9 Applied Anatomy

Rosemary

What we know is not much. What we don't know is enormous.

(Pierre-Simon Laplace)

M. F. Klaassen and E. Brown, *An Examiner's Guide to Professional Plastic Surgery Exams*, https://doi.org/10.1007/978-981-13-0689-1_9

9.1 Key Tips

1. Questions tend to be on functional and applied anatomy
2. Common embryological questions would be on the mandible and branchial clefts
3. Knowledge of flap anatomy of the whole body is essential
4. Orientate the anatomical specimen before identifying the specific structure
5. Practice anatomy questioning, as you would for the long and short clinical cases

Applied anatomy is the foundation of surgery. For the final fellowship exams in plastic surgery it is the comprehensive working knowledge of gross and micro-anatomy from the head-to-foot, and everything in between. Surface and functional anatomy, aesthetic landmarks, important vital structures, dissection planes, surgical approaches and the specific anatomy of local, loco-regional, pedicled and free flaps are the syllabus. Some details of osteology, embryological anatomy and anatomical anomalies are also considered.

9.2 Surface and Functional Anatomy

1. The superficial temporal, occipital and supratrochlear branches of the carotid vascular system.
2. The location of the supraorbital, infraorbital and mental sensory nerves.
3. The location and approach to the main branch of the facial nerve.
4. The terminal branches of the facial artery.
5. The location and preservation of the greater auricular nerve.
6. The radial and ulnar vascular pedicles.
7. The posterior radial collateral pedicle.
8. The origin of the thoraco-acromial axis and its pectoral branches.
9. The circumflex scapular and thoracodorsal pedicles.
10. The deep inferior epigastric pedicle.
11. The superficial and deep circumflex iliac pedicles.
12. The descending branch of the lateral circumflex femoral pedicle.
13. The peroneal nerve and peroneal pedicle.
14. The sural artery and nerve.
15. The lateral tarsal branch of dorsalis pedis.
16. The medial plantar pedicle [1].

9.3 Aesthetic Landmarks

1. The facial dimensions and congruent contours
2. The brow and hairline symmetry
3. The lower eyelid/cheek junction contours

4. The malar prominence
5. The medial cheeks—nasolabial folds and jowls
6. The lateral cheeks and the Obaji cheek profile
7. The cupid's bow/philtral column relationships
8. The nasal aesthetic subunits and contours
9. The chin point and submental regions/cervicomental angle
10. The neck length and contour including the suprasternal notch and sternomastoid definition

9.4 Osteology

1. The facial bones
2. The mandible
3. The skull base
4. The first rib
5. The scapula
6. The radius
7. The ulnar
8. The bones of the hand and wrist
9. The ilium
10. The fibula

9.5 Surgical Approaches

1. To the temporomandibular joint
2. To the infratemporal fossa
3. To the orbit
4. To the nasal cavity
5. To the maxilla
6. To the mandible
7. To the various zones of the neck
8. Tracheostomy (emergency and elective)
9. To the thoracic duct
10. To the brachial plexus
11. To the ulnar, radial and median nerves
12. Hand anatomy
13. Rib cartilage harvest
14. Internal mammary pedicle
15. To delay a TRAM flap
16. Origin and branches of the DIEP flap
17. Sciatic nerve
18. Fasciotomy for limb compartment syndrome

9.6 Local and Regional Flaps (Pedicled and Free)

1. Scalp rotation, transposition and keystone local flaps
2. Forehead flaps
3. Cervicofacial flaps
4. Nasolabial and FAMM flaps
5. Fan and Karapandzic flaps + Bernard flaps
6. Submental flaps
7. Trapezius flaps
8. Delto-pectoral flaps
9. Pectoralis major and minor flaps
10. Latissimus dorsi flaps (antegrade and reverse)
11. Lateral arm flap
12. Forearm flaps (radial, ulnar and posterior interosseous)
13. Dorsal metacarpal flap
14. Rectus abdominis (pedicled, free and perforator flaps)—TRAM, VRAM, ORAM, DIEP
15. The groin flap
16. DCIA flap
17. TFL flap
18. Gluteus maximus flap
19. Anterolateral thigh flap
20. Saphenous flap
21. Gastrocnemius flaps (medial and lateral)
22. Soleus flap
23. Fibula flap
24. Reverse sural artery flap
25. Dorsalis pedis flap
26. Extensor digitorum brevis flap
27. Great toe flaps (wrap around composite flap of Morrison)
28. Medial plantar fasciocutaneous flap of Morrison

9.7 Knowledge of Dermatomes

A dermatome is defined as an area of skin supplied by nerves from a single spinal root.

Behan et al. have shown that island fasciocutaneous flaps can be safely and predictably raised based on a knowledge of the dermatomal anatomy. Vessels travel with nerves (motor and sensory) and therefore the dermatomes can be used as an aide memoire or road map for localisation of the many named and unnamed, random or axial, perforators. This provides improved vascularity and healing with reduced risk of complications.

The angiotome concept evolved from the understanding that the trilaminate composition of skin, fat and fascia supplied by fasciocutaneous, musculocutaneous or septocutaneous vessels can be designed as reconstructive flaps based on vascular and neural anatomy. The term ANGIOTOME refers to a vascularised segment with an axial input, which can be extended in size by its communications with adjacent vessels. Behan first started applying this principle to reconstructive limb challenges in the 1970s and 1980s.

Taylor et al. developed the concept of angiosome in-vitro based on an extensive number of cadaver injection studies. The ANGIOSOME refers to the 3D block of tissue supplied by a source vessel directly or indirectly. The difference between angiotome and angiosome concepts is subtle, but the critical principle is that flaps based on the angiotomal theory do not require dermal connections. They are islanded on their fasciocutaneous perforators and there is a predictable and observable hyperaemic phase. This may be due to a denervation, sympathectomy or metabolic effects.

The role of dermatomes is again noted in the description of various named flaps:

Groin flap L1 dermatome.

Radial forearm flap C6, C7.

Lateral arm flap C6, C7, C8.

Medial instep flap L 5.

9.8 Embryological Development

The candidates should have a working knowledge of the embryological anomalies for the anatomical regions listed. The relevance of this to clinical reconstructive challenges is a key concept for exam preparation and potential discussion with te examiners.

Face.

Limbs.

Hand.

Genitalia.

9.9 Anatomy of Common Flaps

9.9.1 Temporalis Flap [2]

This flap was originally described by Golovine in 1898. The origin of the temporalis muscle is from the temporal fossa and the deep surface of the temporal fascia and its converging fibres end in a tendon inserted in to the coronoid process of the mandible. Its blood supply is from two deep temporal arteries and venae comitantes deep to the muscle. The nerve supply is from the deep temporal branches of the mandibular nerve. The flap is raised via a hemicoronal incision and can be designed as muscle only, muscle + galea and muscle + bone. Clinical uses include: orbit, midface, skull base, palate and pharynx and facial reanimation for facial palsy. The temporalis muscle can be used for filling an exenterated orbit and the pedicled temporalis fascia for covering the cartilage construct of an ear reconstruction.

The temporal fascia can also be used as a new ligament for the TMJ following dislocations.

9.9.2 Forehead Flap [3]

The original application of this flap was by Susruta in 600 BC for nasal reconstruction. The First World War saw widespread use of this flap by Plastic surgery pioneers Gillies and Pickerill, for nasal and facial reconstruction of severe facial injuries. Forehead flaps can be of many designs based on the rich vascular network of superficial temporal vessels laterally and supratrochlear and supraorbital vessels medially. Variations include: paramedian, total forehead, prefabricated and tissue expanded forms of the forehead flap. Some frontalis muscle fibres should be left where the pedicles emerge from the skull. Clinical uses include: nose reconstruction, eyelid reconstruction and potentially intra oral reconstruction.

9.9.3 Facial Artery Flaps [4]

Flaps based on branches of the facial artery have been described since 1881. The majority of these apply to the facial skin, but a musculo-mucosal flap has also been described by Pribaz in 1992, the FAMM flap (Facial Artery Musculo-Mucosal flap). The tortuous facial artery and accompanying venae comitantes follow the nasolabial fold deep to the mimetic muscles and superficial to the buccinator masticatory muscle. The superior labial branch arises at the corner of the mouth and the terminal branch is the angular artery towards the medial canthal region. Skin nasolabial flaps for lower nose and columellar reconstruction, superiorly or inferiorly based, are common repairs in facial surgery and can be in single or two stages.

The musculo-mucosal flap should be designed anterior to Stenson's duct, extending from retromolar trigone to the labial sulcus at the level of the nasal alar margin. It is useful in intra-oral reconstruction of the hard palate, floor of mouth, lip and ventral tongue for small defects.

9.9.4 Cervicofacial Flaps [5]

Esser first described this rotation flap in the German literature, in 1918. Frame and Levick described their Anterior Flicklift flap in 2012 for facial rejuvenation and it has recently (2017) been described for reconstructive problems. Many variations of cervicofacial flaps are possible based on the extensive random pattern blood supply, including the perialar crescentic advancement flaps of Webster (1955). The facelift plane does not need to include SMAS or platysma as demonstrated by Pennington and Poole. Small or large cutaneous defects of the hemiface, lower eyelid/cheek junction, malar and preauricular regions can be repaired with these flaps.

9.9.5 Supraclavicular Flap [6]

Lamberty described this axial-patterned fasciocutaneous flap in 1979. The supraclavicular artery is a branch of the transverse cervical artery in the neck at the mid-clavicular level. The latter artery arises from the thyrocervical trunk and supplies trapezius muscle. The supraclavicular artery runs laterally towards the acromioclavicular joint where it can anastomose with branches of the posterior circumflex humeral vessels. The flap can be islanded and is very useful in head and neck reconstruction including neck scar contractures.

9.9.6 Trapezius Flap [7]

McCraw et al. described this flap in 1979 for head and neck reconstruction. The trapezius muscle myocutaneous flap is a broad triangular muscle arising from the cervicothoracic vertebrae and inserting into the spine of the scapula. The transverse cervical artery is the blood supply (with ascending and descending branches), and the spinal accessory nerve (XI) the motor nerve. It can be used as either a muscle flap or a musculocutaneous flap for large defects of the posterior neck and occipital area. The large donor site is best closed with a keystone perforator island local flap.

9.9.7 Deltopectoral Flap [8]

Bakamijian described this pectoral skin flap for pharyngoesophageal reconstruction in 1965. It is an axial-patterned fasciocutaneous flap based on the second and third intercostal branches of the internal mammary artery, arborizing with the thoracoacromial cutaneous branch in the deltoid region. Delay procedures can help capture more distal extensions supplied by angiosomes of the subscapular and circumflex humeral vessels. The flap has largely been superceded by thinner and more pliable free fasciocutaneous flaps (radial forearm and anterior thigh).

9.9.8 Pectoralis Major Flap [9]

Ariyan described this musculocutaneous flap for head and neck reconstruction in 1979, whilst Arnold and Pairolero emphasised its uses in anterior chest wall (sternotomy) repair the same year. The triangular pectoralis major muscle, on the upper and front part of the chest arises from the sternum, clavicle and first five ribs, inserting as a tendon into the intertubercular groove of the humerus. Its vascular pedicle is deep to the muscle from the pectoral branch of the thoracoacromial axis (from the second part of the axillary artery). The surface landmark for this pedicle follows an oblique line from the coracoid process to the xiphisternum. The motor nerve supply is from the lateral pectoral nerve to the upper half and the medial pectoral nerve to the lower half of the muscle. This flap can be used as a pure muscle flap including a turn-over variant for sternotomy wounds, or as a musculocutaneous flap. Beware of RIMA and LIMA coronary artery donors.

9.9.9 Latissimus Dorsi Flap [10]

The original Latissimus flap was described by Tansini in 1906, derided by Halsted and rediscovered by Olivari in 1976. This large flat triangular muscle covering the lower back arises from the posterior iliac crest, sacrum, thoracolumbar vertebrae (T6–T12) plus ninth and tenth ribs, and inserts as a tendon behind pectoralis major in the intertubercular groove of the humerus. The dominant vascular pedicle, deep to the muscle is the thoracodorsal artery and vein, arising from the subscapular vessels, with a reverse option available on the lumbosacral perforators. The motor nerve supply is from the thoracodorsal nerve from the posterior cord of the brachial plexus. This flap is used in breast and chest wall reconstruction, upper limb reconstruction using a pedicled variant and lower limb reconstruction as a free flap.

In 50% of cases there is an angular branch to the lateral border of the scapular, making an osteo-myocutaneous variant possible.

9.9.10 Hand Flaps [11]

Multiple flaps have been described for hand reconstruction. These include Cross finger flaps of Gurdin et al. in 1950, First Dorsal Metacarpal Artery flap (FDMA) of Foucher in 1979, the Homodigital islanded finger flaps of Venkatswami (1980) and Evans (1988), and the dorsal hand flap of Quaba (1990). The FDMA arises from the lateral radial artery in the anatomical snuffbox and runs distally over the first dorsal interosseous muscle, terminating as the external dorsal artery of the index finger. Innervation is via the terminal branches of the superficial radial nerve. The dorsal hand flap is based on a direct branch of the dorsal metacarpal artery, which perforates just distal to the inter-tendinous connections of the extensor digitorum communis, or 5–10 mm proximal to the corresponding metacarpo-phalangeal joint. Cutaneous hand defects from trauma or cancer excision, with exposure of tendons, nerves or bone are the main indications for these innovative local flaps.

9.9.11 Forearm Flaps [12]

Yang et al. from China are credited with the first foreram flaps based on the radial artery for thumb reconstruction in 1978. Biemer in Germany learned these and inspired Soutar, Scheker, Tanner et al. from Glasgow to perform the first radial forearm free flap for retromolar trigone reconstruction in 1983. Lovie, Duncan and Glasson described the ulnar forearm free flap in 1984. The radial artery and venae comitantes are found in the lateral intermuscular septum of the forearm, distal to insertion of pronator teres and between FPL and FCR, with multiple branches supplying the adjacent flexor forearm muscles, distal radial border of the radius and overlying skin. The subcutaneous veins of the cephalic and basilic venous systems are usually incorporated. Antegrade or reverse flow options are available. The ulnar artery follows the ulnar nerve and can be used equally in similar fashion, but the radial artery must be intact and confirmed by the Allen flow test.

The ulnar artery in the proximal forearm is the segment distal to the common interosseous branch, which runs between FCU and FDS muscle bellies. Perforator branches are located here including a constant main fasciocutanous perforator 3–4 cm distal to the common interosseous branch. Both flaps provide thin pliable skin with or without a small segment of bone for reconstruction of the hand and/or the head and neck as a free flap.

9.9.12 Rectus Abdominis Flaps [13]

Interestingly, the free Transverse Rectus Abdominis Musculocutaneous (TRAM) flap was first performed by surgical trainees Fogdestam and Hamilton in 1978 whilst completing their anatomical studies in Gothenburg. The injection and dissection studies of the lower abdominal wall had started a year or two earlier when they were microvascular fellows in Melbourne. Holmström, who was an assistant at their two first clinical operations, subsequently published those cases omitting Fogdestam's and Hamilton's names.

Hartrampf, Scheflan and Black published the pedicled transverse abdominal island flap, some 4 years later in 1982. The paired rectus abdominis muscles arise from the pubic crest/tubercle and insert into the 5–7th costal cartilages. The dominant pedicle to the lower TRAM flap is via the perforators of the deep inferior epigastric vessels (DIEa, venae comitantes and superficial inferior epigastric vein). This has implications for the free perforator variants of the flap first published by Koshima in 1989 and popularised as the DIEP flaps by Blondeel et al. a decade later. Variants of the TRAM flap include the VRAM (vertical design) and ORAM (oblique design). The CT angiogram/venous phase as championed by Acosta et al. has refined the planning for perforator free flap breast reconstruction. Chest and pelvic/vaginal reconstruction are also good indications for rectus abdominis flaps.

9.9.13 Groin Flap [14]

McGregor and Jackson published the axial-patterned groin flap in 1972. It is based on the superficial circumflex iliac artery pedicle (SCIA) and venae comitantes. The main pedicle branches from the femoral artery in the groin traversing obliquely parallel to the inguinal ligament. Its point of origin is found as a landmark 2.5 cm inferior to the midpoint of a line from the anterior superior iliac spine (ASIS) to the pubic tubercle. The flap is raised laterally, superficial to the deep fascia until dissection reaches the lateral border of Sartorius, when the deep fascia should be included for safety. This flap's best clinical application is as a pedicled flap for covering hand and wrist defects, but requires a second stage about 4 weeks later.

Bilateral islanded groin flaps have been used for vaginal reconstruction and the classic bipedicled groin flap approach, is very safe in elective groin lymph node dissections.

The free groin flap has the disadvantage of a short vascular pedicle. Of all the flaps in the body, the groin flap has the least conspicuous donor site, being a fine linear scar.

9.9.14 Buttock Flaps [15]

Fujino described the gluteus maximus musculocutaneous flap in 1975. This large quadrilateral shaped muscle in the gluteal region has an extensive origin from the Ilium, Sacrum, Coccyx and their adjacent ligaments and fascia. It inserts in to the iliotibial tract of the fascia lata and the gluteal tuberosity of the femur. It has a double blood supply on its undersurface, the superior and inferior gluteal arteries. Its nerve supply is from the inferior gluteal nerve. When used as a large rotation flap it is the classical repair of sacral and ischial pressure sores.

9.9.15 Tensor Fascia Lata Flap [16]

Hill et al. described the free TFL in 1978. This muscle on the upper lateral aspect of the thigh has its origin from the iliac crest, anterior superior iliac spine and the deep surface of the fascia lata. It is inserted between the two layers of the iliotibial tract of the fascia lata. Its vascular supply is from the descending branch of the lateral circumflex femoral artery arising from the profunda femoral artery. Large venae comitantes accompany the artery as it enters the TFL muscle at the level of the greater trochanter, 10 cm inferior to the ASIS. Its nerve supply is from the superior gluteal nerve. Surgical uses of this flap include the repair of trochanteric and ischial pressure sores.

9.9.16 Gracilis Flap [17]

This was initially described as a musculocutaneous flap by Orticochea in 1972. The gracilis muscle is long and thin arising from the lower half of the body of the pubis and inserts into the medial surface of the upper tibia. Its main blood supply is the medial circumflex femoral artery arising from the profunda femoral artery and entering gracilis on its deep surface, at the junction of the upper quarter of the muscle with the lower three quarters. The obturator nerve (L1, L2) supplies the muscle, entering alongside the vascular pedicle after passing through the obturator foramen. The surface landmark of the anterior border of gracilis muscle is a line drawn from the pubic bone to the adductor tubercle of the femur. It can be used as a muscle or musculocutaneous flap, either on its vascular pedicle or as a free flap. The obturator artery branch to adductor longus should be preserved. Surgical uses include vaginal and perineal reconstruction and as a free muscle transfer.

9.9.17 Anterolateral Thigh Flap [18]

Song pioneered this flap in 1984. It is a large fascio-septocutaneous flap based on the cutaneous branch of the lateral circumflex femoral artery, which arises from the profunda femoral artery. The surface landmark for the perforator is a line drawn from the ASIS to the lateral edge of the patella bone, and the exact point is where the upper third of this line meets the middle third. The perforating cutaneous vessels emerge at the apex of the triangle formed by the confluence of rectus femoris, tensor fascia lata and vastus lateralis muscles.

It was originally used for trochanteric and ischial pressure sores but is now very popular as a free tissue transfer in head and neck reconstruction.

9.9.18 Posterior Thigh Flap [19]

Hurwitz described this cutaneous sliding flap in 1980. This is a triangular flap on the upper posterior aspect of the thigh. It is based on the end artery of the inferior gluteal artery which enters medially between the greater trochanter and ischium, deep to gluteus maximus and continuing vertically alongside the posterior cutaneous nerve of the thigh (S1–S3). The vascular territory extends as far distally as the popliteal fossa and it can be combined as a skin flap with the hamstring muscles. This flap is used to repair mid-sized pressure sores of the ischium and trochanteric regions. The flap is advanced upwards in to the defect and the donor repaired in V-Y fashion.

9.9.19 Reverse Sural Artery Flap [20]

Masquelet described this fasciocutaneous flap in 1992. This is a distally based fasciocutaneous or adipofascial flap on the midcalf. The superficial sural artery follows the course of the sural nerve and short saphenous vein of the posterolateral calf. The proximal vessel is found descending between the heads of gastrocnemius muscle, towards the ankle. Distal septocutaneous peroneal artery perforators approximately 5 cm above the lateral malleolus, capture the sural artery territory and allow for reverse flow. A skin island up to 9 × 6 cm can be planned and a 2.5 cm cuff of adipofascial tissue should be preserved around the pedicle. It is ideal for defects of the distal leg, ankle and foot.

9.9.20 Gastrocnemius Muscle Flaps [21]

Pers and Medgyesi are referenced as early pioneers of these calf muscle flaps in 1973. The pedicles are the lateral and medial sural branches of the popliteal artery and accompanying venae comitantes. The motor nerves are branches of the tibial nerve. The neurovascular pedicles enter the gastrocnemius muscles on their deep surfaces. The medial head of gastrocnemius is the larger flap of the two. Surgical uses include the inferior thigh, knee and lower extremity.

9.9.21 Extensor Digitorum Brevis Muscle Flap [22]

Barfred and Reumert described this flap in 1973.

This is a small multipennate muscle arising from the lateral aspect of the calcaneum and lying obliquely under the extensor digitorum longus tendons to the toes. The lateral tarsal branch of the dorsalis pedis artery is the dominant vascular pedicle, found just distal to the extensor retinaculum. It enters the muscle deeply and is accompanied by venae comitantes which drain into the anterior tibial vein. Surgical uses of this muscle flap include small skin defects of the distal leg, ankle and foot.

9.9.22 Medial Plantar Flap [23]

Morrison described this fasciocutaneous flap on the medial, non-weight-bearing side of the foot in 1983. It provides glabrous skin supplied by perforators from the medial plantar branch of the posterior tibial artery deep to abductor hallucis muscle. The skin island is raised distal to proximal, off the flexor hallucis brevis and just deep to the neurovascular plane. The cutaneous fascicle bundles of the medial plantar nerve can be carefully preserved to retain sensation in the flap. This requires an interneural dissection under tourniquet and with magnification. The distal branches of the medial plantar nerve are preserved. Surgical uses include heel reconstruction as a pedicled flap and for the contralateral heel as a free flap.

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