"P^{6}LAND": An Educational Tool for Free Flaps

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Abstract

Background Microsurgical education requires both technical skill and didactic knowledge. Learners are frequently asked to describe free flaps and their knowledge tested in clinical work and during exams.

Methods We have created an educational tool that will aid learners in remembering important information related to flaps.

Results "P6LAND" which divides and organizes information into three parts: Preoperative considerations, Pedicle, Position, LANDmarks, Plane of dissection, Protection and Postoperative considerations.

Conclusion The aim of this paper is to further describe this educational tool and to provide a compendium for the most common fasciocutaneous, muscle, perforator, and bone flaps based on the literature. This tool was also prevalidated among a group of learners.

Keywords
- microsurgery
- learning
- education
- free flaps
- flap
- surgery

Microsurgical education predominantly focuses on skill acquisition with numerous courses,[1] simulators, and nonbiological and biological models[2–5] described. There is little emphasis on the microsurgical literature regarding study techniques to better understand how to raise and inset flaps safely. There are several Web sites that help provide useful summaries,[6] seminal papers,[7] and excellent textbooks.[8,9] Many of these references can be overwhelming and do not provide a succinct and structured way to organize this large volume of information. In addition, there is a lack of structure to learn this information, specifically, a lack of flap study mnemonics. Study mnemonics are a useful way to organize large amounts of data. "P^{6}LAND" divides information into three parts: preoperative, intraoperative, and postoperative considerations. This organization helps highlight the important aspects of raising flaps in a succinct way. The aim of this paper is to highlight the specifics of the mnemonic and provide an appendix for the most common fasciocutaneous, muscle, perforator, and bone flaps. The mnemonic has been referred to as P^{6}LAND: Preoperative, Position, Pedicle, LANDmarks, Plane, Protection, Postoperative.

The order of the mnemonic refers to the steps of the procedure. For example, preoperative workup must come first and includes any physical examination maneuvers or special investigations that needs to be completed before a surgical intervention may commence. The next five focus on important steps intraoperatively including the position of the patient, the main pedicle (and corresponding venous supply and nerve supply), landmarks of the flap (markings, and proximal and distal landmarks), the dissection plane, and anatomic structures to protect when operating. Finally, the postoperative phase refers to important tests, monitoring, or investigations to monitor the viability of the flap. Below, will be a more thorough discussion of each factor.

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Preoperative Considerations

The preoperative workup includes any physical examination tools or special investigations that need to be completed before a surgical intervention may commence. Special tests (such as an Allen's test), use of Dopplers to mark out any perforators, and imaging (i.e., computed tomography) are some examples of preoperative considerations.

Intraoperative Considerations

Position

Position information describes the position of the patient intraoperatively. Most flaps can be procured with the patient in supine position. Variants include lateral decubitus (such as for scapular/parascapular, latissimus dorsi [LD] flaps), prone, or modifications of supine (e.g., "frog-legged" for the gracilis flap).

Pedicle

Pedicle information relates to the artery, veins, and possible innervation of the flap. Pedicle information, first and foremost, describes the main arterial blood inflow and the main venous outflow.

Landmarks

"Land" stands for landmarks of the flap, which include general markings, proximal, distal, and possible medial and lateral landmarks. This provides information related to the general anatomic boundaries of the flaps. For example, the proximal landmark of an anterolateral thigh flap (ALT) is the anterior superior iliac spine while the distal landmark is the lateral border of the patella.

Plane

The plane describes the dissection plane such as suprafascial, subfascial, intramuscular, submuscular and can refer to compartments.

Protection

Protection refers to structures that must be protected which may be encountered during the dissection. These structures include the pedicle itself as well as other neurovascular structures or areas that may result in complications. For example, in the LD flap procurement, the thoracolumbar fascia must be carefully preserved to prevent painful postoperative lumbar hernias.

Postoperative Considerations

Finally postoperative describes the care including flap checks (timing, assessment), need for a stepdown bed, and any other monitoring (i.e., donor site). It also refers to the position of the patient to prevent pressure at the pedicle or donor. For example, for the supraclavicular flap, the recommendation is to decrease pedicle strain by ensuring the neck is in a semiflexed position. Alternatively, after a deep inferior epigastric perforator (DIEP) harvest, the patient sits in a flexed position to prevent undue tension or pressure on the abdominal donor and incision.

Table 1 P[6]LAND mnemonic details

Considerations		
Preoperative	Special tests (Allen's test, Doppler), imaging (i.e., computed tomography angiogram)	
Intraoperative	Position	Patient position
	Pedicle	Involving arteries/veins (and number) ± nerves
	Landmarks	Markings
		Proximal
		Distal
		Other
	Plane	Dissection plane
	Protection	Of neurovascular and anatomic structures during dissection
Postoperative		Flap checks, stepdown, monitoring devices, drains, positioning of patient

Please see ►**Table 1**: P[6]LAND mnemonic details for a concise summary. Also, see **Appendix A**: Flap mnemonic examples, for use of this mnemonic in common free flaps.

Prevalidation of P[6]LAND

We have attempted validation of this mnemonic with trainees. Residents from levels 2 to 5 and fellows were included in the validation process. We randomized 40 learners into "control" and "experimental" groups with training levels considered during randomization. Both groups were asked to provide information on five most common free flaps: (1) DIEP, (2) LD, (3) ALT, (4) fibula, (5) radial free forearm flap. The "experimental" group was shown the P[6]LAND mnemonic. Trainees were asked to then provide information that they would typically give to examiners when asked about each flap. They were timed during the process. The trainees in the control group scored $33.8 \pm 10.2\%$ when describing key information regarding the flaps including but not limited to pedicle, preoperative assessment, and protection of key structures, whereas the trainees in the experimental group scored $72.9 \pm 10.2\%$. The control group took approximately 10 minutes to discuss five free flaps, whereas the experimental group took approximately 14 minutes.

Conclusion

In conclusion, this mnemonic, P[6]LAND, represents a good educational tool for trainees and residents to help in remembering keys points when discussing flaps. The aim of this work was to create a mnemonic that makes logical sense and follows the natural sequence of flap procurement. This would prove to be helpful not only when learning these flaps but also when discussed in formal exams. It provides an organized way that ultimately will allow them to remember

the key points when assessing patients and performing these procedures both efficiently and safely. We believe that this manuscript is additive to the plastic surgery education literature. Much of our tools rely on memorization with the amount of information available for flaps being quite daunting. This mnemonic is helpful to distill this information therefore making it a useful adjunct.

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Conflict of Interest
None declared.

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References

1 Singh M, Ziolkowski N, Ramachandran S, Myers SR, Ghanem AM. Development of a five-day basic microsurgery simulation training course: a cost analysis. Arch Plast Surg 2014;41(03):213–217
2 Loh CYY, Wang AYL, Tiong VTY, et al. Animal models in plastic and reconstructive surgery simulation-a review. J Surg Res 2018; 221:232–245
3 Pafitanis G, Ghanem AM, Myers S. Experimental pork belly : a simulation training model for intramuscular perforator dissection. Plast Reconstr Surg Glob Open 2018;6(01):1–6
4 Pafitanis G, Cooper L, Hadjiandreou M, Ghanem A, Myers S. Microvascular anastomotic coupler application learning curve: a curriculum supporting further deliberate practice in ex-vivo simulation models. J Plast Reconstr Aesthet Surg 2019;72(02): 203–210
5 Pafitanis G, Hadjiandreou M, Miller R, et al. The use of mobile computing devices in microsurgery. Arch Plast Surg 2019;46(02): 102–107
6 Buntic R, Buntic R Atlas of Microsurgery Techniques and Principles. Accessed September 5, 2021 at: https://www.microsurgeon.org/
7 Joyce CW, Carroll SM. Microsurgery: the top 50 classic papers in plastic surgery: a citation analysis. Arch Plast Surg 2014;41(02): 153–157
8 Shokrollahi K, Whitaker IS, Nahai F. Flaps. 1st ed. New York, NY: Thieme Medical Publishers, Inc.; 2017
9 Zenn M, Jones G. Reconstructive Surgery: Anatomy, Technique, and Clinical Applications. St. Louis, Missouri: Quality Medical Publishing; 2012
10 Horen SR, Jahromi AH, Konofaos P. Temporoparietal fascial free flap: a systematic review. 2021;87(06):e189–e200
11 Collar RM, Zopf D, Brown D, Fung K, Kim J. The versatility of the temporoparietal fascia flap in head and neck reconstruction. J Plast Reconstr Aesthet Surg 2012;65(02):141–148
12 Tang AL, Bearelly S, Mannion K. The expanding role of scapular free-flaps. Curr Opin Otolaryngol Head Neck Surg 2017;25(05): 411–415
13 Ferrari S, Ferri A, Bianchi B. Scapular tip free flap in head and neck reconstruction. Curr Opin Otolaryngol Head Neck Surg 2015;23 (02):115–120
14 Powell DK, Nwoke F, Urken ML, et al. Scapular free flap harvest site: recognising the spectrum of radiographic post-operative appearance. Br J Radiol 2013;86(1023):20120574
15 Cobb ARM, Koudstaal MJ, Bulstrode NW, Lloyd TW, Dunaway DJ. Free groin flap in hemifacial volume reconstruction. Br J Oral Maxillofac Surg 2013;51(04):301–306
16 Amouzou KS, Berny N, El Harti A, Diouri M, Chlihi A, Ezzoubi M. The pedicled groin flap in resurfacing hand burn scar release and other injuries: a five-case series report and review of the literature. Ann Burns Fire Disasters 2017;30(01):57–61
17 Al Bayati MJ, Samaha MJ, Samaha G, Habal MB, Thaller SR, Panthaki ZJ. The groin flap revisited: remembering the contributions of Dr Ian Jackson to plastic surgery. J Craniofac Surg 2021;32 (3, Suppl 3):1207–1209
18 Al-Qattan MM, Al-Qattan AM. Defining the indications of pedicled groin and abdominal flaps in hand reconstruction in the current microsurgery era. J Hand Surg Am 2016;41(09):917–927
19 Hwang K. The origins of deltopectoral flaps and the pectoralis major myocutaneous flap. J Craniofac Surg 2016;27(07): 1845–1848
20 Chan RCL, Chan JYW. Deltopectoral flap in the era of microsurgery. Surg Res Pract 2014:420892
21 Andrews BT, McCulloch TM, Funk GF, Graham SM, Hoffman HT. Deltopectoral flap revisited in the microvascular era: a single-institution 10-year experience. Ann Otol Rhinol Laryngol 2006; 115(01):35–40
22 Mikami T, Kagimoto S, Yabuki Y, et al. Deltopectoral flap revisited for reconstruction surgery in patients with advanced thyroid cancer: a case report. BMC Surg 2017;17(01):101
23 Bakamjian VY. A two-stage method for pharyngoesophageal reconstruction with a primary pectoral skin flap. Plast Reconstr Surg 1965;36:173–184
24 Wirtz NE, Khariwala SS. Update on the supraclavicular flap. Curr Opin Otolaryngol Head Neck Surg 2017;25(05):439–444
25 Trautman J, Gore S, Potter M, et al. Supraclavicular flap repair in the free flap era. ANZ J Surg 2018;88(06):540–546
26 Hamidian Jahormi A, Horen SR, Miller EJ, Konofaos P. A comprehensive review on the supraclavicular flap for head and neck reconstruction. Ann Plast Surg 2022;88(06):e20–e32
27 Ullah S, Asif M, Ubaid M, Khalid A, Khan M, Rahman MF. Lateral arm flap: its usage as pedicle and free flap. Cureus 2020;12(12): e12136
28 Kokkalis ZT, Papanikos E, Mazis GA, Panagopoulos A, Konofaos P. Lateral arm flap: indications and techniques. Eur J Orthop Surg Traumatol 2019;29(02):279–284
29 Amin JD, Amin N, Hatten KM. The lateral arm free flap for head and neck reconstruction. Curr Opin Otolaryngol Head Neck Surg 2020;28(05):365–369
30 Tan O, Aydin OE, Cinal H, et al. Latissimus dorsi flap harvest with a short incision. Microsurgery 2013;33(03):203–206
31 Abdelmofeed AM, Fadey MA, Seif O, Abdelhalim MH, Younes MT. Usefulness of nerve-sparing pedicled segmental latissimus dorsi muscle flap combined with lateral thoracic skin flap for partial volume reconstruction in laterally located breast cancer. Eur J Plast Surg 2023;46:541–550
32 Lin CH, Wei FC, Levin LS, Chen MC. Donor-site morbidity comparison between endoscopically assisted and traditional harvest of free latissimus dorsi muscle flap. Plast Reconstr Surg 1999;104 (04):1070–1077, quiz 1078
33 Chung J-H, You H-J, Kim H-S, Lee BI, Park SH, Yoon ES. A novel technique for robot assisted latissimus dorsi flap harvest. J Plast Reconstr Aesthet Surg 2015;68(07):966–972
34 Djordjevic ML, Bumbasirevic MZ, Vukovic PM, Sansalone S, Perovic SV. Musculocutaneous latissimus dorsi free transfer flap for total phalloplasty in children. J Pediatr Urol 2006;2 (04):333–339
35 Chiang I-H, Wang C-H, Tzeng Y-S, et al. Breast reconstruction using pedicled latissimus dorsi myocutaneous flaps in Asian patients with small breasts. Ann Plast Surg 2017;78(3, Suppl 2):S95–S101
36 Patel K, Lyu DJ, Kademani D. Pectoralis major myocutaneous flap. Oral Maxillofac Surg Clin North Am 2014;26(03):421–426
37 Grinsell D, Lonie S, Wilson KC, Choong PFM. The innervated rectus abdominis flap for quadriceps reconstruction. J Plast Reconstr Aesthet Surg 2019;72(06):941–945

38 Radwan RW, Tang AM, Harries RL, Davies EG, Drew P, Evans MD. Vertical rectus abdominis flap (VRAM) for perineal reconstruction following pelvic surgery: a systematic review. J Plast Reconstr Aesthet Surg 2021;74(03):523–529
39 Van Vliet A, Girardot A, Bouchez J, et al. How big is too big? The effect of defect size on postoperative complications of vertical rectus abdominis flap reconstruction. Ann Plast Surg 2021;86(6S, Suppl 5):S571–S574
40 Buchel EW, Finical S, Johnson C. Pelvic reconstruction using vertical rectus abdominis. Ann Plast Surg 2003;52(01):22–26
41 Sinnott CJ, Stavrides S, Boutros C, Kuruvilla A, Glickman LT. Dual-plane gluteal myocutaneous flap for reconstruction of ischial tuberosity pressure wounds. Ann Plast Surg 2020;85(S1, Suppl 1):S23–S27
42 Han HH, Choi EJ, Moon SH, Lee YJ, Oh DY. Combined V-Y fasciocutaneous advancement and gluteus maximus muscle rotational flaps for treating sacral sores. BioMed Res Int 2016:8714713
43 Doi K, Hattori Y, Soo-Heong T, Hiura Y, Kawakami F. Endoscopic harvesting of the gracilis muscle for reinnervated free-muscle transfer. Plast Reconstr Surg 1997;100(07):1817–1823
44 Zukowski M, Lord J, Ash K, Shouse B, Getz S, Robb G. The gracilis free flap revisited: a review of 25 cases of transfer to traumatic extremity wounds. Ann Plast Surg 1998;40(02):141–144
45 Dornseifer U, Kleeberger C, Kargl L, et al. Perfusion controlled mobilization after lower extremity free flaps-pushing the limits of time and intensity. J Reconstr Microsurg 2017;33(03):179–185
46 Walton Z, Armstrong M, Traven S, Leddy L. Pedicled rotational medial and lateral gastrocnemius flaps: surgical technique. J Am Acad Orthop Surg 2017;25(11):744–751
47 Houdek MT, Wagner ER, Wyles CC, et al. Long-term outcomes of pedicled gastrocnemius flaps in total knee arthroplasty. J Bone Joint Surg Am 2018;100(10):850–856
48 Gkiatas I, Korompilia M, Kostas-Agnantis I, Tsirigkakis SE, Stavraki M, Korompilias A. Gastrocnemius pedicled muscle flap for knee and upper tibia soft tissue reconstruction. A useful tool for the orthopaedic surgeon. Injury 2021;52(12):3679–3684
49 Padberg FT, Johnston MV, Sisto SA. Structured exercise improves calf muscle pump function in chronic venous insufficiency: a randomized trial. J Vasc Surg 2004;39(01):79–87
50 Reece EM, Raghuram AC, Bartlett EL, et al. Vascularized iliac bone graft for complex closure during spinal deformity surgery. Plast Reconstr Surg Glob Open 2019;7(07):e2345
51 Zhao D, Wang B, Liu B. Vascularized iliac bone flap transfer for early and middle stages of osteonecrosis of the femoral head. JBJS Essential Surg Tech 2019;9(01):e5
52 Al Deek NF, Kao HK, Wei FC. The fibula osteoseptocutaneous flap: concise review, goal-oriented surgical technique, and tips and tricks. Plast Reconstr Surg 2018;142(06):913e–923e
53 Awad ME, Altman A, Elrefai R, Shipman P, Looney S, Elsalanty M. The use of vascularized fibula flap in mandibular reconstruction; a comprehensive systematic review and meta-analysis of the observational studies. J Craniomaxillofac Surg 2019;47(04): 629–641
54 Guo L, Ferraro NF, Padwa BL, Kaban LB, Upton J. Vascularized fibular graft for pediatric mandibular reconstruction. Plast Reconstr Surg 2008;121(06):2095–2105
55 Sarik JR, Bank J, Wu LC, Serletti JM. Superficial inferior epigastric artery: learning curve versus reality. Plast Reconstr Surg 2016; 137(01):1e–6e
56 Grünherz L, Wolter A, Andree C, et al. Autologous breast reconstruction with SIEA flaps: an alternative in selected cases. Aesthetic Plast Surg 2020;44(02):299–306
57 Chevray PM. Update on breast reconstruction using free TRAM, DIEP, and SIEA flaps. Semin Plast Surg 2004;18(02):97–104
58 Mangialardi ML, Baldelli I, Salgarello M, Raposio E. Thoracodorsal artery perforator flap in partial breast reconstruction: a systematic review. Plast Reconstr Surg Glob Open 2020;8(10):e3104
59 Beugels J, Cornelissen AJM, van Kuijk SMJ, et al. Sensory recovery of the breast following innervated and noninnervated DIEP flap breast reconstruction. Plast Reconstr Surg 2019;144(02): 178e–188e
60 Nahabedian MY, Tsangaris T, Momen B. Breast reconstruction with the DIEP flap or the muscle-sparing (MS-2) free TRAM flap: is there a difference? Plast Reconstr Surg 2005;115(02):436–444, discussion 445–446
61 Tan BKH, Newman MI, Swartz KA, Samson MC. Subfascial perforator dissection for DIEP flap harvest. Plast Reconstr Surg 2009; 124(03):1001–1002
62 Tregaskiss A, Perez-Temprano A, Morris RJ. The subfascial perforator dissection for DIEP flap harvest. Plast Reconstr Surg 2008; 122(05):145e–146e
63 Feingold RS. Improving surgeon confidence in the DIEP flap: a strategy for reducing operative time with minimally invasive donor site. Ann Plast Surg 2009;62(05):533–537
64 Gravvanis A, Niranjan NS. Retrograde dissection of the vascular pedicle of deep inferior epigastric artery perforator (DIEAP) flap. Ann Plast Surg 2008;60(04):395–397
65 Xue EY, Cen N, Reece E, Chu CK, Winocour S. A standardized approach to deep inferior epigastric perforator flap marking. Plast Reconstr Surg Glob Open 2019;7(10):e2479
66 Médard de Chardon V, Balaguer T, Chignon-Sicard B, et al. The radial forearm free flap: a review of microsurgical options. J Plast Reconstr Aesthet Surg 2009;62(01):5–10
67 Avery CME. Review of the radial free flap: is it still evolving, or is it facing extinction? Part one: soft-tissue radial flap. Br J Oral Maxillofac Surg 2010;48(04):245–252
68 Hunter C, Moody L, Luan A, Nazerali R, Lee GK. Superior gluteal artery perforator flap: the beauty of the buttock. Ann Plast Surg 2016;76(May, Suppl 3):S191–S195
69 Mirzabeigi MN, Au A, Jandali S, Natoli N, Sbitany H, Serletti JM. Trials and tribulations with the inferior gluteal artery perforator flap in autologous breast reconstruction. Plast Reconstr Surg Glob Open 2011;128(06):614–624
70 Tsuihiji K, Daniel BW, Kageyama T, et al. Free tensor fascia lata true-perforator flap transfer for reconstruction of the calcaneal soft tissue defect complicated with osteomyelitis in a patient with alcohol-induced Charcot foot: a case report and literature review. Microsurgery 2021;41(05):473–479
71 Singh R, Wadhwani J, Rohilla RK, Kaur K. Proximal femoral resection and tensor fascia lata flap for recalcitrant trochanteric pressure ulcers. Spinal Cord Ser Cases 2019;5:15
72 Zeidler KR, Son JH, Carey JN, Watt AJ, Ho OH, Lee GK. Transverse tensor fascia lata myocutaneous flap for microvascular breast reconstruction: case report and review of the literature. Ann Plast Surg 2013;70(04):438–441
73 Graboyes EM, Hornig JD. Evolution of the anterolateral thigh free flap. Curr Opin Otolaryngol Head Neck Surg 2017;25(05): 416–421
74 Wong C-H, Wei F-C. Anterolateral thigh flap. Head Neck 2010;32 (04):529–540
75 Schoeller T, Huemer GM, Shafighi M, Gurunluoglu R, Wechselberger G, Piza-Katzer H. Free anteromedial thigh flap: clinical application and review of literature. Microsurgery 2003;24(01): 43–48
76 Hoshal SG, Bewley AF. The anteromedial thigh free flap: a primary reconstructive option or second best? Curr Opin Otolaryngol Head Neck Surg 2018;26(05):312–318
77 Zhou X, Wang J, Qiang L, Rui Y, Xue M. Outcomes of using a modified anteromedial thigh perforator flap for repairing the anterolateral thigh free flap donor site: a retrospective clinical review. Medicine (Baltimore) 2018;97(16):e0491
78 Gong ZJ, Zhang S, Ren ZH, Zhu ZF, Liu JB, Wu HJ. Application of anteromedial thigh flap for the reconstruction of oral and maxillofacial defects. J Oral Maxillofac Surg 2014;72(06):1212–1225

Appendix A: Flap mnemonic examples

Table of contents

Flap type	Anatomic location	Flap
Fasciocutaneous	Scalp	Temporoparietal fascia
	Trunk	Scapular
		Parascapular
		Groin
	Upper extremity	Deltopectoral
		Supraclavicular
		Lateral arm
Muscle	Trunk	Latissimus dorsi
		Pectoralis major
		Rectus abdominis
	Lower extremity	Gluteus maximus
		Gracilis
		Gastrocnemius
Bone	Trunk	Iliac crest
	Lower extremity	Fibula
Perforator	Trunk	Superficial inferior epigastric artery
		Thoracodorsal artery perforator
		Deep inferior epigastric perforator
	Upper extremity	Free radial forearm
	Lower extremity	Superior gluteal artery perforator
		Inferior gluteal artery perforator
		Tensor fascia lata
		Anterolateral thigh flap
		Anteromedial thigh flap

Fasciocutaneous

Scalp

Temporoparietal fascia flap

Preoperative (preop)	Doppler superficial temporal artery (STA)	
Position	Supine, gel donut, head turned away	
Pedicle	STA and vein N: auriculotemporal nerve	
Landmarks	Markings	• Pitanguy's line • Preauricular incision extending cephalad toward vertex for 12 cm with Y-extension • Boundaries between zygomatic arch and temporal fusion line (within temporal fossa)
	Proximal	Zygomatic arch
	Distal	Temporal fusion line
Plane	Subsuperficial temporal fascia, supra/subdeep temporal fascia	
Protection	Frontal branch, auriculotemporal n, middle temporal branch; alopecia (minimal cautery use); bony prominences—padding	
Postoperative (postop)	No direct pressure Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[10,11]

Trunk

Scapular

Preop	Doppler pedicle	
Position	Lateral decubitus (with sandbag)/prone	
Pedicle	Circumflex scapular artery (and vein)—transverse branch N: none	
Landmarks	Markings	• Triangular space: - 1st line: midpoint of scapular spine to tip of scapula - 2nd line: at upper 2/5th of line 1, to lateral border of scapula • Center axis on axis (transverse flap): laterally between axilla and lateral scapular border, medially midway between medial border of scapula and midline • Pinch test for primary closure
	Proximal	Midline/scapular spine (midway between medial border of scapula and midline)
	Distal	Posterior axillary line/midback (laterally between axilla and lateral scapular border)
Plane	Subfascial plane toward triangular space (medial to lateral)	
Protection	• Bony prominences—padding • Prone—globe protection, gel rolls, pillow under ankles, foam around face, arms abducted < 90 degrees and externally rotated on arm boards above head	
Postop	No direct pressure on flap Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[12–14]

Parascapular

Preop	Doppler pedicle	
Position	Lateral decubitus (with sandbag)/prone	
Pedicle	Circumflex scapular artery (and vein)—vertical branch N: none	
Landmarks	Markings	• Triangular space localization landmarks - 1st line: midpoint of scapular spine to tip of scapula - 2nd line: at upper 2/5th of line 1, to lateral border of scapula • Center skin on axis; superiorly just inferior to triangular space, inferiorly midway between tip of scapula and posterior superior iliac spine (PSIS) (oblique line) • Pinch test for primary closure
	Proximal	Superiorly just inferior to triangular space
	Distal	Inferiorly midway between tip of scapula and PSIS (oblique line)
Plane	Subfascial plane distal to proximal	
Protection	• Bony prominences—padding • Prone—globe protection, gel rolls, pillow under ankles, foam around face, arms abducted < 90 degrees and externally rotated on arm boards above head	
Postop	No direct pressure Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[12–14]:

Groin

Preop	Femoral artery pulse, Doppler	
Position	Supine with sandbag under hip	
Pedicle	Superficial circumflex iliac artery (and vein) N: none	
Landmarks	Markings	• Line: 2.5 cm inferior and parallel to line from pubic tubercle to anterior superior iliac spine (ASIS) • Flap: centered over line, 2.5 cm above and 5 cm below inguinal ligament (1/3rd above and 2/3rd below)
	Proximal	Lateral (ASIS)
	Distal	Medial border of sartorius
Plane	Suprafascial plane to lateral border of sartorius then subfascial plane to medial border of sartorius	
Protection	Femoral vessels, lateral femoral cutaneous nerve	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[15–18]

Upper extremity

Deltopectoral

Preop	Not applicable (N/A)	
Position	Supine	
Pedicle	1st to 3rd (2nd most dominant) perforating branches of the internal mammary artery (and veins) N: 2nd–4th intercostal nerves	
Landmarks	Markings	• Mark: sternum, infraclavicular line, deltopectoral groove, anterior axillary line, and nipple • Boundaries between sternum to anterior axillary line - Superiorly from infraclavicular line to 4th intercostal space (above nipple) • Narrower the pedicle = more arc of rotation
	Proximal	Deltopectoral groove/anterior axillary line
	Distal	Sternum/infraclavicular line (to 4th intercostal space above nipple) supraclavicular
Plane	Subfascial (lateral to medial)	
Protection	Cephalic vein	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor) No direct pressure	

Sources: Adapted from.[19–23]

Supraclavicular

Preop	Doppler, computed tomography angiogram (CTA)	
Position	Supine with bolster under shoulders, head to contralateral side	
Pedicle	Supraclavicular artery (with venae comitantes) N: supraclavicular nerve branches	
Landmarks	Markings	• Triangle: inferiorly by clavicle, medially by posterior border of SCM, laterally by external jugular vein (origin of supraclavicular artery) • Skin island: elliptical/fusiform design over supraclavicular and shoulder/upper arm • Pinch test for primary closure
	Proximal	Infraclavicular/base of neck
	Distal	Mid-deltoid
Plane	Subfascial	
Protection	Spinal accessory nerve and supraclavicular nerves	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor) ± drain/s Position to decrease pedicle strain (i.e., semiflexed neck position)	

Sources: Adapted from.[24–26]
Abbreviation: SCM, sternocleidomatoid.

Lateral arm

Preop	Doppler, tourniquet	
Position	Supine or lateral decubitus	
Pedicle	Posterior radial collateral artery (venous system: superficial—cephalic vein; deep—venae comitantes) N: posterior brachial cutaneous and posterior antebrachial cutaneous	
Landmarks	Markings	• Line between deltoid insertion and lateral epicondyle • Skin pedicle: centered over the axis ± cephalic vein if possible • Pinch test for primary closure
	Proximal	Deltoid insertion
	Distal	Lateral epicondyle of humerus
Plane	Subfascial dissection	
Protection	Radial nerve, cephalic vein	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor) Posterior elbow splint	

Sources: Adapted from.[27–29]

Muscle

Trunk

Latissimus dorsi

Preop	N/A	
Position	Lateral decubitus (sterile mayo stand with pillow and free arm draped)	
Pedicle	Thoracodorsal artery and vein; n: thoracodorsal nerve	
Landmarks	Markings	• Mark posterior axillary line, posterior iliac crest, dorsal midline, scapula tip, T7 (uppermost medial origin), superior and lateral borders of muscle • Skin paddle design: transverse, vertical or oblique • Most inferior limit is 8 cm from PSIS
	Proximal	Axillae
	Distal	PSIS/dorsal midline
	Medial	Posterior midline
	Lateral	Posterior axillary line
Plane	Supramuscular and submuscular	
Protection	Thoracolumbar fascia (thoracolumbar hernia) Bony prominences (gel pads), axillary roll, pillow between knees	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor) Drain/s in back donor	

Sources: Adapted from.[30–35]

Pectoralis major

Preop	N/A	
Position	Supine with shoulder bump, arms at sides	
Pedicle	Thoracoacromial artery and vein N: lateral + medial pectoral n	
Landmarks	Markings	• Mark axis, sternal border, clavicle, anterior axillary line, 6th intercostal space (lower border of pectoralis major), template of deltopectoral flap (to preserve as salvage) • Mark skin paddle: -Females: horizontal line in IMF - Males: designed medial to NAC in males • Boundaries of skin > any skin overlying muscle
	Proximal	Clavicle/lateral border of sternum
	Distal	Sternocostal head
Plane	Supramuscular plane, submuscular plane	
Protection	Internal mammary artery perforators	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor) Drains	

Sources: Adapted from.[36]
Abbreviations: IMF, Inframmary Fold; NAC, nipple areolar complex.

Rectus abdominis

Preop	Doppler	
Position	Supine	
Pedicle	Superior and deep inferior epigastric arteries, corresponding veins Innervation: intercostal nerves (7–12th)	
Landmarks	Markings	• Mark midline, xyphoid, costal margin, umbilicus, pubis, ASIS • Mark skin paddle: - TRAM: superior incision above umbilicus to include perforators 1. Pinch test: inferior incision marked - VRAM: median straight line (leaving umbilicus in situ), curvilinear laterally, directly over muscle 2. Pinch test: for primary closure 3. Center paddle over muscle (or laterally if diastasis)
	Proximal	Inframammary fold/costal margin
	Distal	Pubis crease
Plane	• Above arcuate line: only anterior sheath • Below arcuate line: only muscle harvested	
Protection	Note any diastasis rectus, hernias, abdominal incisions	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor) Drains	

Sources: Adapted from.[37–40]
Abbreviations: TRAM, transverse rectus abdominus myocutaneous; VRAM, vertical rectus abdominus myocutaneous.

Lower extremity

Gluteus maximus

Preop	CTA, magnetic resonance angiography, Doppler	
Position	Prone, lateral decubitus, or jackknife	
Pedicle	Superior and inferior gluteal arteries and veins, first perforator of profunda femoris artery and venae comitantes N: inferior gluteal nerve	
Landmarks	Markings	• Mark gluteal crease • Four lines: - Line 1: PSIS—coccyx - Line 2: PSIS—ischial tuberosity - Line 3: PSIS—greater trochanter - Line 4: greater trochanter to midpoint Line 1 (PSIS—coccyx) • SGA = junction of medial and middle 1/3rd of Line 3 (PSIS—troch) • IGA = intersection Line 2 (PSIS—ischial tub) and Line 4 (greater troch to mid Line 1) • Line 4: piriformis muscle • SGA perforators above piriformis and lateral to SGA >> major perforator in triangle lateral to SGA and between Lines 3 and 4 • IGA perforators below piriformis and above gluteal crease • Skin paddle: designed as large V-Y design (if future readvancement needed) centered over perforators if possible/over muscle • Rotation: inferior-based rotation with pivot point at medial base of muscle
	Proximal	Third from PSIS to trochanter
	Distal	Midline (gluteal cleft)
Plane	Supramuscular, submuscular	
Protection	Sciatic nerve, posterior femoral cutaneous nerve	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor) Drain	

Sources: Adapted from.[41,42]
Abbreviations: SGA, superior gluteal artery; IGA, inferior gluteal artery.

Gracilis

Preop	N/A	
Position	Supine frog-leg, lithotomy	
Pedicle	Medial circumflex femoral artery (with venae comitantes) N: obturator nerve, anterior femoral cutaneous nerve	
Landmarks	Markings	• ID adductor longus tendon • Mark axis, perforators, estimated pedicle entry, obturator nerve (2–3 cm proximal to pedicle and enters at 45 degrees angle), and skin paddle • Skin paddle boundaries: proximal 2/3rd of thigh, 2–3 cm on each side of muscle • Pinch for primary closure • TUG: skin paddle located transversely over perforators ~ 10 cm distal to pubic tubercle - Placed slightly posterior to gracilis to capture the bulky tissue in gluteal region - o Anterior limit is femoral triangle
	Proximal	Medial tibial condyle
	Distal	Pubis
Plane	Subfascial	
Protection	Greater saphenous vein	
Postop	Drain	

Sources: Adapted from.[43–45]
Abbreviation: TUG, transverse upper gracilis

Gastrocnemius

Preop	Tourniquet	
Position	Supine with leg internally/externally rotated, lateral decubitus	
Pedicle	Medial and lateral sural arteries (w/venae comitantes) N: branches of the tibial nerve	
Landmarks	Markings	• Direct access thru vertical incision 2 cm posterior to tibial border for medial, 2 cm posterior to fibula for lateral incision is in upper 1/3rd • Access thru existing wound
	Proximal	• Medial head: medial condyle of femur • Lateral head: lateral condyle of femur
	Distal	Achilles tendon
Plane	Areolar plane, submuscular plane	
Protection	Lesser saphenous vein, sural nerve	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor) Elevation of lower extremity ± gentle compression dressings	

Sources: Adapted from.[46–49]

Bone

Trunk

Iliac crest (deep circumflex iliac artery flap)

Preop	Doppler	
Position	Supine with bump below hip, hip slightly flexed	
Pedicle	Deep circumflex iliac artery and venae comitantes	
Landmarks	Markings	• Markings of ASIS, inguinal ligament, femoral vessels, iliac crest, flap axis • Medial incision from lateral to femoral pulse to ASIS • Lateral incision over crest (or skin paddle) • Skin paddle boundaries 2/3rd above and 1/3rd below crest, from ASIS to posterior axillary line
	Proximal	Medial incision over inguinal ligament—lateral to femoral pulse to ASIS
	Distal	Iliac crest/gluteus medius/tensor fascia lata
Plane	Suprafascial over external oblique	
Protection	Lateral femoral cutaneous, genitofemoral, ilioinguinal, and iliohypogastric nerves; external iliac vessels	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor) Activity modifications	

Sources: Adapted from.[50,51]

Lower extremity
Fibula

Preop	Tourniquet, CTA (especially in traumatic injuries)	
Position	Supine or lateral decubitus	
Pedicle	Peroneal artery, lateral inferior genicular artery, anterior tibial perforator, and venae comitantes N: superficial peroneal nerve	
Landmarks	Markings	
	Proximal	Head of fibula
	Distal	Lateral malleolus
Plane	Supraperiosteal, subperiosteal, intramuscular	
Protection	Compartments: lateral (common peroneal nerve, around neck of fibula), anterior compartment (anterior tibial artery), posterior (deep; peroneal artery); ankle stability (leave >6 cm of bone proximal to lateral malleolus for ankle stability)	
Postop	Leg in splint, activity modifications, no direct pressure Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[52–54]
Scapula—please see above
Sources: Adapted from.[3–5]

Perforator

Trunk
Superficial inferior epigastric artery

Preop	CTA, Doppler	
Position	Supine	
Pedicle	Superficial inferior epigastric artery and venae comitantes N: segmental intercostals T10–T12	
Landmarks	Markings	
	Proximal	ASIS/pubic tubercle
	Distal	Umbilicus
Plane	Suprafascial to external oblique + internal oblique, deep to Scarpa's fascia	
Protection	Femoral vessels	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor) No full hip extension	

Sources: Adapted from.[55–57]

Thoracodorsal artery perforator

Preop	Doppler, color Doppler ultrasonography, or CTA	
Position	Lateral decubitus with shoulder abduction and 90 degree of elbow flexion (axillary roll, pillow between knees, sterile mayo stand with pillow, and arm free draped)	
Pedicle	Thoracodorsal artery (descending/vertical branch) N: posterior rami of lateral cutaneous branches of intercostal nerves	
Landmarks	Markings	• Standard latissimus dorsi landmarks • Line: starting 8 cm below axilla (vascular hilum of latissimus dorsi) to PSIS • Skin island: centered at ant border of latissimus dorsi • Pinch test: identify widest portion of skin paddle to close by primary closure
	Proximal	Lateral border of inframammary fold
	Distal	Latissimus dorsi muscle
Plane	Suprafascial, subfascial	
Protection	Thoracodorsal nerve	
Postop	Flap checks (Doppler, color, cap refill, temp, turgor) No full abduction of shoulder	

Sources: Adapted from.[58]

Deep inferior epigastric perforator

Preop	CTA of the abdomen, Doppler	
Position	Supine	
Pedicle	Deep inferior epigastric artery, two veins N: 10th–12th intercostal n cutaneous branch/s	
Landmarks	Markings	• Mark superior incision above umbilicus to include perforators • Pinch test: inferior incision marked tentatively
	Proximal	Superior portion of the umbilicus
	Distal	6–8 cm superior to the vaginal cleft
Plane	Subfascial/submuscular	
Protection	Superficial inferior epigastric artery/venae	
Postop	Position: flexion of trunk Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[59–65]

Upper extremity

Free radial forearm

Preop	Allen's test, tourniquet	
Position	Supine	
Pedicle	Radial artery + vein (venae comitantes ×2, cephalic vein) ± lateral/medial antebrachial ± lateral/medial cutaneous nerves	
Landmarks	Markings	• 1 cm distal to antecubital fossa to scaphoid tubercle • Skin boundaries between antecubital fossa and wrist crease • Width up to 2/3rd of forearm circumference with 1/3rd lateral to radial artery to include cephalic vein
	Proximal	Midforearm
	Distal	Wrist crease
	Ulnar	Flexor carpi radialis tendon
	Radial	Brachioradialis tendon
Plane	Suprafacial and subfascial	
Protection	Flexor carpi radialis and brachioradialis tendons and paratenon; dorsal branch of the radial nerve	
Postop	Splint (if osseocutaneous), split-thickness graft for donor coverage Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[66,67]

Lower extremity

Superior gluteal artery perforator

Preop	Doppler	
Position	Prone/lateral decubitus	
Pedicle	Superior gluteal artery (and vein) N: inferior gluteal nerve	
Landmarks	Markings	• Mark gluteal crease • Mark three lines: - Line 1: PSIS—coccyx - Line 2: PSIS—greater trochanter - Line 3: greater trochanter to midpoint Line 1 • SGA = junction of medial and middle 1/3rd of Line 2 • Piriformis muscle = Line 3 • SGA perforators above piriformis and lateral to SGA, major perforator in triangle lateral to SGA and between Lines 3 and 4 • Skin paddle: oriented obliquely in superolateral direction • Skin pinch for primary closure
	Proximal	Trochanter
	Distal	Midline (gluteal cleft)
Plane	Subfascial	
Protection	Sciatic nerve, inferior gluteal vessels	
Postop	Drain Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[68]

Inferior gluteal artery perforator

Preop	Doppler	
Position	Prone/lateral decubitus	
Pedicle	Inferior gluteal artery (and vein) N: inferior gluteal nerve	
Landmarks	Markings	• Mark gluteal crease • Mark four lines: - Line 1: PSIS—coccyx - Line 2: PSIS—ischial tuberosity - Line 3: PSIS—greater trochanter - Line 4: greater trochanter to midpoint Line 1 (PSIS—coccyx) • IGA = intersection Line 2 (PSIS—ischial tuberosity) and Line 4 (greater trochanter to mid Line 1) • Piriformis muscle = Line 4 • IGA perforators below piriformis and above gluteal crease. • Skin paddle: transverse paddle, 2 cm below gluteal crease; superior incision determined by pinch test and include perforators (1ry closure <= 10 cm)
	Proximal	Trochanter
	Distal	Midline (gluteal cleft)
Plane	Subfascial	
Protection	Sciatic nerve, superior gluteal vessels	
Postop	Drain Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[69]

Tensor fascia lata

Preop	Doppler	
Position	Supine	
Pedicle	Ascending or transverse branch lateral circumflex femoral artery and venae comitantes N: superior gluteal n, lateral cutaneous branch of T12 and lateral femoral cutaneous nerve of the thigh	
Landmarks	Markings	• Mark: ASIS, lateral femoral condyle, axis, perforators • Skin paddle: ASIS to 10 cm proximal to knee; greater trochanter posteriorly to lateral edge of rectus femoris border medially -Leave distal 10 cm of Iliotibial tract to maintain knee stability. • Pinch (< 9 cm can close by primary intention)
	Proximal	Greater trochanter
	Distal	Lateral condyle of tibia
Plane	Subfascial plane, submuscular plane	
Protection	Lateral femoral cutaneous nerve	
Postop	Hip flexion (if pedicled), drains Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[70–72]

Anterolateral thigh flap

Preop	Doppler	
Position	Supine	
Pedicle	Descending branch of lateral circumflex femoral artery and vena comitantes N: lateral femoral cutaneous nerve	
Landmarks	Markings	• Lines: -ASIS to superolateral patella -At midpoint, draw circle with 3 cm radius. • Skin island: medial edge of rectus femoris to lateral edge of vastus lateralis - Proximally 10 cm inferior to ASIS and distally 7 cm superior to patella • Pinch test: width of 10 cm can be taken for primary closure
	Proximal	ASIS
	Distal	Superolateral border of the patella
Plane	Supra- or subfascial	
Protection	Intermuscular septum (between rectus femoris and vastus lateralis muscles) to protect vessels	
Postop	Skin graft for donor, drain/s Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[73,74]

Anteromedial thigh flap

Preop	Doppler	
Position	Supine	
Pedicle	Lateral circumflex femoral descending artery—septocutaneous branch	
Landmarks	Markings	• Lines: -ASIS to superolateral patella • Skin island: medial edge of rectus femoris to lateral edge of vastus lateralis - Proximally 10 cm inferior to ASIS and distally 7 cm superior to patella • Pinch test: width of 10 cm can be taken for primary closure
	Proximal	ASIS
	Distal	Superolateral border of the patella
Plane	Subfascial	
Protection	Great saphenous vein Saphenous nerve	
Postop	Drain/s Flap checks (Doppler, color, cap refill, temp, turgor)	

Sources: Adapted from.[75–78]