Upper Extremity Limb Loss:

A comprehensive approach to understanding prosthetics and function

Presented by:
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Goals/objectives

✓ Provide a comprehensive discussion on UE prosthetic options

✓ Discuss types/causes of limb loss including current trends and current events

✓ Review amputation levels/terminology

✓ Improve understanding of pre-prosthetic assessment and intervention

✓ Improve knowledge of prosthetic therapy including specific training techniques, functional skills training and adaptive equipment

✓ Discuss the interdisciplinary team approach for comprehensive treatment

✓ Discuss evidence based practice and current studies
Definitions

- **Amputation**: a condition that results in the loss of limb, or part of a limb.

- **Congenital amputation**: a birth malformation such as an absent or poorly developed limb.
Types of congenital anomalies

- **Phocomelia**: congenital anomaly in which one or more limbs are missing, with the hand and/or foot attached directly to trunk (fig B).

- **Amelia**: congenital absence or partial absence of one or more limbs at birth. Can be caused by environmental or genetic factors (fig A).
Statistics on limb loss

- In U.S., approx 2 million people living with limb loss

- Approx. 185,000 amputations in U.S each year. 507 people per day in U.S

- 42% are over 65 years old

- 65% are male

- Congenital limb anomalies are 26 per 100,000 live births (58.5% upper limb)

(National Limb Loss Information Center, 2008)
Causes of limb loss

1. Dysvascular related amputations (main cause)
2. Trauma related amputations
3. Cancer/infection related amputations
4. Congenital related amputations
   4.1) Amniotic band syndrome/Constriction Band Syndrome - constriction of fibrous bands within membrane that surrounds the developing fetus
   4.2) Teratogenic agents during first trimester (drugs, pesticides, thalidomide (60’s), Chernobyl
   4.3) Genetics

(National Limb Loss Information Center, 2008)
Amputation Statistics by Cause, United States, 1988 to 1996

- Congenital: Lower limb - 41.5, Upper limb - 58.5
- Cancer: Lower limb - 23.9, Upper limb - 76.1
- Trauma: Lower limb - 31, Upper limb - 68.6
- Dysvascular: Lower limb - 97, Upper limb - 3

per 100,000 limb-loss related hospital discharges

Figure retrieved from: National Limb Loss Information Center (2008).
(8) Amputation Levels

1. Interscapulothoracic
2. Shoulder disarticulation
Amputee levels

3. Transhumeral  (Above elbow/AE)

4. Elbow disarticulation
Amputee levels

5. Transradial (below elbow/BE)

6. Wrist disarticulation
Amputee levels

7. Transcarpal (partial hand)

8. Finger amputations
Prosthetic Options

1. No Prosthesis
2. Passive Functional /Cosmetic
3. Body Powered/Conventional
4. Myoelectric/External power
5. Hybrid
6. Adaptive

http://www.armdynamics.com/pages/prosthetic-options
Many People With Limb Loss Who Could Wear A Prosthesis Do Not Wear One:

- Bad First Experience
- Unnatural Look
- Reactions from Others
- Development of One-Handedness
- Financial Concerns
- Unaware of Options
- Limited Functional Ability
- Lack of Sufficient Prosthetic Training
Passive Functional / Cosmetic
### ADVANTAGES
- Cosmetic
- Lightweight
- Simple
- Little Maintenance
- Inexpensive (NON-custom silicone)
- Great for Partial Hands
- Provides Opposition

### DISADVANTAGES
- No Active Prehension
- Limited Function
- Decreased Durability
- Unreal Expectations for Cosmesis
- Custom Silicone Very Expensive
Body-Powered
## Cable Operated Control Principles

<table>
<thead>
<tr>
<th>Level of Amputation</th>
<th>Elbow Flexion</th>
<th>Terminal Device</th>
<th>Elbow Lock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder Disarticulation</td>
<td>Biscapular abduction &amp; Latissimus Dorsi</td>
<td>Biscapular abduction &amp; Latissimus Dorsi</td>
<td>Scapular elevation</td>
</tr>
<tr>
<td>Transhumeral</td>
<td>Biscapular Abduction &amp; Humeral Flexion</td>
<td>Biscapular Abduction &amp; Humeral Flexion</td>
<td>Shoulder Depression &amp; Humeral Abduction &amp; Extension</td>
</tr>
<tr>
<td>Transradial</td>
<td>Intact</td>
<td>Biscapular Abduction &amp; Humeral Flexion</td>
<td>Intact</td>
</tr>
</tbody>
</table>
Terminal Devices

- Two Load Hook

- Variable tension between 2 and 9 pounds so that the amputee can vary the pinch force needed per activity.
<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Heavy Duty Construction</td>
<td>- Grip Force is Limited (shoulder strength and rubber band tolerance)</td>
</tr>
<tr>
<td>- Proprioception</td>
<td>- Functional Envelope (ROM) is Limited</td>
</tr>
<tr>
<td>- Less Expensive</td>
<td>- Harness Can be Uncomfortable and restrictive</td>
</tr>
<tr>
<td>- Lighter in Weight</td>
<td>- Poor Cosmesis</td>
</tr>
<tr>
<td>- Reduced Cost and Maintenance</td>
<td>- Possible Over-Use, Nerve Entrapment Syndrome</td>
</tr>
</tbody>
</table>
Prosthetics for infants and toddlers

- Voluntary closing option
- Passive hands and prehension
Myoelectric /External Power
# Myoelectric /External Power

## ADVANTAGES
- Greater Functional Envelope
- Increased Cosmesis
- Greater Grip Force
- Reduced or Eliminated Harness System (greater comfort and improved ROM)

## DISADVANTAGES
- Increased Cost and Maintenance (initially)
- Increased Weight (typically)
- Battery
# Muscles for Myosites

<table>
<thead>
<tr>
<th>Amputation Level</th>
<th>Muscles for Myotesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Transradial</strong></td>
<td>Flexor Carpi Radialis, Flexor Carpi Ulnaris, Extensor Carpi Radialis Longus &amp; Brevis, Extensor Digitorum</td>
</tr>
<tr>
<td>2. <strong>Transhumeral</strong></td>
<td>Biceps Brachii, Triceps Brachii, Deltoid</td>
</tr>
<tr>
<td>3. <strong>Shoulder Disarticulation</strong></td>
<td>Pectoralis Major &amp; Minor, Trapezius, Teres Minor, Latisimuss Dorsi, Supraspinatus, Infraspinatus</td>
</tr>
</tbody>
</table>
Hybrid Prosthesis

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater Functional Envelope</td>
<td>Control Harness Typically Required</td>
</tr>
<tr>
<td>Reduced Weight</td>
<td></td>
</tr>
<tr>
<td>Greater Grip Force</td>
<td>Increased Weight on Harness</td>
</tr>
<tr>
<td>Reduced Harness System (greater comfort and improved ROM)</td>
<td></td>
</tr>
<tr>
<td>Feedback of Forearm Flexion Velocity</td>
<td></td>
</tr>
<tr>
<td>Reduced Initial and Maintenance Costs</td>
<td></td>
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</tbody>
</table>
Adaptive Prosthesis

- Customized for a Specific Function or Activity

- Recreational and Adaptive Terminal Devices (TD’s)

Texas Assistive Devices
TRS Assistive Devices
Post Operative and Pre-Prosthetic Therapy

- Pre-Prosthetic
  - Preparing the Residual Limb to Wear a Prosthesis

- Post Operative
  - Wound Healing, Pain Management, ROM, Psychosocial, IPOP’s
Pre-Prosthetic Assessment

ROM

Courtesy of Otto Bock
Pre-Prosthetic Assessment
Pre-Prosthetic Assessment

Muscle Site Testing

Circumference
Post Operative and Pre-Prosthetic Therapy

GOALS:

• Edema Control and Residual Limb Shaping
• Residual Limb Desensitization
• Dealing with Phantom Pain/Sensation
• Wound/Incision Management (prevention of contractures and scar management)
• Instruct in Residual Limb Hygiene
• Active and Assisted Range of Motion Exercises
• Increase Muscle Strength
• Home Program
GOALS (continued):

• Explore Psychosocial Issues

• Change in Dominance Activities and Adaptive Equipment Assessment for Increased Independence with ADL’s (Activities of Daily Living)

• Myoelectric Evaluation, Site Selection and Muscle Training if Appropriate

• Arrange Appointment and Attend Prosthetic Facility with the Patient for the Initial Eval (Orientation to Prosthetic Options)
Pre-Prosthetic Therapy

ROM

Wound Care

Shaping/Shrinking
Pre-Prosthetic Therapy

Scar Massage

Weight Bearing
Pre-Prosthetic Therapy

Muscle Training

Phantom Pain
Phantom Limb Sensation

**Phantom sensation:** feeling that the missing body part is still there.

May feel like:

- Tingly, prickly, numb, hot/cold, burning, cramping, or itching
- Missing toes/fingers are moving
- Limb is still there but fisted or in funny position
- Missing limb is getting shorted (telescoping)

(NIH, 2009)
Phantom Limb Pain

- Pain in the missing part of arm or leg
- May feel: sharp or shooting pain, aching burning, or cramping pain
- Lessons over time for most people
- Things that may make phantom pain worse:
  - Being tired
  - Putting too much pressure on residual limb
  - Changes in weather
  - Stress
  - Infection
  - Prosthesis not fitting properly
  - Poor blood flow
  - Swelling

(NIH, 2009)
Ways to manage phantom limb pain sensation

- Relaxation: deep breathing
- Warm towel wrap, warm bath
- Taking mind off pain: reading, music
- Move or exercise the residual limb
- Take off/put on prosthesis
- Wear shrinker/compression stocking
- Gentle tapping/rubbing
- Visualization/mirror image

(NIH, 2009)
Outcome Measures in Upper limb Prosthetics

- The Skill Index Rating Scale (SIRS)

- UNB Test of Prosthetics Function

- Unilateral Below-Elbow Test (UBET)

- Child Amputee Prosthesis Project-Functional Status Inventory (CAPP-FSI)
  - Children 8-17; Toddlers; Preschool

- Prosthetic Upper Extremity Functional Index (PUFI)
Progression of Training

The Skill Index Ranking Scale

1. Wear the prosthesis
2. Use prosthesis as support
3. Spontaneously move and preposition the amputated prosthetic side
4. Spontaneously place the terminal device (TD) in position and use it for support
5. Control the grasp-release function of the TD
6. Use a transverse volar grip, with the weight of the prosthetic limb unloaded from the child
7. Use the tripod pinch, still without the weight of the prosthetic limb
8. Use the transverse volar grip, without support for the prosthetic limb
9. Use the tripod pinch with no support for the weight of the prosthesis
10. Control the grip in various positions around the body
11. Manipulate objects by changing their position in the TD
12. Adjust the grip force in the TD, i.e. to hold without damage
13. Control the grip with the arm moving, i.e. throw things with the arm hanging down
14. Control the grip while moving the arm, throw things from above the shoulder

(American Academy of Orthotists And Prosthetists, n.d.)
Pre-Prosthetic Therapy

Controls
Training
MyoBoy

- Evaluation
- Component Selection
- Training
- Documentation
Post-Prosthetic Intervention

- Residual limb monitoring and hygiene (bony changes, breakdown)
- Est. wearing schedule (i.e. 30 min. intervals 3x/day w/ frequent skin checks)
- Independence in donning/doffing prosthesis (changing batteries)
- Continue muscle training
- Repetitive drills and activities
- Energy conservation and work simplification
- Functional Use Training (see checklist)
- Recreational tasks/return to work/school issues (modification, on-site eval)
- Peer introduction/psychosocial/motivation/ resources (Camp Ability, etc.)

Courtesy of Otto Bock
Controls Training

Practicing:

- Open and close (digital or proportional)
- Supination/pronation; elbow flexion/extension
- Practicing in various planes progressing to overhead
- Stressing good contact w/socket (myo) or proper tension on cable (body powered)
Repetitive Drills

- Grasp & release
  - Squeezing balls diff. density/size, pegs in pegboard, clothespins, stacking cups/cones

- Grasp & release incorporating wrist control by electronic or manual placement (turning cards, stacking cones, velcro strip on wall, cups)

- Flexion/extension of elbow (manual or electric)

- Switching between hand/wrist/elbow (cones)

- Simultaneous control of elbow/hand/wrist (pouring water, reaching into cabinet), different planes
Functional Use Training

- Most Difficult and Prolonged Stage of Prosthetic Training Process

- Patient’s Acceptance Dependent on:
  1. Motivation of the Patient
  2. Engaging in Purposeful, Functional Tasks (Realistic Situations)
  3. Experience of Therapist (continuity of care)
Rating Guide for “Single Upper Extremity Amputation-ADL’s”

Score of 0-3 bimanual tasks

• Personal Needs
  - Put on shirt, belt, gloves, coat, tie. Bra, zipper, nail care, toothpaste, fasteners.

• Eating Procedures
  - Carry a tray, butter bread, cut meat

• Desk Procedures
  - Use phone, ruler, scissors, paper clips, stapler, type/write, wrap present, sharpen pencil.

• General Procedures
  - Key and lock, cards/shuffle, open/close windows.

• Housekeeping Procedures
  - Wash/dry dishes, peel/cut veggies, sweep, vacuum, mop, iron, laundry, sew, open a can

• Use of Tools
  - saw, sand, hammer, drill, power tools

• Car Procedures
  - Drive, change tires, use jack.
Recreational/return to work/school

- Caregiving (changing diapers, etc.)
- Leisure (recreational tasks, riding bike)
- Specific work tasks (may need work site eval)
- Specific school tasks (may need school visit)
- Specific home tasks (may need home visit)
- Functional skills with/without prosthesis
- Switching dominance (handwriting, eating)
Adaptive Equipment (as needed)

- Rocker knife
- Swivel spoon (bilateral)
- One handed cutting board
- Hair dryer holder
- Adaptive keyboard
- Soap dispenser/suctioned sponge
- Long handled equipment (sponge, brush, nail clipper, toilet aid)
- Dycem/adaptive kitchen ware/electric can opener
- Reacher/dressing stick (limited ROM)/toilet aides
- Elastic laces
Secondary issues

- Shoulder issues (pain, rotator cuff, etc.)
- Arthritis
- Diabetes
- Osteoporosis
- Obesity
- Poor muscle sites (injury, obesity, etc.)
- Back pain
- Depression (referral to other services i.e. psych)
- Overuse issues

- Diet/smoking/sedentary lifestyle
- Strength training for older adults
- Falls
- Sleep issues
- Phantom Pain
- Heart problems
- Balance issues
- Cognitive limitations
- Safety issues
Special Considerations

- Patient/caregiver goals (Diamond)
- Cosmesis vs. Function (girls vs. guys)
- Future Goals (Trevor)
- Reimbursement issues
- Early fitting
- Kids vs. adults
- Living alone vs. caregiver
- Unilateral vs. bilateral
- Backup body powered prosthesis/ multi-use
- Pediatrics/ grow rates
- Developmental milestones
- Realistic expectations for prosthesis
Amputees in the Media

- Soul Surfer/ Bethany Hamilton
- Dolphin Tale/ Winter
- Survivor
- Dancing with the Stars
Current Events

- Earthquake in Haiti
- War in Iraq/Afghanistan (over 1,600)
  - The United States Armed Forces
    - Amputee Patient Care Program
  - Walter Reed Army Medical Center
  - Return to active duty programs/Avatar
- Osseointegration/ exoprosthesis-direct bone attachment (titanium bolt at end of stump)
- DARPA (Pentagon)- artificial limb ties into nervous system (researched, not available)
- 3D printing. E-nable
Companies/products

- **Ottobock** (Dynamic Arm, Michaelangelo, Sensor Hand, Grifer, body-powered)
- **Touch Bionics** (i-limb, Prodigits for partial hand)
  - Precision, power & key grip, rotatable thumb, 5 digits
- **BeBionic**
- **TRS**
- **Texas Assistive Devices**
- **Liberating Technologies**
- **Living Skin**
- **Boston Digital Arm**
Touch Bionic Products

I-limb (Precision, power & key grip, ) I-limb ultra/digits

I-limb digits (partial hand)
Interdisciplinary Team

**Ideal Situation:**

- Physician, prosthетist, nurse, occupational/physical therapist, case manager, psychologist, family, and vocational counselor

- Manufacturer’s clinical representative

Courtesy of Otto Bock
Resources

✔ Amputee coalition of America (ACA)

✔ American Academy of Orthotists and Prosthetists (oandp)

✔ Associations/Organizations/hospitals/univ.
  - AOTA, APTA, Rehab inst. Chicago, TIRR, ISPO, ASHT, Kessler, amprehab, ACPOC, helping hands, limb differences

✔ Prosthetic Companies: Living skin, otto bock, liberating tech, Touch Bionics, hosmer, TRS, hanger

✔ Camp Ability/summer camps

✔ Disabled Sports (one-armed bandits softball team)

✔ http://www.armdynamics.com/pages/counselingampresources
Functional Outcome/Study

- Functional Outcome of Adolescents and Young Adults with Congenital Upper Limb Reduction Deficiency

- Purpose: Gain insight into functional outcome of young adults/adolescents ages 12-35 with a unilateral congenital upper limb deficiency, with or without prosthesis.

- All 20 completed questionnaires and tests (Unilateral BE test: UBET, S. Hand Asses proc: SHAP, Child Amputee Prosthesis Project Functional Status Inventory: CAPP-FSI, Prosthetic UE Functional Index: PUF1), & Skill Index Rating Scale (SIRS)

- Results: 20 subjects with congenital below elbow deficiency. All were independent in daily activities, with or without a prosthesis.

- 9 wore a prosthesis an average of 10 hrs./day (6 myo, 3 passive). They found the prosthesis useful for specific activities (riding bike, lawnmower, opening bottle). Most dressed without device. Most needed help for cutting meat w/knife/fork, putting on necklace, chop fruit, can opener, hammer/nail, jump rope, peel apple, sew button, and blow dry hair.

- Results suggest prosthetic devices have additional value in persons with congenital below elbow deficiency in specific activities rather than overall performance of ADL’s.

(Lembregts, et.al, 2005)
Functional Outcome/study


• 242 participants, all ages and levels of upper limb absence completed a survey

• 20% had abandoned prosthesis use

• Biggest factor: level of limb absence

• Other factors: origin of absence, gender, bilateral

• Conclusions: Research on continued development of more comfortable and functional prostheses, for high-level and bilateral amputees

(Biddiss, E., Chau, T. 2007)
Case studies

- A.M.-10 year old girl with congenital syndrome known as heterotaxia syndrome (major organs on opposite side of body at birth). After surgery and 20 days of hospitalization, they did not put her on antibiotics or check her spleen, resulting in sepsis.
- Resulted in amputation of both legs, below elbow on 1 side, partial hand on the other.
- Current level of functioning (video)
- Fit with myoelectric prosthesis and bilateral lower extremity prosthetics
A.M
Case studies

- A.J.- 9 y.o. earthquake victim from Haiti
- Right transhumeral amputation, left 5th digit amputation, multiple injuries
- Fitted with body powered prosthesis for right arm, silicone finger tip prosthesis for left 5th digit.
- Extensive training provided
- Independent in most ADL’s following training. Independent with prosthesis
Diamond

- 11 y.o. girl (now 21) born without arms (bilateral interscalpulothoracic amputee)
- Fitted with “bionic” arms
- Independent/ Functional with feet (see video)
- Chooses not to wear prosthesis

VIDEO: [1](http://www.wctv.tv/home/headlines/126166718.html)
Prosthesis vs. without
Marissa
Functional Tasks
Aiden
Aiden Functional Tasks
Passive hands
Congenital Hand Constriction Band Syndrome
Functional tasks
Myoelectric
Fitting patients with phocomelia
Case study “Juan”

- Bilateral transhumeral amputee
- Electrical accident (lineman in Ecuador), extensive injuries
- Limited ROM
- Received hybrid elbow with myoelectric hand on one side (Ottobock sensorhand)
- Body powered device on other side with TD: hook
- Needed adaptive equipment: Toilet aid/bottom buddy, foot brush (suction cups), swivel spoon, reacher, dressing stick, elastic laces (sammons-preston.com)

Case study “Marco”

- Unilateral transhumeral amputee, MVA
- Occupation: house painter
- Received body powered prosthesis TD:hook
- Secondary shoulder issues/dislocation (misdiagnosed)
- Referred to ortho/therapy prior to starting prosthetic training
- Reimbursement issues/medicaid
Case study “Trevor”

- Unilateral transhumeral amputee, MVA
- Secondary brachial plexus injury
- Poor muscle sites
- Bulky prosthesis
- Dynamic arm with sensor hand
- Future goals
Case study “Maria”

- Unilateral transradial amputee, MVA
- Secondary issues: diabetes, obesity
- Poor muscle sites
- Overwhelmed psychologically
- Opted for passive hand/ cosmetic hand
Profiles

- Bob: Below Elbow/ transradial limb loss
- Ted: Above Elbow/ transhumeral limb loss
- Carol: Shoulder level: Shoulder disarticulation

http://www.amputee-coalition.org/inmotion/jul_aug_07/ue_prosthetic_pt2.html
Advanced Arm Dynamics

- http://www.armdynamics.com/
Video Bilateral Amputee

- http://www.youtube.com/watch?v=8QJ_NlzVVSd
Transradial amputee videos/
prosthetic tips

- [Video](http://www.youtube.com/watch?v=AR3bst7uSzI&feature=BFa&list=PL5E935AA6CAFCC458) Prosthetic tip #1: holding a knife
- [Video](http://www.youtube.com/watch?v=nXgtJBce0H4&feature=autoplay&list=PL5E935AA6CAFCC458&playnext=1) Prosthetic tip #2: tying a shoe
- [Video](http://www.youtube.com/watch?v=1r-RCKpdWWU&feature=BFa&list=PL5E935AA6CAFCC458) Prosthetic tip #3: opening a jar
- [Video](http://www.youtube.com/watch?v=vB4F7HhF4AU&feature=autoplay&list=PL5E935AA6CAFCC458&playnext=1) Prosthetic tip #4: Turning a car key
Donning prosthesis

Quotes by Bethany Hamilton

- People can do whatever they want if they just set their heart to it, and just never give up and just go out there and do it.

- Courage doesn’t mean you don’t get afraid. Courage means you don’t let fear stop you.

- Courage, sacrifice, determination, commitment, toughness, heart, talent, guts. That’s what little girls are made of; the heck with sugar and spice.

- Life is dangerous…enjoy!
  - Bethany Hamilton, 14 year old shark victim, Hawaiian surfer
References


4. Courtesy of Otto Bock

5. Courtesy of TRS
