Muscle Flaps
History

• Tansini (1896): pedicled latissimus dorsi
History: why the void?

- **Olivari (1976):** rediscovered LD

>Halsted WS. The results of surgical operations for the cure of the cancer of the breast. Tr AM Surg. A 25: 61, 1907
History

• Owen (1955), Bakamjian (1963): SCM flap
• Ortichochea (1972): gracilis mc flap
• Baudet (1976): term musculocutaneous flap
• Nahai (1978): TFL
• Mathes-Nahai classification of muscle vascularization (1979)
1- **Safety** = successful wound coverage

- *accessible* muscle
- *adequate size* (pedicle and flap);
- the vascular *pedicle easily located, constant and adequate*.
- adequate arc of rotation
2- **Form**- normal shape or contour

- **Restoration** at defect
- **Preservation** at donor site:
  - ✓ spendable muscle
  - ✓ uninjured adjacent muscle groups
  - ✓ segmental muscle transfer)
The basics

• **Function** – stable closure, specialized functions.
  – Sensation
  – Skeletal Support
  – **motion (or animation)**
Classification and Flap selection
Mathes-Nahai Classification

- Major pedicle
- Minor pedicle
- Dominant pedicle
- Segmental Pedicles
- Choke arteries
- Oscillating veins

Type I

- Single vascular pedicle
  - Tensor fascia Lata
  - Gastrocnemius
Type II

- Dominant Vascular Pedicle and Minor Pedicles
  - Gracilis
  - Trapezius
  - Soleus
  - Rectus femoris
  - Brachioradialis
Type III

- Two Dominant Pedicles
  - *Gluteus Maximus*
  - *Rectus abdominis*
  - *Serratus anterior*
Type IV

- Segmental Pedicles
  - Sartorius
  - Tibialis Anterior
Type V

• Single Dominant and secondary segmental pedicles.
  – *Latissimus Dorsi*
  – *Pectoralis Major*
Venous anatomy

• The venous territories match the arterial territories.
• choke arteries =oscillating veins
• the valves of adjacent territories direct away from each other and towards their respective pedicles.
• **afferent veins**: enter many muscles from the superficial (musculocutaneous perforators) and deep tissues.
• **Efferent veins**: contain valves and drain the muscle into the parent veins

Classification

- **Type I**: single venous territory draining in 1 direction
- **Type II**: 2 territories draining in opposite directions
- **Type III**: 3+ territories draining in multiple directions
Favorable vs unfavorable mc flaps
Reverse transposition

- Type V muscles have two arcs of rotation.
- **Standard arc**: dominant vascular pedicle
- **Secondary arc**: secondary pedicles
Reverse transposition

Hayashida K, et al.
Case report reconstruction of exposed ilium with reverse turnover latissimus dorsi muscle flap. Eplasty. 2011 Apr 14;11:e17.
Distally based flaps

• **Type II muscle** flaps can be based on the minor pedicles.

• **Prior delay** can improve the survival and will permit use of the cutaneous territory of the proximal muscle.

• It is possible to transpose only a portion of the muscle for small defects based on the minor pedicle.
Flap delay

• Division of selected pedicles

I. Dilatation of narrow anastomotic vessels linking pedicles supplying adjoining muscle segments

II. Changes in the preferential routes of venous drainage within the muscle producing backpressure with regurgitant flow through valves towards the unligated pedicle(s)

Innervation

Type I

Single unbranched nerve enters muscle

Latissimus dorsi

Tensor fasciae latae
Type II

Single nerve, branches prior to entering
Type III
Multiple branches from same nerve trunk
Type IV

Multiple branches from different nerve trunks

Pectoralis major

Rectus abdominis
Muscle splitting
Musculocutaneous Flaps
M-N Classification of Fasciocutaneous flaps
Musculocutaneous flaps
Musculocutaneous flaps
Vascularized bone harvest

- Vascular connections between muscle and periostium of bone
- Free flap
- Transposition flap when vascular connections distal to the point of rotation
Chimeric flaps

- Different tissues on the same pedicle: parascapular, LD, serratus anteriors, scapular angle, ribs
Flap prefabrication

All missing components of a given defect by positioning support lining and coverage tissues in preplanned positions and allowing them to vascularize prior to transfer.

Giessler GA et al. The role of fabricated chimeric free flaps in reconstruction of devastating hand and forearm injuries. J Reconstr Microsurg. 2011 Nov; 27(9):567-74
Flap expansion

- Increase in skin island dimensions
- Assists in primary donor-site closure

Sensory flaps

- Muscle flaps with intact motor nerves or with reanastomosis of the motor nerve to motor or sensory recipient site appear to retain protective sensation.
- 2/3 of motor nerves are formed by afferent sensory axons.
- 2/3 axons terminate as free endings in the connective tissue surrounding extrafusal and intrafusal muscle fibers. These free endings probably function as nociceptors.
- Decreased atrophy of the sensory innervated muscle flaps

Preoperative planning

• Muscle type (Mathes-Nahai)
• Location of the neurovascular hilum/a
• length and thickness
• Lengthen the muscle by excising the deep fascia or incising it at different levels (gastrocnemius)
• Cut the motor nerve to avoid contraction and pain
Pedicled flaps

Upper extremity
Flap transposition

- **Point of rotation (pivot):** point of entrance of the pedicle
- **Standard arch of rotation:** length of the vascular pedicle + flap length distal to the pivot
- **Pivot types I, II, III, V:** one end or proximal third
- **Type III:** the whole muscle may not always survive on one of the dominant pedicle
- **Type IV:** only the proximal third transposed
- **Type V:** has 2 arc of rotation
Arc of rotation

Standard arc

Extended arc
Shoulder and upper arm

- LD
- Serratus anterior
- Pectoralis minor
Brachioradialis (II)
Anconeus (I)

Outcome of local anconeus flap transfer to cover soft tissue defects over the posterior aspect of the elbow. Elhassen et J Shoulder Elbow Surg (2011) 20, 807-812 al.

1- Profunda brachii artery; 2- medial collateral artery; 3- radial collateral artery; 4- posterior branch of the radial collateral artery; 5- ulnar collateral artery; 6- the recurrent posterior interosseous artery.
Hand

- **Abductor Digiti Minimi (I)**


Free flaps

1. limited regional options for muscle rotation
2. the volume of the defect is larger than local tissues can reconstruct.
3. Functional deficits from using the regional muscle supply may limit the outcome
4. Infection or prosthetic coverage
Complex wounds

• Osteomyelitis
• Vascular insufficiency
• Chronic irradiation wound
• Infected exposed prosthesis
Muscle vs Fasciocutaneous flaps

- Musculocutaneous flaps vs random fasciocutaneous flaps
- Both muscle flaps and nonmuscle flaps are effective in providing coverage for bone defects with chronic osteomyelitis following adequate debridement.

Functional muscle transfer
Functional muscle transfer

- 1970 Tamai: functional rectus femoris transfer in dogs
- 1976 Harii: gracilis for facial reanimation
- 1976 Sixth People Hospital: lateral pectoralis major for forearm flexors in Volkman
- 1978 Manktelow: gracilis and pectoralis for active finger flexion
Loss of functioning muscle unit

Major loss of skeletal muscle with significant functional deficit that cannot be reconstructed by simpler procedure.

- Direct trauma, burns
- Tumor resection
- Volkmann’s ischemic contracture
- BPP
Criteria

• Single unit replacement must make a difference
• Adequate antagonist muscle function
• Suitable bed for gliding, distal gliding tendons
• Mobile joints, stable bones
• Sensate distal extremity
• Effective motor nerve
• Cooperative patient
FMT in upper extremity

- Long finger flexor function
- Long finger extensor function
- Biceps reconstruction
- Triceps reconstruction
- Deltoid reconstruction
Donor muscle

- Fibre Length
- Fibre configuration
- Excursion
- Vessel and nerve size / position
- Fascia / tendon for insertion
- Ischemia time
Fiber length

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Figure 12-16

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Fiber configuration

- **Strap muscle**: fibers are parallel to the long axis of the muscle
  - shortening: muscle length
  - max force: cross section

- **Pennate muscle**: shorter muscle fiber units attached to central/lateral tendon.
  - <shortening; >power

- Select strap m with large cross sectional area
Donor Muscle

- Gracilis
- Latissimus dorsi
- Pectoralis major
- Rectus femoris
- Tensor fascia lata
Donor Nerves

- **Finger long flexors**: AIN, median nerve (FDS), ulnar nerve (FDP)
- **Finger long extensors**: radial nerve, PIN
- **Biceps**: motor musculocutaneous nerve
- **Deltoid**: motor axillary
- **Triceps**: proximal radial nerve
- **BPP**: IC, cC7, spinal accessory, C5, C6

Healty motor nerve equal cross sectional area
Pretransfer abnormalities

• Nerve loss
• Joint contractures
• Tendon adhesions
## Insertion and origin

<table>
<thead>
<tr>
<th>Insertion tendon</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Side to side repair of FDP/EDC</td>
<td>• Medial epicondyle (flexors)</td>
</tr>
<tr>
<td>• Side to side repair of FPL/EPL</td>
<td>• Lateral epicondyle (extensors)</td>
</tr>
<tr>
<td>• EPL rerouting: extension + abduction</td>
<td></td>
</tr>
<tr>
<td>• Split muscle and innervate with different motor: independent finger and thumb</td>
<td></td>
</tr>
</tbody>
</table>
• Complete loss of the extensor compartment of the forearm
• Exposure of the dorsal aspect of radial and ulnar bones.
• The posterior interosseous nerve was interrupted 3 cm from its origin.
Post operative management

- **Finger flexors:**
  - Passive finger and wrist stretching at 3 weeks
  - Gradual resisted grip exercises
  - For 1 year after development of useful ROM
- **Finger extensors:**
  - Wrist splinted in extension for 10-14 days
  - Passive and active wrist, finger and thumb exercises
  - Exercise against resistance when useful range of finger extension (6 months)
Outcomes

- Tip to palmar crease 0.5-4cm
- Grip strength 38.1% (14-81%)
- Pinch strength 37.8% (0-70%)

- Severity of pretransfer upper extremity injury
- Absence of intact intrinsic function
- Absence of good supination and pronation

Biceps Reconstruction

- Lack of elbow flexion
- Local transfers not possible (LD, pec >)
- Donor nerves: musculocutaneous, intercostal (BPP: 2-4th).
- Contraindications to IC nerves: phrenic nerve palsy, Brown Sequard Sdr
- Awake nerve stimulation: sensory (discomfort in the region of the sensory innervation), motor (deep discomfort localized in the muscle belly)
Biceps reconstruction

- **Origin**: acromion and clavicle
- **Insertion**: remnant of biceps tendon with elbow and shoulder in full extension
- **Post op**: elbow in flexion (3 weeks), active and passive stretching. Transfer activated by breathing

Biceps reconstruction: outcome

- full active flexion (M4), load 5 Kg
- M4 in 78% of patients following transfer of 3 intercostal nerves with recovery in 2 years. Using the spinal accessory nerve, strength of M2+ (interposition nerve grafts)
- Gracilis->gracilis+adductor longus->RF, VL, LD
- LD stronger than gracilis and rectus femoris (IC).

Biceps reconstruction: outcome

Triceps Reconstruction

- **Origin**: lateral aspect of scapula (glenoid fossa)
- **Insertion**: triceps tendon, olecranon
- **Nerve**: radial nerve, IC, cC7 posterior division,
cervical plexus, and distal spinal accessory nerve
- **Muscle**: LD, gracilis
- **Postop**: shoulder flexion and elbow extension
- **Outcome**: LD stronger (M3), gravity aid

Triceps Reconstruction

Deltoid reconstruction

- Shoulder Flexion and abduction
- Complete loss of deltoid: supraspinatus, pec >, biceps and coracobrachialis
- Muscles: gracilis and adductor longus, LD
- Nerve: IC, cC7 root, distal spinal accessory nerve
- Origin: acromion and distal clavicle- nucal line
- Insertion: deltoid
- Postop: shoulder 90°abduction and elbow flexed.
ESTIM. Splint removed at 3 months

Outcome

• LD: The mean muscle grade postoperatively was 3.25. The mean degree of shoulder abduction was 40°.

The Reconstructive Elevator

"In the era of form and function simplest is not always the best."

Lawrence J Gottlieb

British Medical Research Council Scale

- M0: No contraction
- M1: perceptible contraction in proximal muscles
- M2: perceptible contraction in both proximal and distal muscles
- M3: all important muscles able to work against resistance
- M4: All synergistic and independent movements possible
- M5: complete recovery