Amputations/Prostheses

The i-Limb®

Sources: Radomski & Trombly Latham, OT 624 March 31, 2005 lecture by Dr. Matt Malcolm; images through Google Images
i-Limb


Touch Bionics

• 484 BCE: Herodotus tells of a Persian soldier, Hegesistratus, who was imprisoned by the enemy. In order to escape from the stocks, Hegesistratus cut off part of his own foot. He later wore a wooden replacement.

• The oldest known prosthesis discovered in a tomb in Capua, Italy: an artificial leg made out of copper and wood dating back to 300 BCE.

• In the 15th and 16th centuries many prostheses were made from iron. They were created for soldiers by the same craftsmen who made their suits of armor.

Courtesy: University of Iowa Hospitals and Clinics
Terminal Devices
Terminal Devices (for prostheses!)

Check out Amputee Coalition of America and TRS, Inc. in Boulder
Below-Elbow Prosthesis

- Axilla loop
- Control attachment strap
- Inverted Y strap
- Triceps cuff
- Cable to operate TD
- Wrist unit
- Terminal Device (TD)
Transverse terminal deficiency:
Absence of fully-formed metacarpals
Paraxial Deficiency:
Terminal Deficiency
The brief overview of congenital abnormalities would include categories of deficiencies:

- **Terminal deficiencies:**
  - Transverse = complete absence distal to the level of loss – loss of entire limb (ie., shoulder and distal) would be referred to as amelia; loss of half limb (ie., elbow and distal) would be hemimelia
  - Paraxial = complete longitudinal absence, ie., radius and thumb, ulna and ulnar digits; since this also is half limb loss it is referred to as hemimelia
Paraxial Intercalary Deficiency: Paraxial Tibial Hemimelia (absent tibia)
Phocomelia = absence of
central (proximal) element(s)
Intercalary deficiencies

- Paraxial = radius or ulna, but distal segments (ie., hand, fingers) intact; this also called hemimelia – so both terminal and intercalary deficiencies may be hemimelia

- Phocomelia = absence of central (proximal) elements with shortening of the extremity, ie., humerus is missing but forearm and hand intact – overall UE shorter
Acquired UE amputations are categorized as (see figure 46.1 in Radomski & Trombly Latham):

- Above or below elbow
- Long or short (or high or low) within these two categories (i.e., long above elbow implies the cut is just above the elbow allowing for a long residual limb
- Also there are shoulder (Black Knight?), elbow and wrist disarticulations
- Within the hand there may be transmetacarpal amputation
Above-Elbow amputation; also Forequarter Amputation

Turntable - for “humeral rotation”
Below-Elbow Prosthesis

- Axilla loop
- Inverted Y strap
- Triceps cuff
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- Wrist unit
- Terminal Device (TD)
Two major divisions are cable-driven (body powered, conventional) and myoelectric:

- **Cable-driven** operates on the principle of passive insufficiency – stretching the cable across a number of joints between the terminal device (TD) and the harness results in the TD opening or closing (depending on whether it is a voluntary opening (VO) or voluntary closing (VC) TD – which is the basic categorization of TDs. Typical moving parts in a cable-driven prosthesis:
  - TD – directly by cable tension; if VO, rubberbands close the TD; if VC, an internal spring opens the TD
  - Wrist – typically a passive joint – no cable operation; you hit a button (if a wrist unit is built into the prosthesis) and the TD can be “flexed,” in “neutral” or “extended” using gravity or the other hand to position the wrist
Cable-Driven continued:

- Supination/pronation – passive, by rotating the TD with the other hand
- Elbow – flexed through tension in the same cable that control the TD; extended by gravity; held in a position of flexion via a lock activated by a small cable connected to the front of the harness
- Shoulder internal/external rotation – passive via turntable
- Training involves controls training FOLLOWED by use training – use in a functional context
Myoelectric Prostheses

Cost of a Limb in 2007 was $17,000
• Myoelectric prostheses operate by using an electrode (surface electrode built into the socket) to receive an electric current generated by a muscle contraction. This signal is then amplified through the built-in circuitry and run to an internal motor that drives the terminal device. One signal opens, another closes. Training involves:
  • Identification of potential muscles and assessing signal strength from contraction
  • Assessing voluntary control – independent contraction, relaxation and ability to alternate signals and different signal levels
  • Using EMG biofeedback to increase accuracy, strength, repetition and relaxation of selected muscles – all throughout the ROM of the UE and against resistance
Advantages and disadvantages compared to body powered prosthesis:

- Myoelectric found by some to have increased functional use for holding musical instruments, clothing, containers
- Myoelectric:
  - provides decreased sensory feedback (there is no tension felt through the cable associated with function because there is no cable or harness)
  - has increased response time between willing a movement and effecting it
  - decreased ROM due to tight fit of socket
  - high maintenance – esp. the glove
Motorized but not fully myoelectric – either micro switch or combo (hybrid) myoelectric and micro switch
There also are prostheses with motorized TDs or other parts/joints of the prosthesis that are activated with a microswitch built into the socket.

Finally there are hybrids using combinations of cable, myoelectrics and microswitches to activate different parts of the prosthesis.
<table>
<thead>
<tr>
<th>Features</th>
<th>Hooks VO (Body Power)</th>
<th>VC TRS Grip (Body Power)</th>
<th>Hands (External Power)</th>
<th>Hands VO (Body Power)</th>
<th>Greifer (External Power)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmesis</td>
<td>Unfavorable</td>
<td>Unfavorable</td>
<td>Favorable</td>
<td>Favorable</td>
<td>Unfavorable</td>
</tr>
<tr>
<td>Pinch force</td>
<td>1 lb/rubber band; more rubber bands yield stronger grip but require more effort to open</td>
<td>Controlled strong grip &gt;40 lb dependent on force exerted on cable</td>
<td>Strong grip, 22 lb; may have proportional control</td>
<td>Pinch stronger than VO hook but weaker than externally powered TD; relies on internal springs, adjustable</td>
<td>Strong pinch, 32 lb</td>
</tr>
<tr>
<td>Prehension pattern</td>
<td>Precise, exact pinch</td>
<td>Pinch more precise than hand, less than hook</td>
<td>Cylindrical grasp; 3-point pinch; configuration same as BP hand</td>
<td>Cylindrical grasp, 3-point pinch; configuration same as external powered hand</td>
<td>Precise pinch and cylindrical grasp</td>
</tr>
<tr>
<td>Weight</td>
<td>Lighter than hands; aluminum to stainless steel; 3-8.7 oz</td>
<td>Aluminum, polymer, stainless steel; 4-16 oz</td>
<td>Heavy; 16.2 oz</td>
<td>Heavy; 10.5-14 oz</td>
<td>Heavy; 19 oz</td>
</tr>
<tr>
<td>Durability</td>
<td>Durable; stainless steel is strongest</td>
<td>Durable and rugged; especially stainless</td>
<td>Not durable; delicate internal electronics and glove</td>
<td>Not durable; delicate inner spring mechanism and glove</td>
<td>Durable and rugged</td>
</tr>
<tr>
<td>Reliability</td>
<td>Very good; requires minimal service</td>
<td>Very good; requires minimal service</td>
<td>Good if not used for rugged activities</td>
<td>Good if not used for rugged activities</td>
<td>Very good</td>
</tr>
<tr>
<td>Feedback</td>
<td>Some proprioceptive feedback from tension on harness and limb in socket when operating TD/elbow</td>
<td>Better proprioceptive feedback, as tension on cable must be maintained for sustained grasp</td>
<td>Some feedback through intensity of muscle contraction, particularly for proportional control</td>
<td>Feedback similar to VO hook</td>
<td>Same as externally powered hand</td>
</tr>
<tr>
<td>Ease of use</td>
<td>Effort increases with more rubber bands</td>
<td>More effort to sustain grasp; lock available</td>
<td>Low effort to activate</td>
<td>More effort to open; can relax for grasp</td>
<td>Same as externally powered hand</td>
</tr>
<tr>
<td>Use in various planes</td>
<td>Difficult for high planes</td>
<td>Similar to VO hook</td>
<td>Very good for transradial amputation</td>
<td>Similar to VO hook/hand because of harness</td>
<td>Same as externally powered hand</td>
</tr>
<tr>
<td>Visibility of items grasped</td>
<td>Very good</td>
<td>Good; less than VO</td>
<td>Poor for small items</td>
<td>Poor for small items</td>
<td>Poor for small items</td>
</tr>
<tr>
<td>Cost</td>
<td>Lowest</td>
<td>Higher than hook, less than hand</td>
<td>Highest cost</td>
<td>Higher than hooks; lower than externally powered hand</td>
<td>About the same as externally powered hand</td>
</tr>
</tbody>
</table>
Pre prosthetic Tx:

• Hygiene & wound care
• Maximize limb shrinkage: Elastic bandage & elastic shrinker
• Removable rigid dressing
• Immediate/early postoperative prosthesis
Pre prosthetic Tx:
• Desensitization of residual limb
• Weight bearing into various materials
• Massage
• Vibration, tapping
• Wrapping of residual limb
Questions:

What’s better for fit into a socket: long above elbow amputation or elbow disarticulation? Long or short below elbow amputation?

Considering intercalated limb deficiencies, can you reason through a person NOT wanting to be fit with a prosthesis?

Why might someone prefer a body-powered prosthesis with a hook TD to a myoelectric controlled hand?

Why might one advantage be in terms of proprioception using a VC versus a VC TD? Where does the proprioceptive input originate?
Pre prosthetic: Other treatment priorities
• Increase strength
• Maintain or increase ROM
• Facilitate independence
• Explore prosthetic options
• Dealing with phantom sensation and pain
Prescribing the Prosthesis

Consider these factors:

• Residual limb: length, range of motion, skin integrity, strength
• Preference for cosmesis and function
• Hand dominance
• Activities at work, home, school, and community and recreational interests
• Motivation and attitude
• Financial coverage: health care insurance, ability to pay privately, and alternative funding sources
• Cognitive abilities to learn to use prosthetic controls
Treatment Guidelines for Initial Stage of Treatment (ideally within 4–12 weeks of surgery)

- Evaluate the prosthesis.
- Explain program goals to the patient.
- Describe the functions of each component; give the patient an illustration of the prosthesis with components labeled.
- Teach the patient to don and doff the prosthesis.
- Discuss the wearing schedule with the patient.
- Teach limb hygiene care.
- Teach care of the prosthesis.
- Begin controls training using the terminal device.
<table>
<thead>
<tr>
<th>Activity</th>
<th>Y</th>
<th>N</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the prosthesis comply with the written prescription?</td>
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<tr>
<td>2. Is the length of the prosthesis equal to the length of the sound arm? (Measure tip of TD to ground and compare to tip of thumb of sound hand to ground when the patient is standing. Compare elbow length for each side.)</td>
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<tr>
<td>3. Are appearance and workmanship satisfactory? (Examine for smooth edges, smooth interior of socket, no loose rivets or screws, finished harness edges, and satisfactory arm color.)</td>
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<tr>
<td>4. Can the socket tolerate a downward pull of 50 lb without displacing more than 1 in?</td>
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<tr>
<td>5. a. Is there pain or discomfort while the limb is in the socket?</td>
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<td>6. b. Does the limb show abrasions or discoloration when the prosthesis is removed?</td>
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<tr>
<td>7. a. Does the housing cover the cable without restricting elbow flexion?</td>
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<tr>
<td>8. b. Is the cable free of sharp bends?</td>
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<tr>
<td>9. a. Is the axilla loop small enough to keep the figure-eight harness below the seventh cervical vertebra and slightly to the unamputated side?</td>
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<tr>
<td>10. b. Is the axilla loop covered and comfortable?</td>
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<tr>
<td>11. c. Are all straps of adequate length and in proper alignment?</td>
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<tr>
<td>12. a. Does the triceps cuff fit firmly without gapping?</td>
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<tr>
<td>13. b. Can the turntable be rotated manually with relative ease and remain in position?</td>
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<tr>
<td>14. 9. a. Do the TDs and wrist unit function smoothly?</td>
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<tr>
<td>15. b. Is the glove covering for the hand satisfactory in color and fit?</td>
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<tr>
<td>16. c. Does the TD have full opening, closing?</td>
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<tr>
<td>17. d. Can the TD be fully opened and closed at the hip, at 90° of elbow flexion, and at the mouth?</td>
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<tr>
<td>18. Can forearm rotation that is at least 50% of rotation without the prosthesis be achieved?</td>
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<tr>
<td>19. Can elbow flexion that is only 10° less than flexion with prosthesis off be achieved?</td>
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<tr>
<td>20. For transhumeral amputation:</td>
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</tr>
<tr>
<td>a. Can 90° of shoulder abduction and flexion and 30° of arm extension be achieved?</td>
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<tr>
<td>b. Can the prosthetic elbow be flexed by flexing the humerus 45° or less?</td>
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</tr>
</tbody>
</table>

Adapted from Department of Prosthetics and Orthotics. (1986). *Upper limb prosthetics*. New York: New York University Medical Center, Postgraduate Medical School.
### Controls Training for Body Powered Prostheses

<table>
<thead>
<tr>
<th>Component</th>
<th>Movement</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal device</td>
<td>Humeral flexion with scapular abduction (protraction) on side of amputation; bilateral scapular abduction for midline use of TD or when strength is limited.</td>
<td>Manually guide patient through motions. For transthumeral prostheses, keep elbow unit locked in 90° flexion; teach TD control first.</td>
</tr>
<tr>
<td>Wrist unit</td>
<td>Rotate TD to supination (fingers of hook up), midposition (fingers toward midline), or pronation (fingers down). For unilateral amputation, patient uses sound hand to rotate TD. For bilateral amputation, rotate TD against stationary object, between knees, or with contralateral TD.</td>
<td>Have patient analyze the task and determine the most efficient approach for grasp, avoiding excessive or awkward movements. Examples: TD in midposition for carrying a tray, in pronation for grasping small box from table.</td>
</tr>
<tr>
<td>Elbow unit</td>
<td>Depress arm while extending and abducting humerus to lock or unlock elbow mechanism.</td>
<td>Manually guide patient through motions. Begin with elbow unlocked. Patient listens for click as lock activates. Have patient exaggerate movements initially. Use a mirror.</td>
</tr>
<tr>
<td></td>
<td>Practice flexing and locking elbow in several planes.</td>
<td>Use humeral flexion to flex the elbow; go beyond desired height, since the arm will drop with gravity pull as patient is in process of locking the elbow unit.</td>
</tr>
<tr>
<td>Turntable</td>
<td>Rotate elbow turntable toward or away from body using sound hand. With bilateral amputations, push or pull against stationary object to rotate.</td>
<td>Teach patient to analyze task to determine need to use this component for more efficiency.</td>
</tr>
</tbody>
</table>