Basics of Flap Design
Reconstructive Ladder (Mathes & Nahai 1982)

- Consider the defect, systematically
- Move from simple to complex
- Occam’s Razor
- Sutton’s Law
- Ladder is simple, emphasizes closure over form and function
- Consider the goals:
  - Form, Function, Safety
Flap: Definition

- Tissue transferred from a donor site to a recipient site while maintaining its own blood supply
- Used when a defect cannot be closed primarily, should be allowed to heal secondarily, and cannot support a skin graft
- Donor site may closed primarily or with a STSG
- Flaps are created by raising 3 sides and using the 4th as a pedicle
- Length:width ratio should not exceed 2:1 to avoid vascular compromise
Evolution of Flaps

- All flaps were skin flaps or “random” flaps
- Raised **without regard to known blood supply**, only maintain the subdermal plexus
- Classification was easy, due to inherent limited blood supply
- Rigid length-to-width ratios
Milton (1970)

- Flap viability directly proportional to circulatory pattern
- McGregor & Morgan (1973) some regions of the body have discrete and relatively large subcutaneous vessels that pierce the deep fascia, predictably
- Axial flaps: comparatively huge cutaneous flaps, oriented along the axis of the vascular pathway
Musculocutaneous flaps

- **Orticochea:** (1972) clinical application that flat muscles could “carry” their overlying skin as composite flaps
- **McCraw:** (1977) studied vascular territories of several musculocutaneous units, flap dimensions and arcs of rotation
- **Ponten:** (1981) described a novel technique; skin flap based on vascular plexus of the deep fascia
Classifications

- **Mathes & Nahai (1979)**
  - *Muscle flap* research
  - Described 5 types of muscle based on circulatory pattern
  - Categorized on the type of deep fascial perforator

- **Cormack & Lamberty (1986)**
  - *Fasciocutaneous flaps* differentiated by origin of circulation of vascular plexus (3 types)

- **Nakajima (1986)**
  - *Fasciocutaneous flaps* (6 types) each based on a distinctly different perforator of the adipofascial layer
  - Looked at 3D reconstructions of angiograms of 28 segmental arteries
Mathes & Nahai (1979)

Figure 2.3 Mathes & Nahai's tripartite system of fasciocutaneous flaps is based on the three major types of deep fascial perforators.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Single vascular pedicle—eg, tensor fascia lata</td>
</tr>
<tr>
<td>II</td>
<td>Dominant pedicle(s) and minor pedicle(s)—eg, gracilis</td>
</tr>
<tr>
<td>III</td>
<td>Two dominant pedicles—eg, gluteus maximus</td>
</tr>
<tr>
<td>IV</td>
<td>Segmental vascular pedicles—eg, sartorius</td>
</tr>
<tr>
<td>V</td>
<td>Single dominant pedicle and secondary segmental pedicles—eg, latissimus dorsi</td>
</tr>
</tbody>
</table>

Nakajima (1986)

Figure 2.4 The six distinct deep fascia perforators according to Nakajima et al. A different type of fasciocutaneous flap can be sustained by each discrete type of perforator. S, source or "mother" vessel; F, deep fascia.
Common Source, Different paths
Angiosomes (Taylor & Palmer, 1987)

- 2 theories of blood supply to soft tissues
- #1: The angiosome is a composite unit of skin and underlying deep tissue supplied by the source artery
- #2: Two routes of supply to the integument, direct and indirect
  - **Direct**: vessels *primarily directed to the skin*, whether they pierce intermuscular septum or muscle
  - **Indirect**: vessels whose main supply is to muscle or another deep tissue, only *secondarily supply the skin*
Axial Pattern

- Supplied by **direct cutaneous vessels**
Axial Pattern Flaps

- Based on an anatomically defined configuration of vessels
- Unlike random pattern flaps, the defined blood supply means they can be local, regional, or distant; pedicled or free
Classification systems

- No system can perfectly categorize all flaps
- None would ever be accepted
Figure 2.11  The “atomic system” that enumerates all known characteristics that are essential to fully describe any flap (reprinted with permission from Tolhurst59).
6 C’s of Cormack & Lamberty (1986)

- Constituents (composition)
- Circulation
- Conformation (form/shape)
- Contiguity (destination)
- Construction (type of pedicle)
- Conditioning (preparation)
- Update to the atomic classification system (right)
Composition

- Cutaneous flap - skin and variable amount of subcutaneous tissue
- Fasciocutaneous - skin, fascia, intervening subcutaneous tissue
- Muscle flap - muscle only
- Myocutaneous flap - muscle, skin, & intervening tissue
- Osseous flap - vascularized bone only
- Osteomyocutaneous flap - muscle, skin, subcutaneous tissue
Contiguity

- ‘The Source’
- **Local flaps** - from adjacent to the defect
- **Regional flaps** - from the same anatomic region of the body as the defect (e.g. low extr, head and neck)
- **Distant flaps** - transferred from different anatomic region
Contiguity

- Flaps may be pedicled (remain attached to the blood supply at their source)
- Distant flaps may also be transferred as Free flaps using microsurgical techniques
Conditioning

- Increasing the reliability of the flap
- The ‘delay phenomenon’
  - 2 weeks prior to pedicled TRAM flap, divide the deep inferior epigastric artery; the superior epigastric supplies via choke vessels, flap is ‘preconditioned’
### 6C’s: Table

**Table 2.1** The complete classification of a flap

<table>
<thead>
<tr>
<th>Primary characteristics</th>
<th>Pedicled flap</th>
<th>Free flap</th>
<th>Secondary characteristics</th>
<th>Pedicled flap</th>
<th>Free flap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulation (blood supply)</td>
<td>Direct vessels</td>
<td>Direct vessels</td>
<td>Contiguity (destination)</td>
<td>Local</td>
<td>Free flap</td>
</tr>
<tr>
<td>Axial</td>
<td>Axial</td>
<td></td>
<td>Regional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septocutaneous</td>
<td>Septocutaneous</td>
<td></td>
<td>Distant</td>
<td>Unipedicled</td>
<td>Orthograde flow</td>
</tr>
<tr>
<td>Endosteal</td>
<td>Endosteal</td>
<td></td>
<td>Construction (flow)</td>
<td>Bipedicled</td>
<td>Orthograde flow</td>
</tr>
<tr>
<td><strong>Indirect vessels</strong></td>
<td>Indirect vessels</td>
<td></td>
<td>Unipedicled</td>
<td>Orthograde flow</td>
<td>Turbocharged</td>
</tr>
<tr>
<td>Myocutaneous</td>
<td>Myocutaneous</td>
<td></td>
<td>Orthograde flow</td>
<td>Retrograde flow</td>
<td>Supercharged</td>
</tr>
<tr>
<td>Periosteal</td>
<td>Periosteal</td>
<td></td>
<td>Retrograde flow</td>
<td>Supercharged</td>
<td></td>
</tr>
<tr>
<td><strong>Constituents (composition)</strong></td>
<td>Fasciocutaneous</td>
<td>Fasciocutaneous</td>
<td>Turbocharged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle/myocutaneous</td>
<td>Muscle/myocutaneous</td>
<td></td>
<td>Supercharged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visceral</td>
<td>Visceral</td>
<td>Conditioning (preparation)</td>
<td>Delay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nerve</td>
<td>Nerve</td>
<td>Tissue expansion</td>
<td>Tissue expansion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bone</td>
<td>Bone</td>
<td>Prefabrication</td>
<td>Prefabrication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cartilage</td>
<td>Cartilage</td>
<td>Conformation (geometry)</td>
<td>Special configurations</td>
<td>Tubed</td>
<td>Combined flaps</td>
</tr>
<tr>
<td>Other</td>
<td>Other</td>
<td>Tubed</td>
<td>Combined flaps</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Adapted from the 6 Cs of Cormack & Lambert.*

[^24]:
Terminology: Conclusion

- Emphasis on the vascular anatomy
- All cutaneous flaps are either ‘direct or indirect perforator flaps’
- Terms ‘axial’ ‘fasciocutaneous’ and ‘musculocutaneous’ are so entrenched
- Complete classification of flaps is elusive
Random Pattern Flaps

- Based on small, unnamed vessels
- Originating in the dermal-subdermal plexus
- Limited by geometry
- Differ in mobility and geometry
Fundamental vascular patterns of subcutaneous vessels

- Reticular
- Segmental
- Axial
Technique

- Local
  - Advancement, Pivot, Rotation, Transposition
- Distant
  - Direct, tube, free flap
Upper Extremity: local, regional and distant flap options

<table>
<thead>
<tr>
<th>Local Flaps</th>
<th>Regional Flaps</th>
<th>Distant Flaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z-plasty</td>
<td>Cross-finger flap</td>
<td>Groin flap</td>
</tr>
<tr>
<td>Axial flag flap</td>
<td>Reversed cross-finger flap</td>
<td>Latissimus dorsi flap</td>
</tr>
<tr>
<td>Dorsal metacarpal artery flap</td>
<td>Innervated cross-finger flap</td>
<td></td>
</tr>
<tr>
<td>Digital artery island flap</td>
<td>Cross-thumb flap</td>
<td></td>
</tr>
<tr>
<td>V-Y advancement flap</td>
<td>Thenar flap</td>
<td></td>
</tr>
<tr>
<td>Lateral V-Y advancement flap</td>
<td>Neurovascular island flap</td>
<td></td>
</tr>
<tr>
<td>Moberg flap</td>
<td>Radial artery forearm flap, Ulnar artery forearm flap, Reversed posterior interosseous artery flap</td>
<td>Fillet flap, Scapular flap, Lateral arm flap</td>
</tr>
</tbody>
</table>
Advancement Flaps

- Slide forward or backward along the flap’s long axis
- Rectangular advancement flap
- V-Y advancement flap
Atasoy V-Y Volar advancement flap

- Indicated for Transverse fingertip amputation, or amputation with more dorsal tissue loss
- Key steps
  - Skin cut leaving subq tissue intact for vascular supply
  - V-cut points to DIP flexion crease
  - Distal flat edge mobilized and pulled over the top
  - Proximal V segment closed primarily
  - Useful when sensation is vital (e.g. musicians)
Atasoy V-Y

Figure 20.3 Atasoy volar V-Y advancement. (From Rozenthal TD, Steinberg DR. Skin and soft tissue defects. In: Beredjiklian PK, Bozentka DJ, eds. Review of Hand Surgery. Philadelphia, PA: Elsevier; 2004, Figure 3-4.)
Atasoy V-Y
Kutler Paired Lateral V-Y advancement flap

- Similar to Atasoy’s
- V-Y advancement performed on both sides of the digit
- Key Steps
  - Flat distal portions sutured together in the midline of fingertip
  - Cleland ligaments must be freed dorsally
  - Anterior neurovascular supply must be protected
  - Best for transverse fingertip amputations
  - Scar at the tip of the finger may be problematic
Moberg Volar advancement flap

- Typically used for thumb pulp defects
- Key steps
  - 2 midlateral incisions are made, dorsal to neurovascular bundles
  - Flap dissected off the flexor tendon sheath
  - Advanced approximately 2.0 cm
  - Secondary site closed primarily or STSG
  - Flap includes all volar skin, subctaneous tissue, both neurovascular bundles from the tip injury to the MCP
  - IP joint immobilized for 10 days
Dorsal Metacarpal Artery Island Flap

- Neurovascular island flap is raised from dorsum of the index proximal phalanx
- Most useful for: defect on thumb, first web space, proximal long and ring fingers
- Pedicle contains:
  - 1st or 2nd metacarpal artery, veins, branches of the radial nerve
  - Interosseous fascia included in the flap (vessel runs deep)
  - Doppler u/s can be used to identify the vessel course
Dorsal MC Artery Island Flap
Axial Flag flap

- Like a flag on a pole
- Based on the dorsal digital artery at the webspace of the donor finger
- Raised over the dorsum of the proximal phalanx, near the interdigital crease
- Index and long fingers most common donor fingers
- Flap is very mobile
- Flap is particularly useful for coverage of defects with exposed tendon
Axial Flag flap
Regional Flaps

- **Posterior Interosseous Artery Flap**
  - Covers dorsal hand defects; no major artery is sacrificed but posterior interosseous nerve limits flap elevation, short pedicle

- **Radial Forearm flap**
  - Workhorse for coverage of large soft tissue defects of hand, forearm, elbow; based on radial A, rotated at radial styloid, allen test prior

- **Lateral arm flap**
  - Pedicle for elbow coverage, free tissue transfer for hand; based on posterior collateral artery

- **Thenar Flap**
  - Palmar fingertip defects; sewing the fingertip down into the thenar eminence; raised from proximal radial aspect of the thumb; fingertip sewn into flap for 2 weeks...potential for stiffness in adults because of immobilization, better tolerated in youth

- **Dorsal Cross- Finger flap**
  - Random pattern, dorsal skin and subcutaneous tissues elevated and transferred to the palmar surface of involved adjacent finger; fingers held together for 2 weeks until sectioning
Radial Forearm Flap
Thenar Flap

**Post-Accident Condition**
Amputation of the distal third of the right ring finger

**Post-Operative Condition I**
Debridement of the amputation, with full thickness thenar flap graft sutured to the end of the right ring finger

**Post-Operative Condition II**
Division of the thenar flap graft and full attachment of the graft to the right ring finger
Dorsal Cross Finger Flap
Rotational Flaps

- Similar to transposition flaps
- Semicircular, rotate on a pivot point into the defect
- Base can be ‘back-cut’ at the pivot point
- Triangle of skin can be excised ‘burow’s triangle’
Rotational flap, Mucocyst excision
Transposition Flaps

- Rotated about a pivot point into an adjacent defect
- **Primary & Secondary Defect**
- Usually rectangular
- Length of the flap decreases with increasing rotation, so design longer length than defect
- Close secondary with skin graft, direct suture, secondary flap
Z-plasty

- Type of **transposition flap**
- Random
- Used to lengthen contractures or scars
- Two triangular flaps interchanged
- Three limbs (Z) must be equal in length
- Amount of length gained related to the degree of angles of the Z
- Inside angles 60 degrees
- Single large Z-plasty more effective than multiple smaller ones
Z-plasty

- Keep angle >30 degrees to avoid tip necrosis
- All limbs equal length
- Increase scar length by 25% for 30, 50% with 45, and 75% with 60

<table>
<thead>
<tr>
<th>Apical Angle</th>
<th>Factor of Lengthening</th>
</tr>
</thead>
<tbody>
<tr>
<td>30°</td>
<td>1.29</td>
</tr>
<tr>
<td>45°</td>
<td>1.43</td>
</tr>
<tr>
<td>60°</td>
<td>1.79</td>
</tr>
<tr>
<td>75°</td>
<td>2.05</td>
</tr>
<tr>
<td>90°</td>
<td>2.22</td>
</tr>
</tbody>
</table>
M-plasty

- Reduces the amount of skin excised (e.g. lip, forehead)
- Can advance tip with closure
Rhomboid (Limberg) Flap

- **Transposition flap**
- Longitudinal axis - line of minimal skin tension
- Designed around angles of 60 degrees
Rhomboid design
Rhomboid Design
Bipedicle flap

- Two mirror image transposition flaps
- Share their distal, undivided margin (pedicle)
Interpolation flaps

- Rotate about a pivot point (like transposition flaps)
- Defects near, *not adjacent to the donor site*
- Littler (neurovascular island flap)
Neurovascular Island Flaps

- Axial flap, transfer of skin, subq, digital artery and nerve to a defect that requires durable skin and sensation
- Ulnar side of the long or ring fingers is typically used as donor site because these digits have codominant digital vessels
- Digital allen test preoperatively
- Best axial flap for digital amputation can be used for severe thumb pulp defects

Key Steps
- Extensive Brunner incision to mobilize a neurovascular bundle to mid palmar origin
- Reroute flap to the defect through a subcutaneous tunner
Neurovascular Island Flaps
Groin Flap

- Distant, Axial, fasciocutaneous flap used for large soft tissue defects
- Useful when (1) incomplete palmar arch (precludes use of forearm flaps and (2) lack of adequate vessels for free flap
- 2 cm distal to the inguinal ligament
- Based on the superficial circumflex iliac
- Sectioned 3-4 weeks after placement
Groin Flap
Groin flap

- Combined pedicled superficial inferior epigastric & groin flap for reconstruction of a dorsal & volar hand injury
Free Tissue Transfer

- Transfer of autologous tissue from one location to another using techniques of microvascular surgery for small vessel anastomoses

- Three (main) steps:
  - Complete detachment of the flap
  - Revascularization with anastomoses to BV
  - Intervening period of flap ischemia
Microvascular anastomoses

- Most flap pedicle vessels 0.8 - 4.0mm
- Operative microscope between 6 - 40x
- Success rates have increased to 95% (no longer considered ‘last-ditch’)
- Most important factor in free flap failure is thrombosis
Virchow’s Triad

- Factors altering laminar flow, causing endothelial damage, or hypercoagulability
Free Flap: Planning

- Pedicle length & size
- Which recipient vessel to use
- Orientation of anastomosis (e.g. end-to-side)
- Deal with mismatched vessel size
- Overcome unhealthy vessels
- How to inset flap tissues for function & cosmesis
- Routing the pedicle (restore blood flow, avoid kinking, etc)
- Patient positioning
- Postop dressings (avoid compression)
- Backup plan (e.g. interposition vein graft for length)
Conclusions: Technical points

- **Check for joint movement**
  - Ensure this does not compromise the stability or place tension on the flap
- **Consider the zone of injury and scarring**
  - these zones may be unsuitable for re-vascularization of a free flap or for basing a pedicle flap (the stiffness of the tissue may prevent transposition)
Conclusions: The Pedicle

- Vascular pedicle must be protected from
- 1) exposure
- 2) tension
- 3) internal compression
- 4) external pressure