I. BREAST ANATOMY

A. Mastering breast anatomy is essential for understanding how the breast changes with aging and principles of reconstruction, reduction and mastopexy (Figure 1).
A. Breast
1. Glandular and adipose tissue are enclosed by superficial fascia and deep fascia overlying chest wall muscles.
2. Cooper’s ligaments: suspensory attachment of the breast to the overlying fascia anteriorly. Its attenuation results in breast ptosis.
3. Boundaries for mastectomy:
   a. Superior border is the clavicle
   b. Inferior border is the rectus abdominis fascia/inframammary fold (IMF)
   c. Medial border is the sternum
   d. Lateral border is the anterior border of latissimus dorsi muscle
4. Important elements in planning breast surgery
   a. Breast footprint: superior margin of the breast is lower than the clavicle
   b. Conus: three-dimensional shape, projection, and volume of the breast tissue
   c. Skin envelope: adequate quantity and quality to drape the conus
5. Nipple areola complex (NAC)
   a. Diameter 30-45mm
   b. Aesthetic pleasing breast shape has NAC position - proportion 45:55 (Figure 2)

Figure 2. UPL upper pole line, NM nipple meridian, LPL lower pole line, UPS upper pole slope, LPC lower pole convexity.

B. Vasculature
1. Arterial Supply (Figure 3):
a. Internal mammary artery perforators (60%)
b. Lateral thoracic artery (30%)
c. Thoracoacromial artery: pectoral branches supply pectoralis major muscle and overlying breast tissue
d. Intercostal arteries 3, 4, 5
e. NAC receives blood supply through subdermal plexus and parenchymal vessels, dominant supply from 2nd and 3rd branches of IMA. After nipple sparing mastectomy blood supply is the subdermal plexus. After breast reduction or mastopexy the blood supply is the breast pedicle or parenchyma as you must divide the skin and subdermal plexus to reposition the NAC.

**Figure 3. Arterial blood supply to the breast**

2. Venous drainage (Figure 4)
   a. Mainly to axillary vein but some to internal mammary and intercostal veins.
   b. Veins are more superficial on the medial breast and deeper on the lateral aspect of the breast
   c. NAC - superomedial/ medial and inferior pedicles contain the most extensive and more reliable venous drainage patterns for NAC.
Figure 4. Resultant venogram of the right breast using plain radiography showing the venous drainage of the breast, including the inferolateral veins (green), superolateral veins (orange), medial veins (pink and purple), and inferior veins (blue). Note the anastomoses between the dominant veins around the nipple-areola complex.


C. Lymphatics
1. Dominant drainage to axilla (97%)
2. To internal mammary nodes (3%)
3. Level I: nodes lateral to lateral border of pectoralis minor
4. Level II: nodes lying beneath pectoralis minor
5. Level III: nodes medial to medial border of pectoralis minor and extending to apex of the axilla

D. Nerve supply (Figure 1)
1. Cervical plexus: sensory branches of C3, 4 from supraclavicular nerve
2. Lateral branches of intercostal nerves:
   a. Provide sensation to lateral side of breast
   b. Lateral cutaneous branch of the 4th intercostal nerve provides major sensory innervation to nipple (T4 dermatome)
   c. Medial branches of intercostal nerves 2-7 provide sensation to medial breast

II. BREAST RECONSTRUCTION

A. Breast cancer now affects one in eight women over the course of their lifetime and is the leading cause of cancer-related death in women.
B. All patients that have undergone or will undergo mastectomy are entitled to breast reconstructive surgery covered by insurance (Women’s Health Act, 1998). Symmetry procedure for the contralateral breast is also covered.

C. Patients undergoing mastectomy should be offered a preoperative referral to a plastic surgeon.

D. In relation to the timing of the mastectomy, breast reconstruction can be:
   1. Immediate (during the same anesthetic)
   2. Delayed-immediate (uncommon) different anesthesia, different surgery day, but before the skin has fully-healed/retracted
   3. Delayed

E. Possible preferences of patients:
   1. No reconstruction: women may choose to wear an external prosthetic.
   2. Reconstruction of breast mound to attain close to natural breast shape, feel, contour.
   3. Breast mound reconstruction may or may not be followed with NAC reconstruction depending on patient preference.
      a. Mastectomy defects frequently include loss of the NAC (such as in skin-sparing mastectomy). Mastectomy skin necrosis is the unplanned loss of skin due to inadequate blood supply following surgery.
      b. Previous irradiation, such as in BCT, may cause difficulties with wound healing, skin contraction and discoloration, capsular contracture, and fat necrosis
   4. If desired, following unilateral breast reconstruction, the opposite breast can be contoured to obtain symmetry, using mastopexy, reduction or augmentation mammoplasty.

F. Mastectomy options
   1. Breast conservative therapy--BCT (50-70% of breast cancer patients), also called partial mastectomy: removal of the tumor only. Requires post-op radiation. The patients may opt for:
      a. Oncoplastic surgery: i.e. small implants, thoracic anterior perforator TAP flap, muscle-sparing latissimus dorsi flap, intercostal artery perforator flap, lipofilling with or without scar subcision. Timing of this is variable but operating on radiated tissue conveys increased risk.
      b. Contralateral breast reduction for symmetry
   2. Nipple-sparing mastectomy (NSM)/Total skin sparing mastectomy (TSSM): removal of all breast tissue with preservation of all skin, including NAC (Figure 5). The reconstruction can be with autologous tissue or implant-based.
3. Simple (total) mastectomy: removal of all breast tissue, including NAC. Reconstruction in delayed fashion will require tissue expansion or autologous tissue.

4. Modified radical mastectomy: removal of all breast tissue, NAC, pectoralis fascia, as well as Level I and II lymph nodes. Same principles of reconstruction as for simple mastectomy.

5. Halsted radical mastectomy: removal of all breast tissue, nipple/areolar complex, pectoralis major and minor muscles, muscular fascia, Level I, II, and III lymph nodes (this procedure does not improve disease control compared to modified radical mastectomy and is largely of historical interest now)

6. Goldilocks mastectomy: performed through a Wise skin pattern. The inferior de-epithelized mastectomy flap is folded under the Wise pattern in order to obtain a breast mound. Can be fat grafted for further volume.

G. Techniques of breast reconstruction
1. Choose techniques based on:
   a. Patient preference
   b. Need for adjuvant radiotherapy before or after the breast reconstruction (Figure 6, 7)
   c. Uni- or bilateral mastectomy
   d. Defect of the breast envelope: NSM, total simple mastectomy, mastectomy skin necrosis
   e. Immediate or delayed reconstruction (increased skin requirements)
   f. Habitus of the patient: BMI, size of the breast or desired size of the reconstructed breasts, possible donor sites for autologous reconstruction
2. Implant-based reconstruction
   a. Can be:
      i. Direct-to-implant reconstruction: place implant at time of mastectomy
      ii. Use of tissue expanders (TE) with staged breast implant insertion once adequate skin expansion has occurred.
   b. Acellular dermal matrix (ADM) may be used for partial or total coverage of the device.
   c. Breast implants may be saline or silicone filled devices
3. Autologous reconstruction
   a. Pedicled flaps
      i. Latissimus dorsi myocutaneous flaps (Figure 8). For adequate volume of the reconstructed breast usually combined with:
(a) TE with or without ADM; after completion of the tissue expansion, the TE is eventually exchanged for a breast implant
(b) +/- Fat grafting
ii. Pedicled TRAM flap (Figure 9, 10) using superior epigastric vessels for blood supply (rectus abdominus muscle is used as a “carrier” for the blood vessel)

Figure 8. Three different skin paddles for the latissimus dorsi flap. (Above, left) Oblique skin island design in two different orientations. (Above, right) Vertical skin island design (Below, left) Horizontal skin island design at the bra line.

Figure 9. Pedicled TRAM flap

Figure 10. Hartrampf's classification of TRAM flap zonal blood supply. Hartrampf names zone I directly over the muscle pedicle and zone II lying across the midline. (Right) Ninkovic’s classification of TRAM flap and deep inferior epigastric perforator flap zonal blood supply. Holm et al. performed an in vivo study of deep inferior epigastric perforator flaps with indocyanine green and concluded that although zone I remains the most reliably perfused zone, any flow across the midline is less than ipsilateral flow and proposed that Hartrampf’s zone II should be renamed zone III.
b. Free flaps
   i. Technically more demanding, requiring microvascular techniques. Flap is entirely disconnected from abdomen and sewn to vessels in the chest.
   ii. Recipient vessels may be internal mammary vessels (or their perforators) or the thoracodorsal vessels (Figure 11).
   iii. As compared to pedicled TRAM, lower risk of partial flap loss and fat necrosis, but potential total flap loss
   iv. Transverse Rectus Abdominis Myocutaneous (TRAM) flap - rectus abdominus muscle, fat and skin on a transverse paddle, based on inferior deep epigastric artery (DIEA); requires abdominal wall reconstruction/anterior rectus sheath with mesh
   v. Muscle sparing TRAM flap (MS-TRAM)
      (a) Only a portion of the rectus muscle is harvested (Figure 12)
      (b) In unilateral reconstruction can harvest zones 1-3 (TRAM or MS-TRAM)
   vi. Deep Inferior Epigastric Perforator (DIEP) flap - only skin and fat is harvested on perforating vessels from DIEA, technically more demanding, clinical relevance of not taking any muscle compared with muscle sparing techniques is still under debate. CT angiography may help with perforator harvest planning (Figure 13).
      (a) Unipedicled (Figure 14)
      (b) Double pedicled
   vii. Superficial Inferior Epigastric Artery (SIEA) flap: SIEA has to be of adequate caliber (artery with a palpable pulse, vein >1mm) to be used for anastomosis. Not all patients have an adequate SIEA, may be affected by the position of the lower abdominal incision. SIEV may be the dominant venous drainage and is commonly preserved in case it is needed for venous outflow.
   viii. Gluteal artery perforator (GAP) flap on superior (S-GAP) or inferior (I-GAP) gluteal artery perforators (Figure 15): Typically reserved for patients without sufficient abdominal wall tissue or for those who are not candidates for abdominal based reconstruction
   ix. Transverse upper (TUG) gracilis flap (Figure 16) and vertical upper gracilis (VUG) flap
   x. Turbocharging:
      (a) Vascular augmentation using the vascular sources within the flap territory
      (b) Example: performing a DIEP flap to the recipient internal mammary vessels then anastomosing an additional vessel from this system
   xi. Supercharging:
      (a) Vascular augmentation using a distant source of vessels such as axillary or thoracodorsal vessels
      (b) Example: performing a pedicled TRAM flap, then augmenting the flow by anastomosing the deep inferior epigastric vessels to the thoracodorsal vessels
Figure 11. Exposure of the thoracodorsal recipient vessels (left) and internal mammary recipient vessels (right). *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconstr Surg 2017;139(1):204e-229e.*

Figure 12. Classification of muscle-sparing free TRAM procedures. MS0 refers to sacrifice of the full width of the rectus muscle, MS1 preserves the lateral segment, MS2 preserves the lateral or medial segments, and MS3 preserves the entire muscle (equivalent to a DIEP flap). MS1 can be further subdivided into MS1-M and MS1-L, depending on whether it is the medial or lateral segment that is spared. *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconstr Surg 2017;139(1):204e-229e.*
Figure 13. Computed tomographic angiography

Figure 14. DIEP flap
Figure 15. SGAP flap and IGAP flap
H. Fat grafting
1. Does not increase the risk of breast cancer recurrence
2. Volume augmentation of a reconstructed breast
3. Improve shape of the breast, corrects contour deformities, commonly in the upper pole for fullness

I. Ipsilateral corrections include:
1. Nipple reconstruction
2. Scar revisions
3. Volume adjustments either by reduction (i.e. direct resection or liposuction) or by augmentation (i.e. implants, additional flaps or lipofilling)
4. Shape corrections: can be accomplished by repositioning and/or rotating the flap or implant, skin resections, and adjustments of the inframammary fold or other borders of the flap.

J. Symmetry is the goal of the reconstruction. The contralateral side may be adjusted by the common techniques of:
1. Augmentation
2. Reduction
3. Mastopexy

K. Nipple-areola complex (NAC) reconstruction. NAC is one of the aesthetic units of the breast. For the completeness of the aesthetic of the breast some women chose to have the NAC reconstructed.

1. Nipple sharing (graft from the contralateral nipple) if available and dimensions adequate (Figure 17)
2. Local skin flaps (C-V, C-Y, star flap, skate flap) with or without use of cartilage, ADM graft, revision with fat grafting to improve projection (Figure 18, Figure 19)
3. Intra-dermal color tattoo to match opposite NAC:
   a. May follow nipple reconstruction procedure
   b. 3-D tattoo to simulate also the nipple projection from frontal view (no surgical nipple reconstruction)
4. In-situ or remote-donor skin graft (groin or labia majora/minora) may also be used for areola

Figure 17. Drawings demonstrating the two commonly accepted techniques for nipple sharing. Both harvest 50 percent of the nipple. (Above) Drawings show sagittal harvest for nontubular nipples. The lower half of the nipple is taken and the donor site closed with simple interrupted sutures, leaving an imperceptible scar under the nipple. (Below) Drawings show coronal harvest for tubular, large nipples. Note that the donor site is closed with a purse-string suture, leaving a natural appearing nipple.

Figure 18. C-Y flap diagram

Figure 19. Different techniques for nipple reconstruction. (Above) CV flap. (Center) Star flap. (Below) Skate flap.
REFERENCES