well. If there is a loss of arterial signal, change the Doppler batteries. Make sure the blood pressure is normotensive. Hydrate the patient with an IV bolus if necessary or if blood loss is suspected and/or CBC confirms, a blood transfusion, to return to a normotensive state. Confirm that the patient did not receive vasoconstricting inotropes which may be causing spasm of the vessel. We also restrict the use of certain migraine medications (such as Imitrex) for possible similar effects. If this is not the case, explore quickly. An arterial salvage intervention is usually successful if caught early enough.

If you need to return to the OR to explore the flap, communicate with the team (equipment is readily available) and the anesthesia staff (avoiding pressors on intubation, especially with a bilateral flap in order to avoid damage to the other side). Once prepped and the incisions are opened, then gently secure the flap with either staples or sutures, so that if while exploring the flap there is less help in the OR, or in trying to evaluate the vessels, there is not an inadvertent avulsion injury performed. If it is strictly positional and everything is flowing well but the vein appears to be open but clotted, then TPA can be used. This can be done in several ways, including disconnecting the arterial side of the flap and injecting arterially, injecting the accessory vein, or disconnecting the anastomosed vein and flushing through that. Mainly, it is important that after the TPA is used, that the vessels be flushed with heparinized saline to help move the clotting process out of the main system and hopefully the TPA into the microcirculation where more damage can occur if this is not properly flushed. It is tempting to try to rush through this step, however, if there is an internal vessel blockage that you can release this way, your chances of success postoperatively will be higher.

Troubleshooting the flap is done in a systematic fashion. Determining when to operate and when to treat conservatively can take experience in judgment. If in doubt, an exploration will allow you to visualize the actual flow of the vessels and will allow you to see if there is a physical problem that can be repaired in order to have a successful flap.

Sometimes there is a nonoperative fix for a problem such as congestion, or sensitive positioning. In these cases, prolonged nonoperative interventions may be the only way to fix the issue. Some of these are prolonged bed rest for positional changes, cool or warm therapy for the flap, and/or leech therapy. If all the venous avenues are maximized that are possible, the vein is working and flap is draining but slowly, or unable to provide enough drainage to the whole flap or the area in question, then, ice the flap to slow the arterial flow down, and keep changing it to keep the flap cool. Patient positioning to help with drainage, by keeping the patient flat in bed may be needed. Trendelenberg positioning may be useful but difficult to maintain. Keeping the patient in bed for up to a week is hard to do but can be helpful. If the patient is in bed, make sure that pressure areas are protected to avoid decubitus ulcers, especially the posterior scalp.

Leeches are another way to address venous congestions. Medicinal leeches may be stored in the pharmacy or a unit floor may keep them in a refrigerator. Leeches are usually kept in two containers, the first inside the second and the second or first taped, as they are maneuverable creatures and love to escape. They are not supposed to be reused, but used as a one time application, and may not be released due to the biohazard of blood borne pathogens. They like a warmer environment, so if initially they don't want to feed, warm the flap first with a warm blanket or wash cloth. Then if they still won't, make a small prick in the skin with a needle to get them to attach to that area. Hold them with plastic pincers or plastic covered/rubber shod covered instruments. It is not always easy to tell which side is head first. If it really won't attach, then try another leech. If there is congestion and not enough arterial flow (i.e. congestion has progressed too far and the flap has or is shutting down) the leeches will not attach or will not stay long. Barriers and making sure that the flap is secure is key. Oftentimes, a flap will be opened first to relieve congestion. Make sure that the flap area is reclosed and/or sealed with tissue glue before applying leeches. They will want to crawl into a dark space. Make sure the patient is on antibiotics, and check a CBC. Do a pediatric stick as time goes on and check q6 at first to make sure they don't drop too far. When using leeches, keeping a Hgb of 10 is a good guide because there will be some shifting and this way it won't drop too far. If you let them drop, and they will, the flap will shut off due to low flow.

After leeches are finished, they will often want to "wander." This can be stressful for the patient and the staff. Make sure room cleaning is available often if they travel across the floor. Again, with surgery, and as surgeons, we are used to so many anomalies of the human condition that this can be seen as a minor issue. Sometimes patients and their families handle it extremely well, sometimes not at all. Sedation is helpful for the patient if their blood pressure tolerates it. Keeping the area clean helps the family. Frequent checks, at least q 1hour is helpful to corral rogue leeches. Social work support and counseling for the patient can be helpful. Usually the process is around 3-7 days in all. Other means to help are frequent washes and changing of the sheets, occlusive dressings as a barrier, and reiterating the temporal nature of the intervention as a helpful alternative to keep their flap for the rest of their lives. Scarring can be permanent from where the leeches latched. Smaller skin paddles are harder to get good drainage from.

Leech therapy, *Hirudo medicinalis*, has a longstanding presence in microsurgery. The gut flora of the leech, *Aeromonas hydrophila*, can cause infections in 2-20 of patients not treated prophylactically with antibiotics. Ciprofloxacin is the drug of choice for prophylaxis, but there can be resistance to this as well. Monitoring hemoglobin levels closely and replacing with blood products as needed is vital. Giving the patient psychological and social support during this period is sometimes a forgotten but vital part of the treatment. [22-29] (Figure 19.)



Figure 19. Medicinal leeches in storage ready for application.

Currently, I prefer to catheterize a vein if possible or ice the flap versus using leeches. And of the two, I like icing. It avoids the loss of blood, the patient can easily participate as it is a commonplace remedy, it can be continued at home and it is very effective. Catheterizing the flap can be done by inserting an angiocatheter into a vein that was preserved in the initial dissection (superficial inferior epigastric). The angiocatheter can be secured with a 3-0 silk tie to the vein. This is then connected to arterial line tubing which in turn can be secured to the skin with a suture or occlusive dressing to keep it from avulsing the catheter from the flap. This can then be accessed by gently drawing off blood from the catheter to help prevent congestion. This can be done if there is no other alternative. A difficulty I have found is if the line coagulates. Flushing with heparinized saline post draw is helpful. If it becomes too blocked TPA can be used as well judiciously. Also, connecting the catheter to an external ventricular drain (CSF monitor) to calibrate a constant drip rate can aid in a measured release of pressure as well as prevention of clotting. Hemoglobin levels must be checked and addressed with this intervention. (Figure 21.)

Using ice to cool the flap and treat congestion can be done in the operating room, using sterile ice in sterile bags, or on the floor using ice packs or cold gel packs. Have the nursing staff

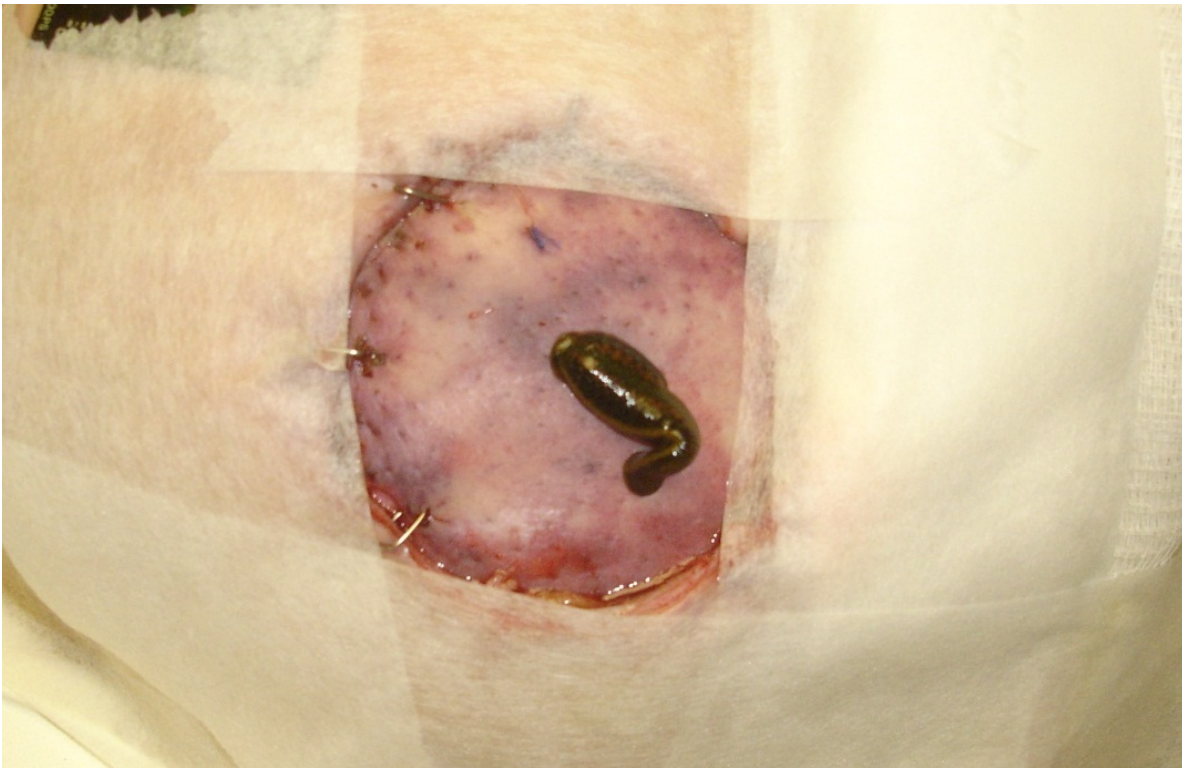


Figure 20. Application of leech for congestion therapy. In this instance, surgical paper tape was applied to help prevent leech attachment to mastectomy flap skin.

continuously change them to keep things cool. Continue to use the ice until the capillary refill time has improved, then you can increase the time interval between the ice applications gradually, using the capillary refill as a gauge. The skin color will usually be hyperemic and so you cannot always rely on a pink color of the flap as being a sign of congestion. Capillary refill is the most accurate measurement of this. If the patient is able to monitor the refill times accurately and is reliable, then you can discharge the patient home using ice packs as well.

If there is firmness with upright positioning, put the patient back down, give it a day or 12 hours and try again slowly. If the flap is cool after the surgery has finished, then warm the flap with a blanket in recovery. If it is functioning, it should be able to maintain the temperature as long as it is covered and not exposed for extended periods of time. I don't like forced air blankets (Bair huggers) as they falsely elevate the temperature but if a warm blanket is placed and then the flap maintains that temperature, then most likely all is well. Sometimes the temperature will drop if the flap is exposed to examine it, if so then continue to keep it covered quickly after examination. If it continues to improve then it is doing well, if it continues to fall, you may have arterial insufficiency or impending congestion.

If one flap is congested slightly and the other is cool with a quieter arterial signal, then warm one and cool the other. Even though it may be a bilateral reconstruction, treat each flap individually. If a flap looks mottled at the edges then it is likely will lose that skin especially if it gets worse. However, you can also cool it down to see if those areas can be preserved and continue to observe. If the flap has a black eschar, go in and debride to healthy tissue, and

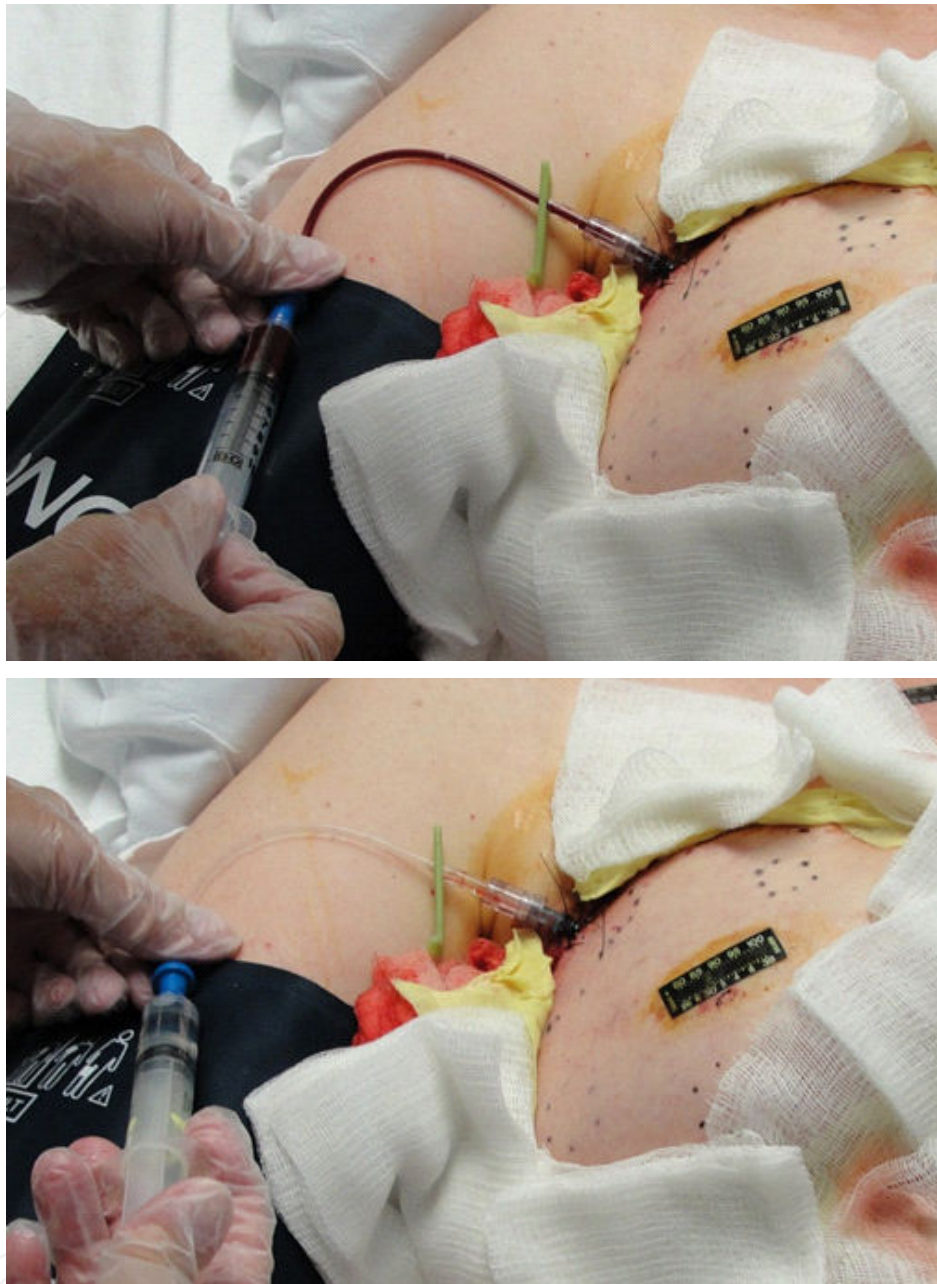


Figure 21. Catheterization of the superficial inferior epigastric vein. In this instance, catheterization of the superficial vein with an 18 gauge angiocatheter had been hooked to sterile arterial line. This was secured with sutures to the skin. A 10 cc syringe was used to gently draw blood back every half an hour until the flap coloration improved, or at longer intervals depending on the signs of congestion. After each draw, heparinized saline was flushed into the tubing to help keep the catheter open. This time interval for the process was extended over each 12 hour period. After 2 days, the drainage was discontinued. CBC's were used to assess the patient's possible need for transfusion.

cover with skin if possible. Integra may or may not be helpful if there is no skin coverage, and no granulation tissue.

Flexibility in times of trouble to shift therapy, or continue to change modalities as the flap progresses is key. Usually a flap will declare itself as salvaged within the first week or two

postoperatively. During these times, discussions with the patient can help to keep them positive and willing to participate in an intervention that may only need a couple of extra days to work. Persistence and attentiveness to detail can salvage many flaps.

6. Solo surgeon

Performing flap surgery as a solo practitioner has its own challenges. To do so as part of your career will take dedication and some extra work at first. It can be successfully done and can be a rewarding part of your practice. There are several arrangements that need to be made initially and then during the growth phase of the process to ensure success. This is both on a professional level as a practitioner and with the hospital, including support from administration in time and materials, as well as support staff.

If unfamiliar with perforator flaps, and/or free flaps in general, it is highly recommended that you get some training in these procedures first before branching out. Even if familiar with free TRAMS, there can be a significant amount of difference with a DIEP that can make this less likely to succeed. If at all possible, spend some time with a surgeon who performs these to get a better idea of how they work. If these have not been a part of residency training at all, and you are just starting out, then a fellowship is recommended. Even performing as a resident and making the leap to doing them in practice can have unexpected stressors that may impact the success of the operation.

If working at a community hospital, it is likely that they may not be set up for flap reconstruction surgeries. If this is the case, you will want to discuss the matter with the operating room director and or surgical administrator to ensure their support with this venture. You will want to have at least a couple microsurgery sets of equipment and a team of people who will be initially assigned for training and working with you in the operating room, postoperatively in recovery and on the floor. You may want to discuss billing with the hospital, as these can initially be very costly for the hospital if the times are long, but can work out much better as the operative times are condensed.

6.1. OR setup

I would recommend at least two set of microsurgery instruments and possibly three. One is the backup for the first in case anything is damaged. A note here, sometimes in cleaning, if the sterile processing is unfamiliar with microinstrumentation, the instruments can be ruined by rough or improper handling. Make sure the team is inserviced on the handling of these instruments. Often, the company will send someone to help with this step. I will usually use a partial set for the harvest dissection and a full set for the anastomosis. A second set is there for backup as well as for a bring back cart. The main thing here is to have a set that you are comfortable working with, that will handle the tissues appropriately and that is in enough supply so that if something is damaged, or being processed, there is another set to use in case of emergency, or take back.

6.2. Instrumentation

When ordering instruments there are some practical items to consider. Medium and long length instruments are useful. Sometimes the recipient vessels are located in a deep pocket and you will need the length to get there. If it is not possible to get both sets, I opt for the long one, as I can reduce the length of grip on the long ones if need be, and still have access for the deeper vessels.

It is very useful to have fine tips for small vessels. I consider a dilator to be indispensable for this, as well as for pulling vessels through tight spots (i.e. small couplers). They are not textured that I have found and this is a limitation in the grip. Oftentimes I am able to position something quickly with these, but then immediately move to a textured forceps to actually maneuver the tissue in the place I would like it to be.

Textured instruments are a must, both for needle drivers and for pickups. These help when there is loose tissue nearby that is slipping and you would like to trim, or if the vessel itself is slipping, this is helpful to get a good bite on it. Needle drivers can slip and roll the needle especially if the needle is rounded throughout its construction. Again, anything that can help to keep the position, and allow force to be applied without losing the angle of the needle or positioning will continue to speed the process up.

A fine tipped, blunt-tipped instrument is very helpful in dissection. A scissors that is sharp and one that is blunt tipped is helpful in these maneuvers. The blunt edges allow for dissection through the muscle and loose tissue without inadvertently cutting branches or the vessels of interest. Sharper scissors can be nice for trimming vessel edges prior to anastomosis.

A coupler anastomosis system is helpful while operating as a solo surgeon. Their use is simple enough to have limited to no assistance from another person, the handling can be done one handed while stabilizing the other hand, and the closure helps to prevent leaking of the anastomosis thereby preventing the solo maneuvering of the vessel to get a posterior wall bleed. Also, you can observe the lumen throughout the process so that you know that it is open. The coupler instrumentation is something I recommend having two or three of in case one has failed. Instruments that can be useful with this process are dilator, textured forceps, j-hook and curved forceps. A wide range of couplers is useful, but usually a range from 1.5 mm to 3 mm will get you through most of what you need. With couplers, less assistance is needed for both the artery and vein. Suturing is still useful but placement, tying, and cutting without assistance can result in a lot of steps that add time to the case.

Retractors- Anything that will help minimize variability in positioning, or possibly supporting staff expertise is useful for success. Self-retaining retractors such as gelpies, or wheatlaners (I prefer blunt), are useful in the dissection and positioning of tissues. Staples can help as well, when a flap is swaddled in a lap sponge or on its own. The most useful retractors I have found are a hook with a silastic tubing or silicone tubing attached to the end. They can be sharp or dull tipped. I prefer the dull. They are called several names, including lone stars, fish hooks or urinary retractors. They hook on to the tissue edge, can be pulled back and secured with a hemostat. These can be used during any part of the procedure and are easily repositioned. (Figure 22.)



Figure 22. A tray of useful items for retraction for the solo surgeon. These include self-retaining gelpi retractors, lone star elastic retractors, army navy retractor, as well as surgical staplers and clamps.

Knowing the instruments-It is important to have the staff learn which are textured which are not, how to load a coupler, how to handle instruments, whether you want them to load suture or not, etc. how to work the microscope, positioning, prep work, tucking the arms, etc. crucial and noncrucial times of the case. Good communication in these areas is the best way to keep your cases running smoothly and to decrease frustration of the surgeon and of the support staff.

Assistance- if you are able to, utilize a first assistant or an RNFA, PA or resident. This type of help can be useful for items, such as retracting- when is too much, how to keep you out of trouble, how to handle the tension on the perforators, irrigating, getting a global view; closing-closing the abdominal wall, putting in drains, closing the abdomen itself, closing the skin on the flaps, depending on skill level and future training, de-epithelializing the flap, finding the superficial veins, dissecting the initial superior, and lateral borders of the flap, raising the chest skin flaps, (fellows only for me-dissecting out IMA/axillary vessels). If this option is possible, then you may find a reliable assistant to be invaluable in these cases to expedite the process.

6.3. Anesthesia

The importance of working with anesthesia cannot be overstated. A well informed anesthesia team is worth so much in this case. Having anesthesia on board, with the goals clearly stated

and the parameters understood is paramount to success. “The intraanesthetic basic goal is to maintain an optimal blood flow for the vascularized free flap by: increasing the circulatory blood flow, maintaining a normal body temperature to avoid peripheral vasoconstriction, reducing vasoconstriction resulted from pain, anxiety, hyperventilation, or some drugs, treating hypotension caused by extensive sympathetic block and low cardiac output.” [1] Communication with anesthesia can help in planning for the case at hand and for unexpected issues. [2] A postoperative extubation that is deep, preventing the bucking phenomenon can help maintain appropriate flow patterns for the flap and the new anastomosis. Finishing a case and then having the patient buck and blow a branch, or having pressors given throughout the case, can either ruin the flap or cause you to reexplore. As a solo surgeon, additional time for preventable trouble shooting can be less and less productive as you may become fatigued. Without a partner to help carry the additional burden, it is important to keep all aspects of the case running as smoothly as possible.

7. Floor and postoperative care

Training the nurses to follow up flaps can take a large investment of your time. Presentations are helpful especially when illustrated. Your physical presence during the monitoring of the cases is extremely useful. Initially you may find that staying overnight at the hospital for the first 25 or 50 cases is useful until the teams understand what you are looking for. After a core team is trained, they can help to train others. Making yourself available 24 hours a day for phone calls, or with direct contact is extremely useful, especially in instances where there is a question about the viability of the flap.

8. Personal OR time

In the operating room if you will be practicing by yourself with or without first assistants who are not physicians, you will need a plan to approach the flaps. If there will be an assistant who can help retract, etc, and you are able to know who they are, then go through the procedure with them a few days in advance in order for them to think of questions and rehearse the plan before the actual procedure. If you are by yourself entirely, then it is good to come up with a timing plan. By yourself, plan to take a 10-15 minute break every 2 hours except at the time of the anastomosis. This allows for a small intake of nutrition and a chance to let your mind relax. Microsurgery is a surgery of finesse, and as you get worn out, it can turn a simple dissection into a nightmare by a small judgment error or a rougher handling of the tissue. This in turn can lead to extra hours in the case, to first fix the issue that was made, and then continue with the case. As a resident, I have witnessed a competent surgeon destroy the vessels at the final hour of anastomosis because he was mentally fried, and so the hours of prior dissection and careful handling were lost in a matter of minutes. Again, this can seem like an odd concept, but if you are going to be working alone, you have no one else to help you so you need to make sure that you are as sharp and relaxed as you can be. If you do have help, such as an RNFA or

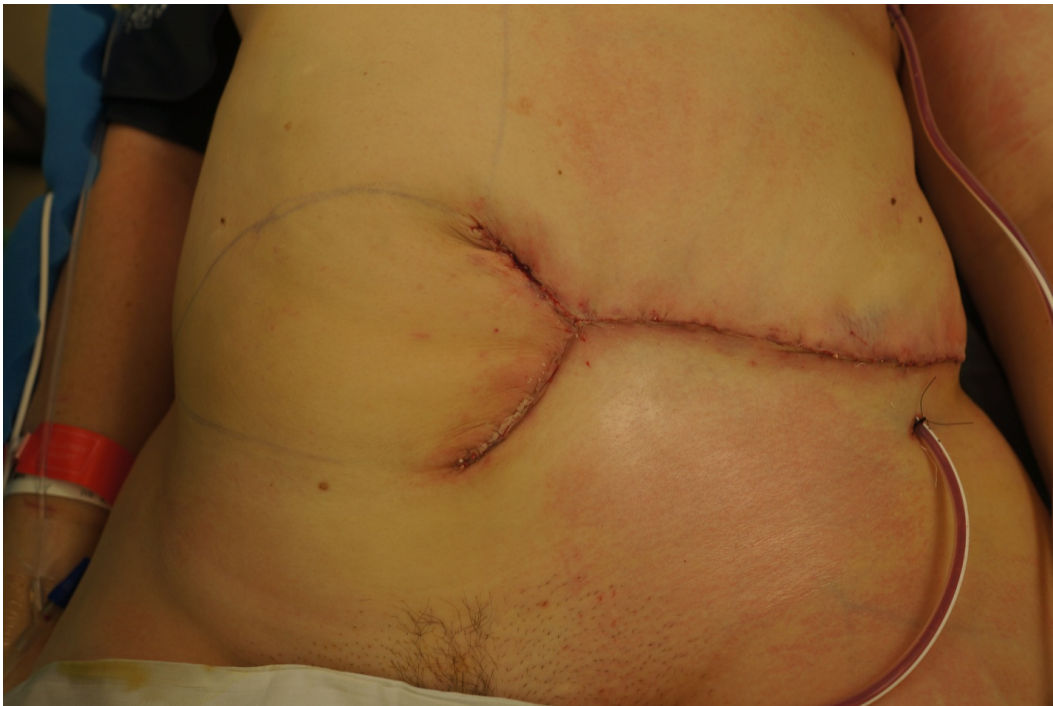


Figure 23. Use of hemiabdominal technique when needing to delay for a double flap reconstruction if operating solo, or for a backup if the vessels fail for a unilateral, or a source of fat for fat grafting in a thinner patient who does not need the full effect of a double pedicled flap.

PA, you might want to take a break every 4 hours, or at least just before the anastomosis in order to perform that portion in a rested fashion. Nothing is more frustrating than trying to save time by plunging ahead for the anastomosis and keep the ischemic time as limited as possible and then find that you are inadvertently taking twice or three times as long as you usually do because you are slightly fatigued and you hadn't realized it. Once the vessels are transected and the flap is ready to be anastomosed, then I consider it not a time to break at all until it is flowing, unless there seems to be a chain of events that is making the condition worse every time you try to repair it. In that instance, make sure that the bleeding is controlled, clamped or whatever, that the patient is stable, that you step out for a second to get a different perspective and again, something to eat or drink, and/or a chance to telephone another expert to ask for advice.

When it comes to reconstruction with the patient's tissue, a factor to keep in mind is that there is a limit to how many opportunities a person has to use their body as a source for reconstruction. Once it is successful, it lasts for a lifetime. A delay, a prolonged recovery, a second surgery, while not easy for the patient or the surgeon, is relatively miniscule in comparison to the rest of the lifetime, versus rushing a procedure for convenience or determination, and then losing that opportunity for the patient and having to come up with a second option which is likely not as optimal as the one you had selected. (Figure 23.)

When working alone, you want to modify the variables during the operation and postoperatively that may impede the success of your efforts. The procedure will be challenging enough

on its own. These techniques can be useful to help create a rhythm for you regardless of who you have to help. Once you find your own level of comfort, then you can plan accordingly and with success. If the case is really bad, stop, close and cover, talk to the family, and come back the next day. A lot of these things may seem to be a waste a time, but in the scheme of things, 12 hours or 24 hours later can make a difference between salvage and failure and the design of something completely different.

Although working alone, if it is possible, have a group of colleagues, or meet other physicians who perform these surgeries regularly and who may be available to you by telephone or other immediate communication. When you are in the middle of surgery and you are not sure why something is not working, it is useful to have the opinion of someone who has experience and who is not fatigued or emotionally involved in the case to help you come up with a different solution or to confirm your own judgment.

In conclusion, performing perforator flap reconstructions is a challenging and rewarding way to help those have had breast cancer. It can be done as a group or in a solo practice. There are many techniques to make the initial dissection successful, and then if running into difficulty, tricks to salvage the flap to result in a successful perforator flap reconstruction.

Author details

Rebecca Studinger MD, MS*

St. John-Providence Hospital, Ascension Health, Novi, MI, USA

References

- [1] Hagau N, Longrois D. Anesthesia for free vascularized tissue transfer. *Microsurgery*. 2009;29(2):161-7.
- [2] Scholz A, Pugh S, Fardy M, Shafik M, Hall JE. The effect of dobutamine on blood flow of free tissue transfer flaps during head and neck reconstructive surgery*. *Anaesthesia*. 2009 Oct;64(10):1089-93.
- [3] Richard K Spence, MD; Hemostatic Disorders, Nonplatelet. *Medscape reference* Updated: Jan 12, 2010
- [4] Chang LD, Buncke G, Slezak S, Buncke HJ. Cigarette smoking, plastic surgery, and microsurgery. *J Reconstr Microsurg*. 1996 Oct;12(7):467-74.
- [5] Reus WF 3rd, Colen LB, Straker DJ. Tobacco smoking and complications in elective microsurgery. *Plast Reconstr Surg*. 1992 Mar;89(3):490-4.

- [6] Chang DW, Reece GP, Wang B, Robb GL, Miller MJ, Evans GR, Langstein HN, Kroll SS. Effect of smoking on complications in patients undergoing free TRAM flap breast reconstruction. *Plast Reconstr Surg*. 2000 Jun;105(7):2374-80.
- [7] Vandersteen C, Dassonville O, Chamorey E, Poissonnet G, Nao EE, Pierre CS, Leysale A, Peyrade F, Falewee MN, Sudaka A, Haudebourg J, Demard F, Santini J, Bozec A. Impact of patient comorbidities on head and neck microvascular reconstruction. A report on 423 cases. *Eur Arch Otorhinolaryngol*. 2012 Oct 19. [Epub ahead of print]
- [8] Schleifer SJ, Keller SE, Camerino M, Thornton JC, Stein M. Suppression of lymphocyte stimulation following bereavement. *JAMA*. 1983 Jul 15;250(3):374-7.
- [9] Zisook S, Shuchter SR, Irwin M, Darko DF, Sledge P, Resovsky K. Bereavement, depression, and immune function. *Psychiatry Res*. 1994 Apr;52(1):1-10.
- [10] Biondi M, Picardi A. Clinical and biological aspects of bereavement and loss-induced depression: a reappraisal. *Psychother Psychosom*. 1996;65(5):229-45.
- [11] Metcalfe KA, Semple J, Quan ML, Vadaparampil ST, Holloway C, Brown M, Bower B, Sun P, Narod SA. Changes in psychosocial functioning 1 year after mastectomy alone, delayed breast reconstruction, or immediate breast reconstruction. *Ann Surg Oncol*. 2012 Jan;19(1):233-41. Epub 2011 Jun 15.
- [12] Garvey PB, Villa MT, Rozanski AT, Liu J, Robb GL, Beahm EK. The Advantages of Free Abdominal-Based Flaps over Implants for Breast Reconstruction in Obese Patients. *Plast Reconstr Surg*. 2012 Nov;130(5):991-1000.
- [13] Chang DW, Wang B, Robb GL, Reece GP, Miller MJ, Evans GR, Langstein HN, Kroll SS. Effect of obesity on flap and donor-site complications in free transverse rectus abdominis myocutaneous flap breast reconstruction. *Plast Reconstr Surg*. 2000 Apr;105(5):1640-8.
- [14] Greenspun D, Vasile J, Levine JL, Erhard H, Studinger R, Chernyak V, Newman T, Prince M, Allen RJ. Anatomic imaging of abdominal perforator flaps without ionizing radiation: seeing is believing with magnetic resonance imaging angiography. *J Reconstr Microsurg*. 2010 Jan;26(1):37-44. Epub 2009 May 18.
- [15] Pennington DG, Rome P, Kitchener P. Predicting results of DIEP flap reconstruction: The flap viability index. *J Plast Reconstr Aesthet Surg*. 2012 Nov;65(11):1490-5. doi: 10.1016/j.bjps.2012.05.015. Epub 2012 Jun 14.
- [16] Keys KA, Louie O, Said HK, Neligan PC, Mathes DW. Clinical utility of CT angiography in DIEP breast reconstruction. *J Plast Reconstr Aesthet Surg*. 2012 Oct 18. pii: S1748-6815(12)00564-5. doi: 10.1016/j.bjps.2012.09.025. [Epub ahead of print]
- [17] Smit JM, Klein S, Werker PM. An overview of methods for vascular mapping in the planning of free flaps. *J Plast Reconstr Aesthet Surg*. 2010 Sep;63(9):e674-82. Epub 2010 Jul 31.

- [18] Greenspun D, Vasile J, Levine JL, Erhard H, Studinger R, Chernyak V, Newman T, Prince M, Allen RJ. Anatomic imaging of abdominal perforator flaps without ionizing radiation: seeing is believing with magnetic resonance imaging angiography. *J Reconstr Microsurg*. 2010 Jan;26(1):37-44. Epub 2009 May 18.
- [19] Vasile JV, Newman TM, Prince MR, Rusch DG, Greenspun DT, Allen RJ, Levine JL. Contrast-enhanced magnetic resonance angiography. *Clin Plast Surg*. 2011 Apr;38(2):263-75.
- [20] Hee Hwang J, Mun GH. An evolution of communication in postoperative free flap monitoring: using a smartphone and mobile messenger application. *Plast Reconstr Surg*. 2012 Jul;130(1):125-9.
- [21] Luu Q, Farwell DG. Advances in free flap monitoring: have we gone too far? *Curr Opin Otolaryngol Head Neck Surg*. 2009 Aug;17(4):267-9.
- [22] Patel KM, Svestka M, Sinkin J, Ruff P 4th. Ciprofloxacin-resistant *Aeromonas hydrophila* infection following leech therapy: A case report and review of the literature. *J Plast Reconstr Aesthet Surg*. 2012 Oct 18. pii: S1748-6815(12)00578-5. [Epub ahead of print]
- [23] Hermansdorfer J, Lineaweaver W, Follansbee S, Valauri FA, Buncke HJ. Antibiotic sensitivities of *Aeromonas hydrophila* cultured from medicinal leeches. *Br J Plast Surg*. 1988 Nov;41(6):649-51.
- [24] Lineaweaver WC, Hill MK, Buncke GM, Follansbee S, Buncke HJ, Wong RK, Manders EK, Grotting JC, Anthony J, Mathes SJ. *Aeromonas hydrophila* infections following use of medicinal leeches in replantation and flap surgery. *Ann Plast Surg*. 1992 Sep;29(3):238-44.
- [25] Elyassi AR, Terres J, Rowshan HH. Medicinal leech therapy on head and neck patients: a review of literature and proposed protocol. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2012 Jul 20. [Epub ahead of print]
- [26] Whitaker IS, Josty IC, Hawkins S, Azzopardi E, Naderi N, Graf J, Damaris L, Lineaweaver WC, Kon M. Medicinal leeches and the microsurgeon: a four-year study, clinical series and risk benefit review. *Microsurgery*. 31(4):281-7, 2011 May.
- [27] Elyassi AR, Terres J, Rowshan HH. Medicinal leech therapy on head and neck patients: a review of literature and proposed protocol. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2012 Jul 20. [Epub ahead of print]
- [28] Porshinsky BS, Saha S, Grossman MD, Beery II P, Stawicki S. Clinical uses of the medicinal leech: A practical review. *J Postgrad Med* 2011;57:65-71.
- [29] Nguyen MQ, Crosby MA, Skoracki RJ, Hanasono MM. Outcomes of flap salvage with medicinal leech therapy. *Microsurgery*. 2012 Jul;32(5):351-7.

