Outline:

Introduction: Much has been written about free and rotational flaps, but there are few book chapters dedicated to grafts. This presentation is designed to discuss techniques for harvesting grafts for a variety of head and neck reconstruction challenges. It will focus on the procedures and complications of harvesting autologous grafts with a few pearls thrown in. It will mention some common general indications for harvest.

- Grafts:
  - Bone
    - Calvarium—split in situ and full thickness
    - Iliac crest
  - Cartilage
    - Costal
    - Auricular
    - Septal
  - Skin
    - Split thickness
    - Full thickness
  - Fat

Bone grafts:

Bone biology is important to understand for grafting. Similar to stages of skin graft assimilation, bone undergoes several interrelated processes before integration and replacement by new bone. Critical to all of these is blood supply.

Surprisingly, most donor osteoblasts necrose after harvesting. Instead, most active osteoclasts and osteoblasts producing new bone on the devitalized graft are delivered by new blood vessel invasion in a process called osteocoinduction. The few surviving osteoblasts do produce new bone through osteogenesis. Finally, the third process of new bone production comes from the grafted bone itself. It releases active factors called bone morphogenetic proteins that stimulate osteoprogenitor cells from the host to differentiate into osteoblasts for bone production.
Cancellous bone grafts generate bone more quickly than cortical bone grafts, but a greater portion is resorbed. Depending on the defect and type of graft used, bony consolidation can be expected within 4-10 weeks, and once bone is consolidated, the effect is permanent. Bone grafts are usually used to correct bony deformities in the facial skeleton.

**Tips on bone grafting in general to reduce complications:**

- Limit length of skin incisions. Avoid subcutaneous dissection: instead, directly incise superficial fascia and periosteum. Periosteal elevators should be sharp, and chosen for width and curvature appropriate to harvested graft. Retractors specific to anatomic site should be chosen. Osteotomes are specific to chosen graft: thin for the ilium, thin and short for the calvarium. Use swabs compressed under the retractors to obtain hemostasis instead of cautery—more time efficient which leads to less bleeding. Use Hemovac in the scalp, but not in the thorax or ilium. Do not use saws or burrs that are dull as they can burn the bone. Bone dust from burring or sawing is useless to fill dead space as it will be resorbed, whereas filler bone chips milled in an osteomicrotome encourage osteoblastic activity and new bone production.

**Calvarium:**

A study of calvaria in 281 skulls from the Hamman-Todd osteological collection was used to map thickness at 40 different points and compare results among sexes, races, and ages. They found female skulls to be slightly thicker on average than male skulls. The thickest area of the parietal bone for female skulls was lateral and posterior, whereas male skulls tended to be thicker in the posterior midline. African American skulls were found to be thicker than Caucasian, particularly in the posterior parietal bone. There was no significant thickness difference among the ages studied (21 to 105 years), but bone becomes more brittle with less diploe thickness as age advances. The authors suggest that the ideal area for bone grafting is 2 cm lateral to the sagittal suture line and 2 cm medial to the squamous suture in the posterior parietal bone.

Two variations for harvesting parietal bone grafts are total splitting or the split in situ methods. The preoperative CT should be evaluated for parietal bone thickness and any midline abnormalities. Plan the grafts at least 1 cm from coronal suture and 1.5 cm from sagittal suture. A posterior coronal incision optimizes hair coverage and reduces paresthesias. After incision, clamp the posterior edge with Dandy clamps. Incise the pericranium and elevate with sharp square elevators, then pull the scalp down with firm hand pressure. Obtain hemostasis with cautery on the scalp and Gelfoam and bone wax on the skull.

Split in situ grafts are first outlined on the outer table with an oscillating saw, then a burr is used to deepen the incisions to the diploe. About 5-10 mm anterior to the initial graft, a saw is used to tangentially remove a leading edge to allow calvarial splitting with sharp osteotomes. The outer table grafts are removed and the diploe is taken in sheets down to the inner table. Once hemostasis is obtained excess bone wax should be removed. Any dural tears should be exposed and sutured, then covered with bone chips. The skull is then covered with Surgicel, a Hemovac is placed, and the scalp closed in layers.
The total splitting technique is the same as any neurosurgical approach. Cranial perforations are created with a brace, then the dura is elevated with Penfield elevators. A Gigli saw is used to perform the beveled craniotomies. The strips obtained should be split manually so bone is not burned or wasted as dust. Closure starts by suspending the dura at the edges of the defect, then placing half the split segments back. They will not need fixation if they are replaced in continuity from their source. Fill the burr holes with extra bony tissue, then cover with Surgicel and place Hemovacs posteriorly. Close in layered fashion.4

Ilium:

The ilium can provide a sizeable corticocancellous graft up to 11 cm in length with no weak points. When properly harvested and reconstructed, postoperative pain is decreased, and the bone can regenerate in 2 years for reharvesting. The key portion of the procedure is the splitting of the crest between the abdominal and gluteal aponeuroses, then wiring the crest back together to preserve its structure and function. The distal ends must be wired to stable bone, bridging the defect created by the harvest.5

Position the patient supine or with one hip slightly elevated. Arrange the surgical team for the most efficient movement. Incision is 5 cm below the crest to avoid the lateral femoral cutaneous nerve. Be vigilant to avoid laceration of the outer periosteum and gluteal muscles. Pull the skin medially to position the planned incision over the iliac crest. Incise through the superficial fascia and use hemostats to control bleeding vessels. Insert two serrated Farabeuf retractors to medialize abdominal soft tissues. Palpate the anterior spine, crest, and tuberosity. Incise through the periosteum and aponeurosis without elevating the periosteum of the crest. Use sharp osteotomes to split the crest obliquely one cm longer than the planned harvest anteriorly and posteriorly. Then use a sharp osteotome inferomedially to create the medial leaf of the split crest. Cut all along the desired length before elevating medially so it may move as a single piece. The lateral part is split in the same manner, but the curve of the split must follow the convexity of the crest to save the most bone without driving into the gluteal muscle. This is also retracted in one piece. Sponges and specialized retractors are used to reflect the leafs. Extract the bone grafts as planned for reconstruction. Control bleeding by applying bone wax or cautery of the gluteus.

To close, place a large piece of Gelfoam into the donor site. Four 26 gauge wires are used to approximate the medial and lateral leafs of the split iliac crest. The ends of the leafs should rest on the anterior superior spine for stability. Turn the ends of the wires in to avoid postoperative pain on palpation. Close in layers.5

Fractures of the leafs of the crest can occur—they can be managed the same way if only one leaf is fractured. Bleeding is managed with cautery or bone wax.5

Cartilage:

An excellent graft material: easy to carve but maintains structural integrity, easy to harvest or procure from donor banks, and easily preserved. It is frequently used in reconstruction of nasal or ear defects, or in cosmetic nasal surgery. Cartilage can also be useful for orbital reconstruction and correcting tarsal plate defects.6
Rib cartilage:

For constructing a helical framework in ear reconstruction, the 6th and 7th ribs are most useful because the synchondrosis between them creates an adequate size donor for the majority of the helix. The rim is often carved separately from the 8th or 9th rib as it must have adequate length. It has been noted that the cartilage at the periphery of the rib is more prone to warping over time than the central portion of the cartilage. This consideration is most critical to rhinoplasty grafts.

Complications of costal cartilage harvest are most commonly pain, chest wall deformity, clicking of the ribs, and donor site scar. Pneumothorax and infection are less frequent. Postoperative pain peaks at 7 days, then resolves slowly and steadily. Most patients do not complain of significant pain after three months. Chest wall deformity can be reduced or eliminated with reimplantation of left over cartilage if the perichondrium is preserved during harvest. The perichondrium provides necessary support for regeneration of cartilage, or the cartilage is simply resorbed. Pneumothorax or pleural tears may be managed intraoperatively with suturing, patching, or a chest tube if necessary.

There are several variations of costal cartilage harvest techniques designed to limit complications. One of these is patient selection. There is general agreement that a child should have chest circumference of at least 60 cm before undergoing rib graft harvest. Agreement also exists regarding preserving the posterior perichondrium in situ to decrease risk of pneumothorax.

One of the larger series reported in the literature uses the following method. The incision is planned to overlie the 7th rib in males and along the inframammary crease in females. The dissection is carried down to the perichondrium. This is incised along the center of the cartilage with care not to damage the cartilage itself. The perichondrium is raised with specially curved elevators to limit damage posteriorly which could result in pneumothorax. Perichondrium is raised 1 cm past the costochondral junction for ease in harvest. A Doyen raspatory is inserted around the cartilage 1 cm away from the costochondral junction and used as a template to incise through the cartilage while protecting the posterior perichondrium from damage. The perichondrium is then sutured in interrupted fashion with 4-0 nylon, leaving one area open. The cartilage left over from carving the auricular framework is cut into 2-3 mm blocks and a funnel is used to introduce the cartilage back into the perichondrial pockets which are then sewn shut. Local anesthetic is used to create a nerve block of the area. The stub of cartilage is left at the costochondral junction to promote continued longitudinal rib growth, especially important in children.

Another method of harvesting a large amount of cartilage for ear reconstruction suggests that a bupivicaine pump may be left in the operative field to reduce postoperative pain for the first 48 hours. This study advocated reconstruction of the donor site with left over cartilage as well, and found that it does reduce chest wall deformity. Scars were noted to be an average of 5.5 cm in length, of little consequence to most patients compared to the benefit of a new ear.

Usually, less volume of costal cartilage is required for rhinoplasty. One method describes a central segment harvest of costal cartilage grafts without removal of the rib. Once the rhinoplasty surgeon determines that septal and conchal bowl cartilage will be insufficient for correction of nasal defects, the assistant begins harvesting rib cartilage in vivo. A 3 cm incision is made. Dissection is carried down to the perichondrium, which is incised and elevated. A 45 degree wedge is removed from
the anterior rib, usually the seventh, and grafts are sequentially harvested, keeping the superior and inferior curvature of the rib structure intact. Care is taken not to incise through the posterior perichondrium. Once sufficient rib volume is harvested, the perichondrium is reapproximated and the incision is closed in a layered fashion. No drain is required, and few complications were reported.10

Auricular cartilage:

Conchal cartilage is a convenient graft for use in rhinoplasty, particularly secondary rhinoplasty when septal cartilage is insufficient. Usually the cymba concha and cavum concha are harvested in one piece,12 but some authors endorse leaving a supporting strip continuous with the helical crus for support.13

There is some disagreement in the literature regarding the anterior approach vs. the posterior approach. Both approaches seem to have a similar rate of complications, less than 5% hematomas.12-14

The anterior approach is described. The auricular graft harvest may be under general or IV anesthesia. Local anesthetic is infiltrated on the anterior ear in the subperichondrial plane to assist in hydrodissection, and in the posterior ear in the subcutaneous plane. The anterior incision is carried along the lateral edge of the perpendicular concha. The flap is lifted in the subperichondrial plane with blunt dissection or scissors. Once exposed, the intended cartilage is incised into the posterior subcutaneous tissue. Most of the cymba concha and cavum concha can be harvested together. A rim of perpendicular cartilage should remain for structural integrity and to prevent scar inversion. The posterior perichondrium should be harvested with the cartilage and the graft should be placed in a saline bath on the back table. Care should be taken to avoid excessive cautery use in obtaining hemostasis as this can cause tissue necrosis and flap loss postoperatively. 4-0 Chromic, prolene, or nylon may be used to close the incision. Chromic should be used for a delicate basting incision to bring the flaps together and reduce hematoma formation, but the flaps will necrose if this stitching is too tight. Antibiotic ointment is used, then a bolster is placed and secured with 3-0 Prolene, gently as well, and left in place for 3 days.12

The posterior approach is described in a similar manner. In addition, these authors advocate leaving a 5 mm strut of helical crus intact to prevent step deformity or total collapse of the ear structure.13 Of note, other authors report no gross aesthetic deformities,12 even in studies of conchal cartilage complications.14

The authors that advocate a posterior approach and helical strut preservation approach the graft by preserving 2 mm rim of perpendicular cartilage throughout and a 5 mm lateral strut from the crus helicis to the outer rim. First, local anesthetic is infiltrated in the same manner, then the harvest is planned from the anterior side and a 30 g needle is used to mark the boundary with multiple punctures with brilliant green. The ear is then retracted forward and a posterior incision is made. The dissection proceeds down to the cartilage. The cartilage is gently incised along the markings and the dissection proceeds in the subperichondrial plane to avoid damage to the anterior skin. Only the marked portions of cymba concha and cavum concha cartilage are removed along with their posterior perichondrium. The subcutaneous layer is closed with 4-0 chromic and the skin is closed with running locking 4-0 nylon. Separate bolsters are placed in each graft site and gently sutured with 4-0 nylon, removed 5 days later.13
The most common early complication of conchal cartilage harvest is hematoma (3-5%), followed by hypesthesia, anesthesia, and pain at the harvest site (2% each). Late complications include hypesthesia at the incision (10%), hyperesthesia of the scar (3%) and unsightly scar formation (3%). A clever packing technique is described: use Merocel that has been cut transversely to pack the cymba and cavum concha, and gently secure them through a posteriorly placed full size merocel. Saline was used to expand the Merocel, and it was left in place for 5 days. The authors report no hematomas and no skin loss or wound dehiscence from dressing pressure in the Merocel treated patients.

**Septal Cartilage:**

Nasal septal cartilage is the most common and desirable material for rhinoplasty work. It is strong and able to maintain its structure for a variety of applications. However, 10 mm caudal and dorsal struts must be left in place for structural integrity of the nose, and this limits the amount that can be harvested for grafts.

Septal cartilage harvest is carried out in much the same way as a septoplasty. First decongestion with cottonoids soaked in Afrin is performed. The septum is then infiltrated with lidocaine and 1:100,000 epinephrine in the subperichondrial plane bilaterally to assist with hydrodissection. Time is given for the vasoconstriction to take effect, then the mucosa is incised, often using a hemitransfixion incision (at the caudal border of the septal cartilage) or Killian incision (2-3 mm cephalic to the caudal border). The mucosa and perichondrium are then raised in a bloodless plane back to the bony/cartilaginous junction and from the dorsum down to the maxillary crest. The incision is planned, then may be carried out with a variety of instruments including a Cottle elevator, D knife, or 15 blade. The contralateral mucosal plane is then elevated with a Freer, cottle, or even just suction or a nasal speculum, and the graft is harvested, leaving at least 10 mm dorsal and caudal struts. The mucosal layers can be brought together with a quilting stitch using 4-0 chromic and a Keith needle, and the mucosal incision is closed with interrupted absorbable sutures. Splints or packing may also be placed.

Septal cartilage may provide an insufficient amount of cartilage for all planned grafts in a rhinoplasty. This is particularly problematic in the Asian population and in secondary rhinoplasty. The external nose size has not been found to be predictive of the amount of cartilage available for harvest.

**Skin grafts:**

Compared to skin flaps, skin grafts have less optimal color match and texture. Skin grafts fall into two major categories: full thickness and split thickness. Split thickness skin grafts include the epidermis and varying amounts of the dermal layer of skin. Full thickness grafts include the epidermis and the entire dermis.

Split thickness skin grafts can be used to cover any wound that has a blood supply sufficient to support its survival. Some areas cannot support a split thickness graft such as cortical bone without periosteum, cartilage without perichondrium, tendon, nerve, or any surface with intact squamous epithelium. Sites that have undergone radiation are more difficult to cover with a skin graft. Split thickness skin grafts contract more than full thickness grafts. Common donor sites are the thigh, abdomen, and buttock. They are harvested using a dermatome set to the appropriate thickness and the graft may be meshed to provide larger coverage. Once the graft is placed, it is immobilized for 5-7 days.
for the initial stages of healing to take place and prevent shear, seroma, or hematoma to form, usually with a pressure dressing. The graft donor site can be covered with an occlusive dressing. A moist donor area heals more rapidly than a dry area.19,20

The phases of healing are as follows: serum imbibition, revascularization, and organization. Serum imbibition lasts about 2 days from initial placement on the site. Fibrin secures the graft in place initially and plasma transudate provides nutrients. Revascularization is believed to happen with two complementary processes: neovascularization (ingrowth of new vessels from the site into the graft) and inosculation (direct anastomoses of graft and host vessels). The last phase is organization. Leukocytes initiate this process shortly after graft placement, then as revascularization progresses, fibroblasts appear and proliferate, eliminating the fibrin layer. The organization phase resolves after about 9 days.21

Full thickness skin grafts consist of the entire epidermal and dermal layers of skin. They retain their original color and texture after transplantation. If hair follicles are harvested, they continue to grow on the grafted tissue. They contract less than split thickness grafts but they take longer to revascularize. Defects of nasal tip, eyelids, and auricle are popular applications for full thickness grafts. Donor sites should match in color and texture if possible. Often preauricular, postauricular, supraclavicular, and upper eyelid sites provide a good match for facial applications and are frequently used.19

Fat grafting:

Fat may be harvested from a variety of sites and used to fill cosmetic defects such as prominent nasolabial folds. It has the advantage over other fillers of being native tissue, but its disadvantages include unpredictable amounts of reabsorption (up to 100%) and prolonged facial edema after transplantation. It also may require multiple procedures to obtain the desired results.6,22

One author has created a technique of harvesting, refining, and injecting fat that takes a delicate approach to the fatty tissue and attempts to keep the structure intact. He reports near permanent results with little reabsorption in over 1000 cases. It does not use traditional liposuction equipment, but a 10 cc luer lock syringe under gentle hand suction is used to harvest the fat from the abdomen or buttocks. The fat is gently refined in a centrifuge to spin the oil and lidocaine off. The intact fatty cellular tissue is removed from the middle layer, and injected on withdrawing a blunt cannula in small layered quantities under local anesthesia to achieve the desired effect. Cold compresses or ice packs are used for 2 to 3 days postoperatively. The emphasis of this technique is to deliver intact fatty parcels to well vascularized recipient tissues, and they become integrated seamlessly into the native tissue. The most consistent early complication is prolonged facial edema, significant for up to 2 months, attributed to the hundreds of passes with a blunt cannula. Bruising and hematomas may be caused by sharp injection of local anesthetic but usually resolve quickly. The most common late complication is under correction, which may require a repeat procedure. Fat necrosis has also been noted when fat is injected into areas that had previous silicone injections. Perforating the oral mucosa can cause infection of the injected areas if it is not noted and managed. Damage to vital structures can occur but is less likely with the blunt cannula method. Donor site pain, swelling, and infections can also occur.23
Conclusion:

Many grafts are available to the reconstructive and cosmetic head and neck surgeon for a variety of challenges. This grand rounds attempted to outline some general “how to” for graft harvest, and point out some complications and considerations when planning. This is by no means a comprehensive guide, and I point you to the excellent resources in the reference section for further details.

References

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