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Internal mammary artery perforator (IMAP) flaps

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Oncologic defects of the head and neck require a detailed understanding of regional anatomy to optimize and simplify reconstruction. While free tissue transfer has become the standard bearer for most soft tissue defects, local flaps still remain a high-quality, reliable option. The internal mammary vasculature provides predictable perforators to the chest wall skin that can be transposed to lower neck wounds. Paired arteries and veins perforate through the second and third rib interspaces to perfuse skin overlying the parasternal and infraclavicular areas. Donor site morbidity is minimal with primary closure performed in most occasions. This flap is ideal for smaller esophageal fistulae, paratracheal wounds, and neck incisional dehiscence.

Introduction

Skin flaps based off perforators of the internal mammary artery and vein have become an innovative solution for head and neck reconstructive surgeons. Perfusion of the upper chest is reliable and permits modest sized flaps with little to no donor site morbidity. The simplified description of these flaps has a unique past that draws from trial and error with deltopectoral flaps and microsurgical breast surgery.

The origin of the deltopectoral flap is traced back to Aymard (1917) and Bakamjian (1965) when they used lateral chest skin based off parasternal inflow to resurface the nose and pharynx, respectively.[1] Despite incomplete investigation, it was proposed that branches of the intercostal vessels supplied skin over the chest and shoulder. Illustrations from Manchot's *Cutaneous Arteries of the Human Body* and sentinel work by Joseph pointed to reliable inflow and downstream perfusion.[2] The Bakamjian flap gained widespread popularity in the late 1960s and became an early workhorse for neck resurfacing and airway reconstruction. Flap dimensions ranged from 5 × 10 cm to 10 × 20 cm and generally thin, pliable, and with good color match. The primary drawback of the deltopectoral flap was the limited arc of rotation. In addition, a skin graft is routinely necessary to close the donor site and flap division and inset are required for transposed flaps. There is also an inconsistent reported rate of partial flap loss (20%) due to the random perfusion of distal skin beyond the deltopectoral groove and clavicle.[3]

Innovation with internal mammary artery perforator (IMAP) flaps also draws its origins from reconstructive breast surgery. Early descriptions of breast reduction and mastopexy demonstrate reliable blood supply and innervation to the nipple areola complex based off of perforating vessels from the internal mammary and intercostal systems. Pioneering groups in breast reconstruction began incorporating these vessels in microsurgical anastomoses. The traditional approach during the 1980s and early 1990s was to anastomose abdominal-based flaps to the thoracodorsal

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vessels in the axilla. This was commonplace due to the familiarity with the latissimus muscle and the concomitant axillary dissection with modified radical mastectomy. Identification of alternative vessels became a priority in cases of delayed reconstruction, axillary radiation, and potential injury by oncologic surgeons.[4] The course and caliber of the internal mammary artery and vein were then carefully documented.[5] The use of internal mammary vessels mirrored the rate at which breast oncologic surgeons changed practice patterns and performed sentinel node biopsy instead of axillary node dissection.[6] Among other reasons, reconstructive surgeons chose against the thoracodorsal vessels to avoid iatrogenic, anastomotic injury in cases with false-negative sentinel node biopsy. The primary benefits of these vessels were easier set up for microsurgery, less need for a long flap pedicle, more predictable arterial inflow, and improved positioning of the breast mound. However, there was a learning curve with this change in practice pattern. Dissection requires removal of a small segment of rib cartilage for better exposure. Since there is only a thin layer of parietal pleura between the vessels and the lung, there is a potential for pneumothorax.

As a refinement of the deltopectoral flap, the IMAP draws on the previous work of perforator-based microsurgery.[7,8] The evolution from random pattern flaps to myocutaneous flaps and finally perforator flaps was built off the early studies by Manchot, Salmon and Taylor. The driving force has been to minimize donor site morbidity while still perfusing a large skin paddle. Koshima and Soeda were the first to describe the inferior epigastric artery skin free flap for floor of mouth reconstruction.[9] Composed of skin and subcutaneous fat, the flap was raised without sacrificing the rectus abdominis muscle and abdominal wall fascia. It was learned that the muscle was a passive carrier for the perforating vessels. Each perforator has its own vascular territory, called a perforasome. These perforasomes are connected to one another by linking vessels and communicating branches, which can permit a single perforator to perfuse a large skin paddle.[7] There was consequently an explosion of newly named flaps that relied on a clinically relevant perforator and subsequent retrograde dissection to achieve pedicle length.

Anatomy

The exact origin of the IMAP is unclear. Sasaki et al described a free deltopectoral flap based off the second intercostal perforator.[10] Karabulut and Kalendar created pedicled island flaps for sternal and breast reconstruction.[11] Formal naming of the flap was assigned by Peirong Yu, who was motivated to use perforator flaps in a pedicled fashion since previous descriptions focused on free tissue transfer.[12] This novel procedure relied on island flap creation after skeletonizing parasternal perforating vessels of the internal mammary vasculature. Subsequent anatomic studies have defined the perforator and vessel position as well as routine perfusion patterns.

The internal mammary artery has a constant course approximately 15 mm from the lateral border of the sternum. The IMV runs medial to the IMA but can be paired on the lateral side of the artery, most commonly in the lower intercostal spaces.[5] Five perforating vessels are routinely identified during cadaver dissection. The perforating vessels traditionally perforate along the inferior border of the rib cartilage along with an anterior nerve branch of the intercostal nerve through the intercostal and pectoralis major muscles. Once the vessels pierce the pectoralis muscle, they traverse superficially in the subcutaneous tissue in a lateral to laterocaudal direction (Figure 1). Vesely et al initially showed that perfusion extends from the midsternum medially to just beyond the anterior axillary fold laterally, from the clavicle superiorly to the xiphoid at the fifth intercostal space inferiorly.[13] A more selective dye study identified that each perforator zone of perfusion extends laterally from the sternum and then slightly caudal, parallel to the deltopectoral groove. The second intercostal space perforator has the largest area vascularized, approximately 140 cm^2 and excludes the nipple areola complex. Compared to adjacent perforators, the second intermammary perforating artery also has the largest artery mean external diameter of 1.6 mm.[14] This large area of perfusion is directly related to linking vessels between the IMAP perforators and the lateral thoracic artery perfusion pattern laterally (Figure 2).[15] The dominant perforator was located in the second and third intercostal space in 67% and 19%, respectively. The mean length of the dominant perforators, measured from vessel branchpoint to entry into the subcutaneous tissue, was 47 mm (range 30-66 mm).[16]

Imaging

Elevation of perforator flaps requires meticulous dissection of the vessels through the overlying muscle. This dissection can often be tedious and challenging, which places greater technical demands on the surgeon. In addition, there can be variability in position and size of the perforator vessels. Imaging can bridge the gap between clinical inexperience and operative efficiency. While handheld Doppler ultrasound can help with localization, it is imprecise and can be misleading. The audible volume of the signal does not always correlate with vessel size and flow dynamics. Cross-sectional imaging, CT and MRI angiography, provide more detailed understanding of the vessel position, caliber, and perforating course.[15] It can also illustrate any anatomic anomalies or concomitant cardiothoracic disease, which may obviate use of the internal mammary vessels. Nonetheless, it is rare to have omission of internal mammary perforators across the ventral thorax. Schmidt et al dissected 100 intercostal spaces and only found an absence of 7 perforators.[14]

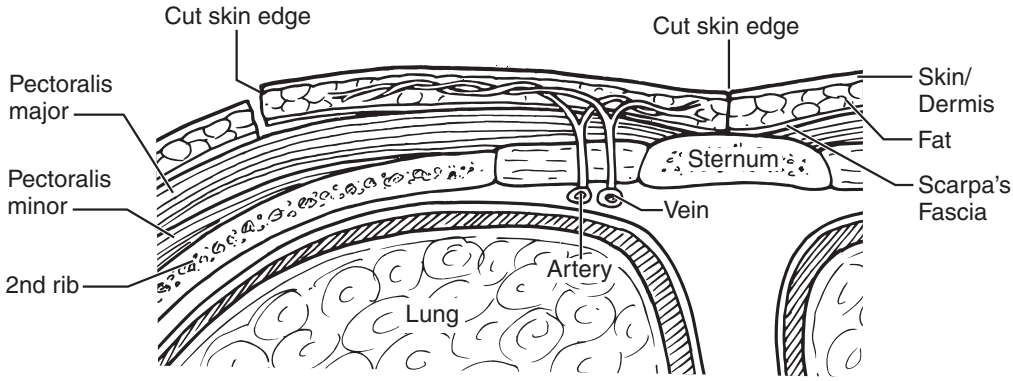

Figure 1 Axial, cross-sectional anatomy of the internal mammary artery, vein, and perforating vessels.

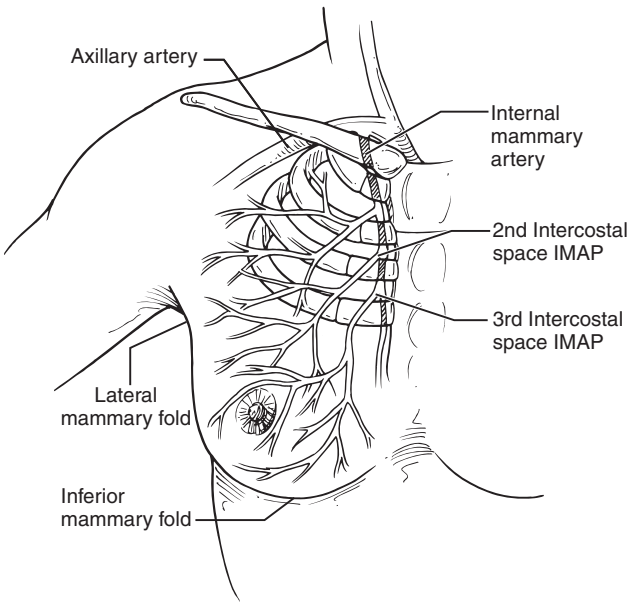

Figure 2 Vascular territories of the internal mammary artery perforators in the first, second, and third intercostal spaces.

Techniques

A variety of techniques are available to elevate the IMAP safely. The most described and consistent method is a lateral to medial approach after perforator identification. First, handheld pencil Doppler is routinely employed to determine which intercostal space to base the flap in the absence of preoperative imaging. A high-quality perforator will have both distinguishable arterial and venous tones. The second intercostal space is utilized more commonly due to its proximity to the neck defect and large perfusion territory. The ipsilateral chest is chosen for wounds with more lateral wounds (greater than 2 cm off midline). The flap is designed with its long axis parallel to the intercostal space towards the deltopectoral groove. The length of the flap will be determined by the defect size. The medial limit of the flap is the sternal midline. Results indicate that IMAP flaps can be raised from an average of 13×7 cm up to the size of 20×13 cm. Cross-sectional imaging or intraoperative indocyanine green laser angiography can provide confidence to surgeons in their learning curve but is not required due to vessel reliability.

A conservative approach is to incise the limb of the incision between the second and third intercostal spaces. Subfascial dissection is performed just lateral to the sternal border to identify the perforating vessels of the second intercostal space. If no vessels are found in the second interspace, the dissection can be taken 1 level inferiorly to inspect the third intercostal space. After perforator identification, circumferential dissection is performed to release any muscular or fascial bands that predispose for vessel compression or kinking. If sufficiently traumatized, small perforator vessels have the tendency to undergo vasospasm and thrombosis, which can threaten flap survival. Microdissection with the aid of the operating microscope can facilitate division of fascial or muscular bands inhibiting pedicle rotation. Despite the absence of a formal anastomosis, there may be also a role for antispasmodic or thrombolytic agents during dissection.

The remaining elliptical design of the flap is then incised based on exact perforator location and defect size. The plane of distal flap dissection will depend on the defect type. For more dead space obliteration, a subfascial dissection of the pectoralis muscle is appropriate. If the flap will serve a primary resurfacing role, a thin 1.5-2.0 cm flap can be elevated.[17] Elevate the elliptical flap from lateral to medial until the previous parasternal dissection is encountered. Once the flap is circumferentially islanded, the decision to do additional perforator dissection will depend on the proximal extent of the defect. There are reports of flaps reaching the mandibular angle in select cases. A stepwise approach should be undertaken to gain pedicle length. First, proceed with a muscle splitting dissection of the pectoralis major. Small accompanying branches will need to be sacrificed with hemostatic clips or bipolar cautery. Enhanced length can be obtained with additional deep dissection. The intercostal musculature can be divided until the internal mammary artery and vein are identified. Next, the costal cartilage and perichondrium of the second rib are resected. If the dominant perforator is in the third intercostal space, both third and second rib cartilages can be partially resected along with the surrounding intercostal musculature and pectoralis muscle. The internal mammary

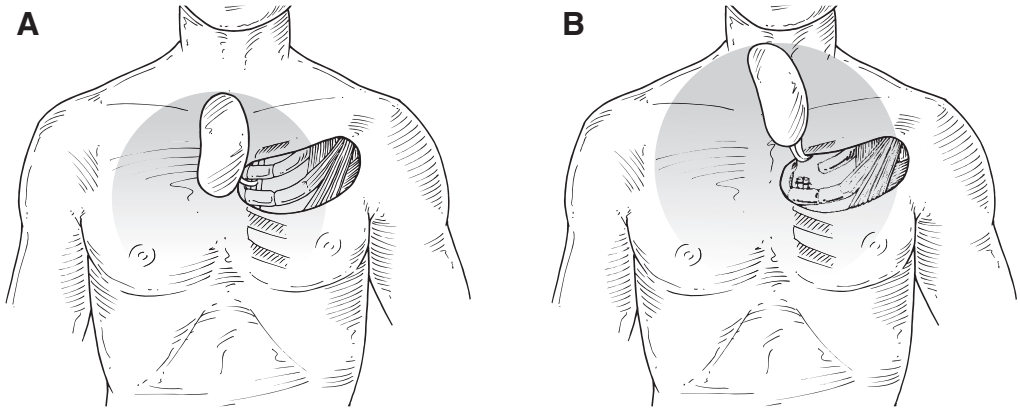

Figure 3 (A) The IMAP flap raised as an island flap for lower neck reconstruction. (B) The extent of dissection will reflect how distant the wound is from the perforator pivot point. Removal of the second rib cartilage, ligation, and retrograde dissection of the internal mammary pedicle will permit reconstruction of more distant wounds.

artery and vein are then clipped distal to the perforator take off and pedicled superiorly. If the flap pivot is the caudal portion of the first rib, pedicle length can extend to a mean length of 9.2 cm (Figure 3).[13,18]

The flap can then be rotated through a widely dissected subcutaneous tunnel or by dividing the narrow skin bridge between the defect and the chest skin. Throughout multiple stages of the elevation, it is wise to check perfusion of the distal tip of the flap and audible Doppler signals. After inset, repeat indocyanine green laser angiography can be employed for greater confidence about pedicle tension or compression.

Applications

The first descriptions for IMAP flaps highlighted its ease of use in treating hostile sternal wounds. Elevation of the flap on a single perforator without intramuscular dissection would easily reconstruct skin loss related to mediastinitis and sternal osteonecrosis.[11,19] Peirong Yu was the first to publish reports of this flaps versatility in head and neck reconstruction. The case report showed promise in resurfacing anterior neck skin and reinforcing small defects around previously radiated tracheostomas (Figure 4).[12] A subsequent paper demonstrated its use in resurfacing of the entire anterior neck with bilateral 7 × 17 cm flaps. The author did mention some venous congestion treated with leech therapy and a minor degree of dehiscence distally that healed by secondary intention.[13]

A series of additional case reports would follow demonstrating technical modification to minimize donor site morbidity and ensure reliable distal flap perfusion.[18,20] Grinsell and Kolb described use of the IMAP flap for postreconstruction defects of the pharynx. In a small case series, interposition flaps were designed to address annular pharyngeal strictures after previous tubed flap reconstruction and adjuvant radiation.[21,22] Flap width of 7 cm or less can be closed primarily in most situations. In women, the orientation of the flap may need to be adjusted to prevent

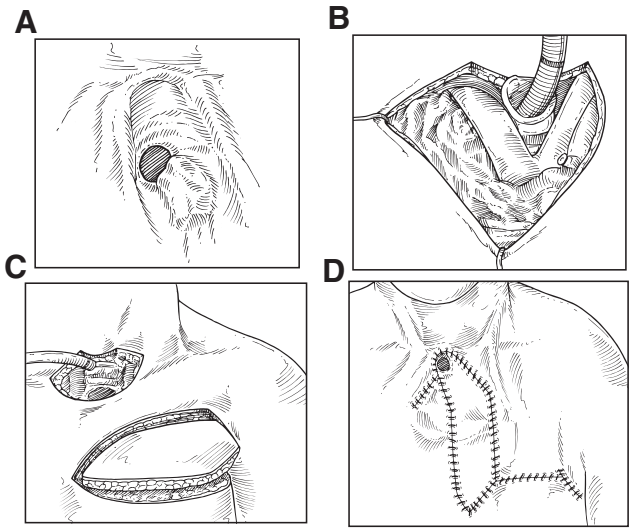

Figure 4 (A) Tracheostoma recurrence of adenoid cystic carcinoma of the larynx 30 years after total laryngectomy. (B) Tumor resection involved the anterior tracheal wall, neck and chest skin, and left internal jugular vein. (C) A left pedicled IMAP flap based on perforating vessels at the second intercostal space. (D) Early postoperative photograph showing a well-vascularized flap and widely patent tracheostoma without complications.

distortion of breast mound and nipple areola complex. IMAP selection may be contraindicated in patients who have undergone coronary artery bypass grafting with IMA harvest. It is wise to verify the patient's previous cardiac operative records and obtain cross-sectional imaging.

The primary benefits of IMAP flap selection are its superior texture and color match and sensation through preservation of the anterior cutaneous branches of the intercostal nerves. The only recognized downside of this flap selection is the difficulty of simultaneous oncological resection and flap harvesting. In patients with large reconstructive needs who have already undergone failed reconstruction, the expanded IMAP provides an attractive local option. A tissue expander is placed from a lateral approach along the planned flap axis in a subcutaneous

plane.[23] This staged procedure requires delay of weeks to months for skin expansion but can allow for larger flaps (average size, 18×10 cm) with less donor site morbidity and avoidance of skin grafting. For example, pre-expanded IMAP flap is an ideal local flap for severe neck contracture secondary to burn injury. As one can imagine, authors have also elevated IMAP flaps as a free flap, which can be an alternative to more traditional thigh or forearm donor sites.[18]

Summary

Complex oncologic and traumatic wounds of the neck can be treated safely with locoregional flaps. Internal mammary artery perforators provide reliable perfusion of the lateral chest. IMAP flaps can be easily designed around these skeletonized vessels. Unilateral or bilateral flaps can resurface large primary wounds of the neck. More commonly, surgeons rely on IMAP flaps to salvage areas of wound dehiscence, large vessel exposure, or tracheoesophageal fistula. Despite some expertise required for delicate perforator dissection, IMAP flaps are powerful options with little to no donor site morbidity.

Conflict of Interest

There are no conflicts of interest to disclose. I have received consultation fees from Biomet Zimmer over the last calendar year. None of this company's products apply to techniques described in this manuscript.

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