Amputation Rehabilitation and Prosthetic Rx

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Educational Objectives

- Review amputation epidemiology
- Describe the Phases of Amputation Rehabilitation
- Compare prosthetic components
- Contrast Lower vs Upper Limb Amputation Rehabilitation
- Write a Prosthetic Prescription

Amputation

A definition

- Amputation surgery should be considered a reconstructive procedure intended to create a functional residual limb capable of pain-free weight bearing and function:
  - Meticulous technique and gentle tissue handling
  - Avoidance of skin grafts and adherent scars
  - Minimal periosteal stripping with balance of muscle forces should always be attempted
Prevalence of Amputation

- Based on data from the NHIS-D there are 1.2 - 1.9 million persons living in the U.S. with limb loss
  - http://www.cdc.gov/nchs/about/major/nhis_dis.htm

- The patient population with limb amputations is expected to double by 2050

Incidence of Amputation

- There are approximately 50,000 new major limb amputations every year in the US
  - National Health Interview Survey, 2012

- Worldwide estimated number of new amputations range between 1,000,000 and 1,500,000 per year

- US rate for LE amputation 47/100,000 vs. 5/100,000 UE amputation
  - http://www.amputee-coalition.org/people-speak-out/background.html

Upper Limb Amputation Levels

- Transcarpal 18%
- Wrist Disarticulation 10%
- Transradial 31%
- Elbow Disarticulation 5%
- Transhumeral 27%
- Shoulder Disarticulation 7%
- Forequarter 2%
Incidence of Limb Amputation by Level

Causes of UL Amputation

Prevalence of UL Amputation

Of the 5/100,000 UE amputations in the US
3.8/100,000 were trauma related,
1.3/100,000 were dysvascular related,
<1/100,000 were congenital or cancer related.

http://www.amputee-coalition.org/people-speak-out/background.html

Esquenazi, Disability and Rehabilitation 2004

Causes of Upper Limb Amputation at MossRehab over 5 year period
N=139
- Malignancy: 63%
- Trauma: 24%
- Vascular: 11%
- Congenital: 2%

Upper Limb Amputation by Age Distribution
- 0-15: 10%
- 16-35: 25%
- 36-55: 35%
- 56-90: 30%

Transcarpal
Prosthetic Control Options

- Myoelectric
- Switch control
- Tension
- BCI
- External Power
- Voluntary opening
- Voluntary closing
- Prefabricated
- Custom

External

Body Power

Cosmetic

Hybrid

• External power
• Body power
• Cosmetic

Passive Terminal Devices

• Cosmetic Restoration

Body Powered

- Voluntary Opening
- Voluntary Closing

External Powered

- Electric Hand
- Single grip
- Multiarticulated
- Electric Hook

Terminal Device Activation Systems
Active Terminal Devices

- Body Power
  - Voluntary Opening, Hook
Active Terminal Devices: BP Voluntary Closing, Hook

Active Terminal Devices: BP Voluntary Closing, Hook

Active Terminal Devices: Body Power, VO & VC Hands

More Acceptable Cosmesis
External Power Terminal Devices

- Powerful Grip + Graded Prehension
- Ease of Operation
- Better Cosmesis

Myoelectric Control System

- Makes use of remaining muscle signals after amputation to control prosthetic functions

External Powered UL prosthetic use
Multi Articulate Hands
5 motors
- From lateral or tip pinch to multiple grip styles

Comparative T.D. Force Generation
Single Motor

T.D. Opening at Tip for grasp in cm
Switch Control
External Power Prostheses

Independence in ADLs is the goal
Passive Function Terminal Devices

Wrist Components
External flexion
Internal flexion
Friction rotation
Elbow Components

- Mechanical
- Electro-Mechanical
- Spring assisted
- External power
  - Switches and sensors
  - Myoelectric controls

Mechanical Elbow Designs

Single Axis
Polycentric
Step-up Hinges
Stump Activated
Locks
External Locking
Internal Locking Elbow

Electronic Elbows

Boston
ErgoArm Otto Bock
Utah 3
63% of persons with Upper Extremity amputation use a Body Powered Prosthesis
Prosthetic Suspension Systems

- Harness
- Anatomical
- Suction
- Friction

Prosthetic Harness Function

- Suspension
- Activation of TD
- Activation of Elbow
- Actuation of elbow lock

Body Powered Control Systems

<table>
<thead>
<tr>
<th></th>
<th>Terminal Device</th>
<th>Elbow Flexion</th>
<th>Elbow Lock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder Disarticulation</td>
<td>Biceps &amp; Latissimus</td>
<td>Biceps &amp; Latissimus</td>
<td>Scapular elevation</td>
</tr>
<tr>
<td>Transhumeral</td>
<td>Biceps &amp; Humeral Flexion</td>
<td>Biceps &amp; Humeral Flexion</td>
<td>Shoulder Depression &amp; Humeral Abduction &amp; Extension</td>
</tr>
<tr>
<td>Transradial</td>
<td>Biceps &amp; Humeral Flexion</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
How does a BP prosthesis works

- VO TD is closed by rubber bands
- VO TD is opened by tension on harness via Bowden control cable
- TD closes when harness relaxes
- For TH, elbow flexes then locks before TD opens

TRA BP Harness

Figure 8 Harness Functions
- Suspension
- TD Activation

TRA Harness Functions

Figure 9 Harness Function
- TD Activation
- No suspension
THA Harness Functions

Elbow Locking
- Shoulder elevation

Dual Control Harness Functions
- Suspension
- Elbow Activation
- TD Activation

Elbow must be locked to activate terminal device

Alternative Harness System

Shoulder Disarticulation Harness
External Powered Prosthesis

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Silicone Suspension

- Useful in cases where skin is delicate 2nd to scars
- Short residual limb friction provides suspension

Silicone Suspension for TR body powered prosthesis

Improves the suspension and comfort for some transradial amputees

Suction Suspension

Myoelectric systems can use suction suspension
Suction & Friction Suspension for myoelectric THA

Myoelectric Control Socket Design

Bilateral Shoulder Disarticulation

Esquenazi
Osseo-integration

Targeted Muscle Re-innervation (TMR)

- Kuiken, et al; 2004
- Performed so far in +/- 70 patients
- Dissection of musculocutaneous, radial, ulnar, and median nerves
- Reimplanted on pectoralis and serratus muscles
- Allows simultaneous control of multiple prosthetic joints

Targeted Reinnervation
Targeted Muscle Re-innervation (TMR)

- Nerves must regenerate: 3 months for detectable signal
- Need intact brachial plexus
- Utilizes existing technology
- Time to proficiency much shorter, once training starts
- Potential for sensory feedback

The Evolution of the Transhumeral Prosthesis

22 movements 3 movements 7 movements

7 Movements Demonstration
Training
Quadrilateral amputation driving

Toileting and Showering

Primary use of UL prosthesis
Unilateral Upper Limb Loss: Satisfaction and Prosthetic Device Use in Vietnam and OIF/OEF Soldiers

- Prostheses use is more frequent for TRA or distal levels
- Other hand is used more often in a compensatory fashion for higher levels.
- Most use prostheses (70% Vietnam and 76% OIF/OEF).
- BP devices are favored by the Vietnam cohort, while OIF/OEF cohort use both myoelectric and BP devices
- Frequency of prosthetic rejection due to dissatisfaction is high for the Vietnam cohort (23%) and higher for the OIF/OEF cohort (45%)

Principle Causes of UL Prostheses Rejection

- Decreased shoulder mobility
- Brachial plexopathy
- Delay in initial prosthetic fitting > 6 months
- Pain
- Hot and humid weather
Other Reasons for Rejection:
- Limited usefulness
- Late fitting
- Excessive weight
- Socket discomfort
- Poor cosmesis
- Poor satisfaction
- Not enough training to become proficient user

Comparison of Upper Limb Prostheses

<table>
<thead>
<tr>
<th>Passive</th>
<th>Body-Powered</th>
<th>Battery Powered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightest</td>
<td>Lightest</td>
<td>Lightest</td>
</tr>
<tr>
<td>Better cosmesis</td>
<td>Best sensory feedback</td>
<td>Limited sensory feedback</td>
</tr>
<tr>
<td>No harnessing</td>
<td>Most harnessing</td>
<td>Less or no harnessing</td>
</tr>
<tr>
<td>May be high cost</td>
<td>Moderate cost</td>
<td>Functional</td>
</tr>
<tr>
<td>Passive function</td>
<td>Functional</td>
<td>Functional</td>
</tr>
<tr>
<td>No energy expenditure</td>
<td>Most energy expenditure</td>
<td>Less energy expenditure</td>
</tr>
<tr>
<td>May stain easily</td>
<td>Most durable</td>
<td>Few or no maintenance required</td>
</tr>
<tr>
<td>Choice of terminal device</td>
<td>Choice of TD and elbows</td>
<td>Choice of TD and elbows</td>
</tr>
<tr>
<td>No body movement required</td>
<td>Most body movement to operate</td>
<td>Least body movement to operate</td>
</tr>
<tr>
<td>No grasp</td>
<td>Weaker grasp (VC)</td>
<td>Stronger grasp (active)</td>
</tr>
<tr>
<td>Body-Powered Advantages</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
- Heavy Duty Construction
- Proprioception
- Less Expensive
- Lighter in Weight
- Reduced Cost and Maintenance
Body-Powered Disadvantages

- Limited grip force
  (shoulder strength and # rubber bands tolerance)
- Functional envelope (ROM) is limited
- Harness can be uncomfortable and restrictive
- Less cosmesis
- Possible over-use, nerve entrapment syndrome

Body power prosthesis
most prescribed

Transradial Rx
- Double wall socket
- VO hock
- Quick disconnect wrist
- Flexible hinges
- Triceps pad
- Figure 8 harness

Transhumeral Rx
- Double wall socket
- VO hock
- Quick disconnect wrist
- Internal lock elbow
- Bowden control cable
- Figure 8 harness with elbow lock strap