Operative Efficiency in Deep Inferior Epigastric Perforator Flap Reconstruction

Key Concepts and Implementation

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KEYWORDS

• Deep inferior epigastric perforator flaps • Microvascular breast reconstruction • Lean • ERAS • Enhanced recovery • Operative efficiency

KEY POINTS

- Preoperative assessment should include imaging.
- Patient education is essential for timely discharge.
- Assess patients for risk factors: smoking, clotting disorders, prior surgeries, obesity, and comorbidities.
- Use LEAN techniques to enhance flow in the OR.
- Utilization of enhanced recovery pathways allow for increased operative efficiency, faster postoperative recovery, fewer complications, and reduced hospital stay.

INTRODUCTION

The deep inferior epigastric perforator flap (DIEP) was first introduced in breast reconstruction by Dr Robert Allen Sr. in the early 1990s and has since become one of the most popular approaches for breast reconstruction.[1] As with many new techniques, the first generation of DIEP flap surgeons had to develop, through trial and error, the most efficient and safe ways to carry out the procedure. Both operative time and hospital stay were frequently long and resource intensive. This could be attributed primarily to undeveloped process mapping, extended flap monitoring, dependence on opioids for pain control and delayed patient mobilization. However, as health care has become focused on value-based treatment and reducing the operative time, length of stay and complications after deep inferior flap reconstruction have become areas of focus in high-volume centers.[2] The goals of operative efficiency are to improve the quality and consistency of outcomes, decrease waste, prevent mistakes and complications, and optimize the surgical experience for both the patient and caregivers. In this article, we will examine key areas that contribute to operative efficiency and provide tips on how practitioners can integrate these protocols within their own practice and health systems.

PREOPERATIVE EFFICIENCY

Patient Risk Assessment

Proper patient selection helps to reduce complications, readmissions, and reoperations. Patients with breast cancer may have comorbidities that must be considered before surgery for appropriate preoperative planning. Studies analyzing preoperative risk factors for patients undergoing microvascular breast reconstruction show that the most important preoperative factors to consider are obesity, smoking, hypercoagulable conditions, prior radiation, hypertension, and chronic obstructive pulmonary disease.[3–6]

Smokers have been shown to have higher rates of partial flap loss. A study from Germany in 2020 noted that while total flap loss was not greater in 4577 free flaps (3926 women patients), there were a larger number of wound healing difficulties

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and greater numbers with partial flap loss in the smoking cohort than in the nonsmoking cohort. Partial flap loss was seen in 3.2% of the smoking group versus 0.9% in the nonsmoking cohort, $P < .001$. Wound-healing disturbances requiring revision surgery in both donor sites and recipient sites were also significantly higher in smokers than in their nonsmoker counterparts.[7] Staging strategies have been used to mitigate some of the wound-healing risks and allow time for smoking cessation before surgery. These include delay procedures at the donor site to improve blood supply, putting off definitive microsurgical reconstruction by placing tissue expanders, or delaying reconstruction altogether.

Obesity and high body mass index have also been noted to be an important preoperative risk factor for DIEP outcomes.[8] Larger mastectomy specimens may lead to increased risk of skin flap necrosis while larger flaps make harvesting technically more challenging. In addition, seroma risk and donor site wound healing issues are both increased.

Frailty and age have also been recent areas of focus regarding preoperative risk assessment in microvascular breast patient candidates. Although older patients tend to be more frail, age alone should not preclude patients from undergoing microvascular breast reconstruction.[9] However, those who are considered to have higher frailty scores, tend to be at greater risk for postoperative complications and should have the appropriate preoperative planning and clearances before going to the operating room.[10,11]

Hypercoagulability is another concern in patients undergoing DIEP flap reconstruction. Although routine genetic testing for hypercoagulable conditions is discouraged due to low yield, those with a personal or family history of thromboembolic events or acquired risk factors for hypercoagulability may benefit from the evaluation by a hematologist preoperatively to assess the need for testing.[12] One study reported that approximately 80% of patients with hypercoagulable conditions still had successful flap reconstructions, with vascular events or flap loss in the other 20% usually occurring in the delayed postoperative period.[13] Studies have also shown that intraoperative vascular problems may lead to increased risk of subsequent vascular complication and flap losses. However, these postoperative vascular events do not seem to be affected by choice of anticoagulation.[14]

Preoperative Imaging

Preoperative imaging provides information on perforator location and size, communication with the superficial venous system, intramuscular course, and branching patterns, in addition to assessing potential disruption of the pedicle from prior surgeries, thus making it an essential step in surgical planning and efficienct decision making in the operating room. The most common imaging modalities are magnetic resonance angiography (MRA) and computed tomography angiography (CTA). Meta-analysis of the utility and evaluation of the accuracy of the different modalities of locating perforators for DIEP flaps indicate that MRA and CTA are usually better than ultrasound because they give you multiple cross-sectional views of the abdominal wall and its vasculature. By having a three-dimensional visualization of the perforators, surgeons are able to identify perforator location, diameter, and intramuscular anatomy in order to select the perforator(s) that will best perfuse the flap.[15]

CTA for preoperative DIEP planning has been shown to decrease operative times (mean operative reduction time of 58 minutes) and lower risk of partial flap failure (RR 15, $P < .001$)[16] specifically about perforator identification and selection. Surgeons who do not use CT angiogram for preoperative planning have been shown to include more perforators (2.3 vs 1.4, $P < .001$) in the flaps than those who did not, reducing efficiency and potential increasing morbidity to the abdominal wall.[17] Similar to any imaging modality, however, CTA imaging comes with its own set of drawbacks including exposure to ionizing radiation and higher incidence of contrast sensitivity and nephrotoxicity.[18] Our preference is to use MRA because it provides excellent visualization of the venous anatomy, which we believe to be an important consideration in perforator selection. We use prone positioning for the study, which limits motion artifact (from respirations) and puts the superficial venous system in a single plane against the table so on coronal viewing it allows the surgeon to topographically map the perforator locations and see the communication of the deep and superficial venous systems. The sagittal and axial views are useful in determining the intramuscular course of the perforating vessels. The primary determinants used in perforator selection are degree of communication with the superficial system, vessel caliber, and length of intramuscular course.[19–22]

Patient Education

A good relationship and open communication between surgical team and the patients aids in a successful and efficient perioperative course and leads to better outcomes in DIEP flap surgery. It is important that the patient has planned ahead for their surgery and recovery period.

Some centers provide standardized patient education classes for prospective breast reconstruction patients. The classes allow patients to think as though they are a part of the decision-making process and enable them to organize their questions before their individualized appointments.[23] These preoperative group classes also reduced individual preoperative appointment times (31.8 minutes vs 53 minutes) and allowed a 43% increase in new patient visit availability for the surgeons without diminishing patient satisfaction.[24,25]

OPERATIVE EFFICIENCY

Intraoperative Efficiency

Although preoperative planning sets a surgeon up for success, intraoperative organization is an important component to carrying out a successful procedure in an efficient manner. Intraoperative efficiency can be defined by the flow that allows surgeons to operate most productively, sharpening mental faculties and manifesting in optimized performance. The key to achieving flow is promotion of the environment. This is something that is not determined by just the surgeon but by the entire intraoperative team and by standardizing team roles and briefing team members on the operative plan to promote pride and autonomy.

Unnecessary prolonged OR times and postoperative stays can be harmful to patients and can also be wasteful from a financial and resource perspective. Duration of surgery is an independent risk factor for postoperative complications and should be minimized.[26] Bekeny and colleagues describe 2 theories in operations management that apply to throughput in the health-care arena.[27] The first is Little's law, the idea that throughput is maximized by increasing the capacity to host patients or reducing the time they spend in the system. The second is Lean management, a process of identifying and eliminating waste within the system. Simply put, to maximize the number of patients that can be treated, one can either increase the capacity of the system (ie, expand infrastructure) or become more efficient (ie, Lean) in moving patients through the system.[27] Because infrastructure expansion is often cost prohibitive, many health systems are using Lean management concepts that focus on identifying value, mapping the process, identifying bottlenecks, minimizing waste and performing continuous self-improvement. If we consider what is of value in surgery, there is great value in reducing operative time, reducing inefficiency and waste, and having an environment that is conducive to peak performance by the surgical team. By mapping the steps in an operation, one can begin to see where bottlenecks and wasted time and resources occur. Focusing on correcting these inefficiencies provides the best return on effort. Below we discuss some approaches we have used to improve intraoperative efficiency.

Multiple Surgeons

Although DIEP flap surgery can be performed by a single plastic surgeon, multiple studies have shown that having 2 plastic surgeons involved decreases operative time, hospital length of stay and donor site complications.[28,29] Considering that immediate reconstruction usually already entails that the plastic surgeon is working concomitantly with a breast surgeon, introducing a third surgeon requires additional coordination to maximize surgeon productivity. This may vary by breast surgeon and their willingness to perform surgery with an additional 1 or 2 plastic surgeons present and must be adjusted accordingly.

Surgical Instruments and Supplies

Unnecessary instruments on a surgical tray are a common source of waste and inefficiency during surgery. Unused instruments still need to be counted (wasted time), resterilized (additional processing and cost), and they clutter the surgical table (excess inventory).[30,31] In addition, fine microsurgical instruments are easily damaged during sterilization so keeping additional instruments on the tray often results in those instruments sustaining damage that goes unrealized until they are actually needed during the case. Instead, we prefer to keep additional instruments in a separate set or peel packed so that they are only used on an as-needed basis. One study examined a plastic surgery service line during the course of 3 months and noted that only 15.8% of instruments on plastic surgery trays and 23.5% of instruments on breast reconstruction trays were used intraoperatively. After review, it was determined 45% of instruments could be removed from a general plastic surgery tray and that approximately 37% could be removed from the breast reconstruction tray. This amounted to a reduction of approximately 81,696 instrument sterilization cycles annually, potentially saving US$163,800 in instruments costs and US$69,441 on sterilization.[31]

Having all sutures, equipment, and implantable materials readily available, either by using a specific room that is fully stocked for the procedure or by creating an equipment cart that contains these items so that they can be brought to the room on the day of surgery, are ways to reduce the time wasted retrieving these items during surgery.[32]

Operating Room Setup

An important contributor to surgical efficiency is how the operating room is set up for the case. Organizing the operating room in such a way as to minimize the need to move equipment and tables once the procedure starts is another way to reduce disruption during surgery. For example, on a bilateral mastectomy case, our breast surgeons typically prefer to operate on the noncancerous breast first. This reduces the need for a second set of breast instruments for the prophylactic mastectomy side. Traditionally, the nurse would set up their table on the side of the first mastectomy and when it was completed, would stay there and work across from the breast surgeon when he or she performed the opposite side mastectomy. However, this approach prevents the plastic surgery team from accessing and preparing the first mastectomy site for flap transfer (ie, wasted time and non-utilized talent). Instead, we now have the nurse set up across from the first mastectomy side, and once the mastectomy is completed, rather than taking additional time to get hemostasis, the breast surgeon moves to the opposite side where the nurse is already set up to work on the second breast while the plastic surgeon and their assistant come in to get hemostasis and begin preparing recipient vessels. In addition, the microscope is set up on the side of the first mastectomy so that once the recipient vessels are prepared the microscope can access the field for the flap transfer, even if the breast surgeon is still performing the second mastectomy. **Fig. 1** details how we have set up the operative room theater to optimize efficiency.

We have also found it helpful to set up a Mayo stand with all the instruments necessary to get hemostasis, prepare the recipient vessels, and do the microsurgical transfer, ahead of time. This allows the second surgeon to be relatively self-sufficient while the scrub nurse focuses on the surgeon performing the flap harvest and avoids the scrub nurse having to hand instruments across the harvesting surgeon's surgical field or behind the surgeon. **Fig. 2** shows a picture of the Mayo stand with instruments for recipient site preparation.

POSTOPERATIVE EFFICIENCY

Enhanced Recovery Pathways

Enhanced recovery after surgery (ERAS) pathways were originally introduced in colorectal surgery but have since expanded into other surgical disciplines, including plastic surgery[33–37] and efficient and effective patient discharge from the hospital postoperatively. Because the term ERAS is now a registered trademark, we use ERP (enhance recovery pathway) as our abbreviation. There are various ERP protocols that exist; however, the one outlined here is used by our group and was based on the study published by Jablonka and colleagues[38] and involves a 2-day hospital stay.

This protocol incorporates the key elements that have been shown to decrease complications and length of stay after surgery. Invoking the idea behind the Paredo Principle (ie, 80/20 rule), which states that 80% of the effect is the result of 20% of the interventions, we have tried to hone in on the key elements that have demonstrated the most clinical benefit in our hands while eliminating the remaining 80% that have relatively minor impact on outcomes. The other 80% may provide an additional small potential benefit but at the expense of additional risk of untoward side effects, logistical hurdles, or added cost that mitigates that benefit.

Nonopioid Pain Control

Perhaps, the greatest influence on length of stay has been achieved by using a multimodal, nonopioid, pain management approach. Although many ERAS pathways use preoperative medications to decrease opioid use intraoperatively, our focus has been on avoiding opioid use after surgery. This begins with intraoperative nerve blocks using a combination of intermediate and long-acting local anesthetics. We typically prepare a mixture of 20 cc of 1.3% liposomal bupivicaine (Exparel - Pacira Biosciences, Inc, Tampa, FL), 30 cc of 0.25% bupivicaine, and 100 cc of injectable saline. Before flap transfer, we inject a total of 10 cc of the mixture directly into the pectoralis and intercostal muscles at the internal mammary recipient site and at the drain site. An additional 10 cc is injected in the serratus plane to block the lateral intercostal nerves. If axillary or inframammary incisions are used, an additional 5 cc is injected along those sites as well. After flap transfer, bilateral transversus abdominis plane blocks are performed under ultrasound guidance using 30 cc of the mixture on each side. Another 20 to 30 cc is injected along the lower abdominal incision and drain sites. At the end of surgery, the patient is given a 1-g dose of intravenous acetaminophen and 15 mg of IV ketorolac. This is continued every 6 hours postoperatively until the patient is taking food orally, at which time oral equivalents are used.[39] Narcotic use is reserved only for breakthrough pain. Multiagent antiemetic use is also given during surgery to avoid postoperative nausea. By avoiding narcotic use, patients have less nausea, constipation, and lethargy after surgery. Given that, in a

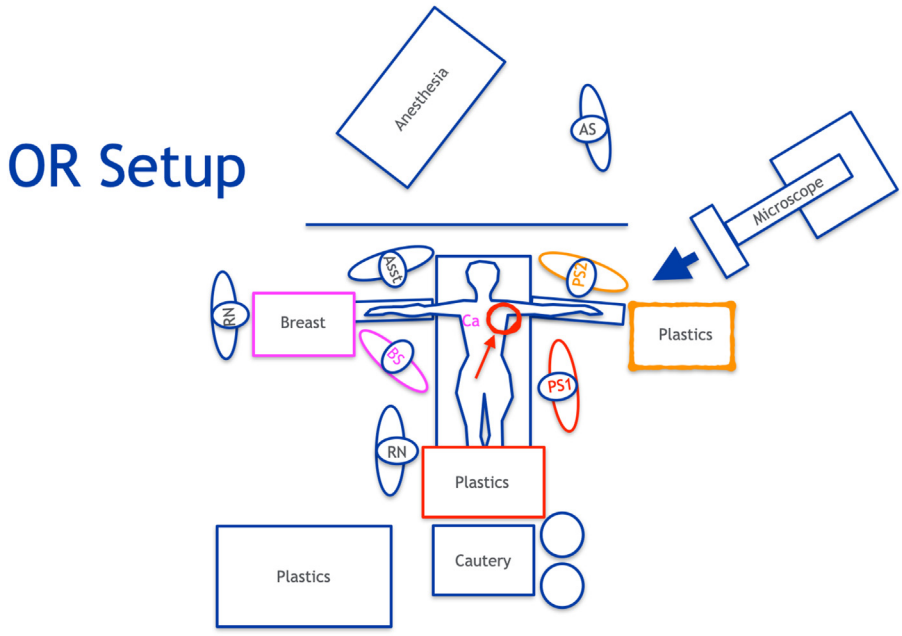

Fig. 1. Recommended DIEP flap operating room setup: Setup for second mastectomy showing breast surgeon (BS) on the side of the cancerous breast while the harvesting plastic surgeon (PS1) begins harvesting the second flap. The recipient site plastic surgeon (PS2) begins preparation of the recipient vessels and then does the microsurgical anastomoses. The red circle with the arrow marks the first mastectomy site. AS, anesthesiologist; Asst, Assistant; RN, Nurse.

recent study, 6% of opioid naive patients were still using opioids 3 to 6 months after even minor surgical procedures (compared with 0.4% of nonoperative controls), reducing opioid exposure helps reduce the risk of opioid dependency.[40]

Venous Thrombo-Embolic Prophylaxis

All patients receive Lovenox 40 mg or Heparin 5000 units given subcutaneously before surgery. Pneumatic compression wraps are placed on the lower extremities. Patients continue prophylactic dose anticoagulation throughout their hospital stay and wear the compression wraps while in bed. The length of postoperative venous thrombo-embolic prophylaxis depends on risk. Patient with a Caprini Score of 8 or more are continued on prophylactic Lovenox for 4 weeks postoperatively.[41]

Postoperative day 0

Depending on the facility and the nurse staffing, several postoperative monitoring environments have been used by our team for the first night after surgery, including overnight stay in the recovery room or transfer to an ICU, step-down, or regular floor bed. Ideally, patients are transferred to a private room on a regular floor to have a quieter environment. We usually use near-infrared spectroscopy-based tissue oximetry (Vioptix) or implantable Doppler probes (Cook Medical, Bloomington, IN) to follow flap perfusion postoperatively. Ideally, a Doppler signal from the perforator is marked with a small suture on the flap skin island as a backup site for monitoring in case of device malfunction. Patients are typically allowed to take ice chips or small amounts of clear beverages the first night. Laboratory studies are usually not drawn unless there is a concern due to existing medical conditions or blood loss during surgery.

Postoperative day 1

Patients have their urinary catheter removed in the morning and are moved into a chair to eat breakfast. They are then ambulated several times the first day. Intravenous hydration is stopped once adequate oral intake is established and IV pain medications are changed to oral format. Patients are given instructions by the nurse on how to manage the drains.

Postoperative day 2

Flap monitoring is discontinued, and patients are discharged home with follow-up arranged within 1 week to assess surgical sites and to remove any drains with low output.

Although many surgeons remain concerned about the risk of flap loss if flap monitoring is

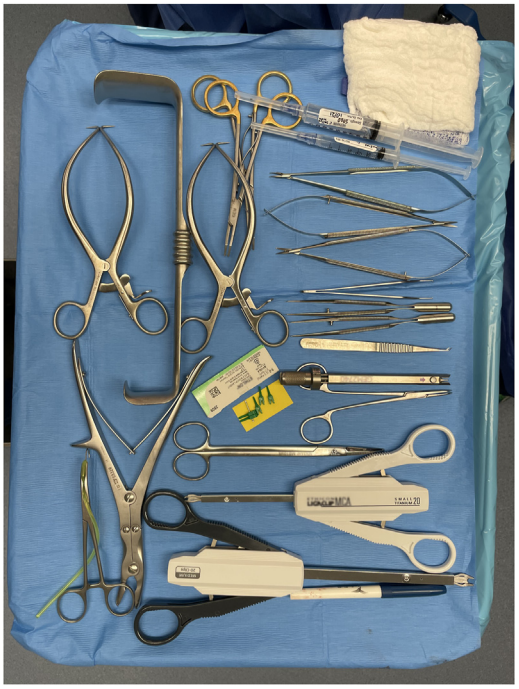

Fig. 2. Mayo stand with recipient site instruments for the second plastic surgeon. It is important for each team to develop its process map and to engage all team members in the discussion regarding intraoperative coordination to ensure optimal efficiency and integration. It is expected that things may change based on the surgeons' experience and speed, the introduction of new technologies and changes in staffing resources; however, it important to remember that Lean management is an iterative process that requires continuous reevaluation to incorporate change and to maintain optimal efficiency.

discontinued prematurely, a recent study by Jablonka and colleagues that looked at a series of 1813 patients and 2847 flaps showed that by postoperative day 2, the cost-utility of inpatient flap monitoring exceeds acceptable societal thresholds. This is because after postoperative day 2, both the likelihood of flap loss and flap salvage drop such that the odds of undertaking a successful flap salvage at this time point is less than 1 in 900.[40]

Our experience using this protocol during the last 5 years, for more than 500 patients and more than 1000 DIEP flaps, has demonstrated a mode length of stay of 2 days and a flap loss rate less than 0.3% demonstrating that short length of stay and high flap success rate are not mutually exclusive.

SUMMARY

As health care evolves to a more value-based approach, it is essential for surgeons doing resource intensive procedures to optimize efficiency and outcomes. Efficiency in DIEP flap breast reconstruction entails a multipronged approach that incorporates effective preoperative planning, patient education, operative efficiency and postoperative pathways to ensure successful outcomes while limiting resource consumption and waste.

CLINICS CARE POINTS

- Preoperative Assessment: Most complications can be managed but are greatly facilitated by preoperative counseling of the patient on what may be entailed. In patients who we identify as having an increased risk of complications, we discuss the relative risk of various reconstructive options and the management of their associated complications. For patients who are amenable to proceeding, we document the discussion and include the specific risks in our informed consent. For the highest risk patients, delayed reconstruction, with or without placement of an expander as an interim spacer, should be considered to make sure that cancer treatment is not impeded by surgical complications and to potentially allow more time for medical optimization of the patient (eg, smoking cessation, A1c optimization).
- Preoperative Imaging: In a high volume practice, it is useful to meet with your radiologist to discuss the intent of the study, how it should be reported and how incidental findings are communicated to physician and patients. This ensures optimal views of the anatomy and ensures that incidental findings, which may be present in more than 50% of studies, are not missed by the surgeon.[42]
- Patient Education: In our practice, we direct patients to our website where we provide them with information and a list of questions to consider. At their visit, we also provide a checklist and review key elements of the surgical process including time/date/location of their surgery, presurgical testing date, medications to avoid before surgery, presurgical cleansing instructions, nil per os instructions, what to bring to the hospital and what to leave home, how to prepare at home for after surgery, what to expect in the hospital including the anticipated length of stay, activity restrictions, bathing, sleeping position, prescription and over-the-counter medications that might be needed, drain care instructions, follow-up appointment time, and

what to look out for after surgery. This helps patients understand and prepare for surgery, avoids miscommunication, and sets expectations for the recovery process. Patients who have expectations set for early discharge are more likely to go home on schedule than those who do not.[25]

- Intraoperative Efficiency: It is critical to review the efficiency goals with the entire team, including nursing, anesthesia, and hospital administration in advance of implementation in the operating room. Once the patient benefits and cost savings are understood, buy in for the process is usually much more enthusiastic.
- Enhanced Recovery Protocols: Similar to intraoperative efficiency measures, it is critical to in-service nurses on monitoring and recovery goals so that they understand the concepts behind enhanced recovery protocols. Nurses whos are not familiar with nonopioid pain management techniques may actually encourage patients to take opioid medications after surgery unnecessarily, anticipating that they will be in pain if they do not.

DISCLOSURE

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