

Chapter 24:

Amputations and Prosthetics

Brian Monroe, CPO

1. Overview
 - a. Terminology for amputation
 - i. Acquired
 1. Trans: across the axis of long bone
 2. Disarticulation: through center of joint
 3. Partial: amputation distal to the wrist
 4. Exception: forequarter (amputation at scapulo-thoracic /sternoclavicular joint)
 - ii. Congenital
 1. Transverse
 - a. Normal development until the point of deficiency
 - i. Name long bone involved
 - ii. Length
 1. Complete
 2. Upper-third
 3. Middle-third
 4. Lower-third
 - b. Carpal, metacarpal or phalangeal
 - i. Only complete or partial are used
 2. Longitudinal
 - a. Absence of skeletal anatomy within the long axis of the limb - may include normal distal anatomy
 - b. Named by bones affected in proximal to distal sequence
 - i. Described as totally or partially absent
 - ii. Metacarpal and phalanges
 1. State the number of the digit affected
 - a. Start at radial side
 - b. Thumb – 1
 2. Example: longitudinal deficiency, right; radius, complete; carpals, partial; metacarpals 1,2, complete; phalanges 1,2 complete
 - b. Etiology of amputation
 - i. Approximately 90% due to trauma
Other causes: Congenital, tumor, infection, neurologicalⁱ
 - ii. 4:1 male to female
 - iii. Peak occurrence between 20-40 years of age
 - iv. Right=Left in adult, Left > Right in Congenital
 - v. 10% bilateral
 - vi. Approximately 5 per 100,000 UE amputations per year in U.S.ⁱⁱ
 - c. Levels of amputation (the more distal the amputation, the more function available)

Chapter 24: Amputations and Prosthetics

Brian Monroe, CPO

- i. Finger
 1. Reasons for prosthetic use
 - a. Cosmesis
 - b. Mechanical protection
 - c. Increased length for activities such as typing or musical instrument
 2. Thumb
 - a. Loss of opposition
 - b. 40% loss of hand function
 - c. 36% loss of function for the entire upper limb
 - ii. Partial hand
 1. Maintains wrist motion
 - iii. Wrist disarticulation
 1. Styloids allow for suspension
 2. Maintains pronation and supination
 - iv. Trans-radial
 1. Distal 1/3 maintains pronation/supination
 2. Mid 1/3 loss of approximately 50% pronation/supination
 3. Proximal 1/3 complete loss of pronation/supination
 - v. Elbow disarticulation
 1. Condyles allow for suspension
 2. Active humeral internal/external rotation with prosthesis
 3. Poor cosmesis and limited componentry due to length
 - vi. Trans-humeral
 1. Loss of active internal/external rotation with prosthesis
 2. Need 3" from end of residual limb to elbow center for most prosthetic elbows
 - vii. Shoulder disarticulation
 1. Complete loss of glenohumeral flexion as a control option
 2. Increased need for complex control systems and smaller socket interphases to allow for heat dissipation
 - viii. Forequarter
 1. Most debilitating UE amputation both physically and psychologically
 2. Great deal of skin loss for heat dissipation
 3. With out a prosthesis or shoulder cap the disfigurement is easily apparent through clothing
 - ix. Bilateral
 1. Not treated as two unilateral amputations
 2. Person relies on prostheses for most ADL
2. Six Prosthetic Options
 - a. No prosthesis
 - i. Advantages
 1. Sensation and proprioception
 2. Comfort – no socket interface

3. Mobility – range of motion not limited by trim lines, harnessing or weight of prosthesis
- ii. Disadvantage
 1. No active prehension
 2. Poor body symmetry (cosmesis)
 3. Balance issues with higher amputation levels (unless congenital)
- iii. Possible use of foot skills in higher levels or bilateral
- b. Passive (semi-prehensile- moldable fingers)
 - i. Advantages
 1. Increased length (opposition post for intact limb)
 2. Body symmetry (cosmesis)
 3. Finger can be manually positioned for holding light objects
 4. Light weight
 - ii. Disadvantages
 1. No active grasp
 2. Durability of cosmetic covering
 3. Prosthetic skin does not change color as intact limb does with change in temperature or seasons
 - iii. Patient can have unreal expectation of cosmesis
- c. Body powered
 - i. Gross body motions used to control and power the various prosthetic components
 1. Bowden (single control): terminal device only
 - a. Gleno-humeral flexion and/or bicipital abduction
 2. Dual control (split cable)
 - a. Gleno-humeral flexion and/or bicipital abduction control elbow flexion
 - i. Once the elbow is locked, further gleno-humeral flexion and/or bicipital abduction controls terminal device
 - b. Shoulder depression, gleno-humeral extension, and abduction lock the elbow
 3. Triple control: Independent control of terminal device, elbow flexion, and elbow lock
 - a. Bicipital abduction controls the terminal device
 - b. Gleno-humeral flexion controls the elbow
 - c. Shoulder depression, gleno-humeral extension, and abduction lock the elbow
 - ii. Advantages
 1. Proprioception through cable and harness
 2. Typically less expensive
 3. Typically more durable
 4. Typically lighter in weight with good distribution of prosthetic center of gravity
 - iii. Disadvantages

Chapter 24: Amputations and Prosthetics

Brian Monroe, CPO

1. Decreased functional ROM
 2. Must be able to generate required power and have adequate ROM to operate
 3. Increased harnessing to capture gross body motions
 4. Possible nerve entrapment syndrome of sound limb due to axilla anchor point of typical harness designs
 5. Potential atrophy of distal intrinsic muscles due to disuse
- d. External power (Fig. 1)
- i. Typically uses battery power, control inputs can include EMG, switches, touch pads, or servos
 - ii. Advantages
 1. Increased functional ROM
 2. Reduced or eliminated harnessing
 3. Cosmetic value of hand with increased grip strength
 4. With EMG control the same or similar neuromuscular pathways are used to control the prosthesis
 5. Limited or no body motions are used to power/control the prosthesis
 - iii. Disadvantages
 1. Typically relies on battery for operation
 2. Increased weight
 3. Cost and maintenance of electrical componentry
 4. Less proprioception than body powered systems
 5. Electrical components can be damaged by moisture
- e. Hybrid (Fig. 2)
- i. Combines the benefits of various systems while limiting the disadvantages (passive, body powered, or external powered componentry)
 1. Typical trans-humeral example: body powered elbow and externally powered hand
- f. Adaptive or activity specific (Fig. 3)
- i. Prosthesis designed for a specific activity such as a sport or vocational need
 - ii. Adaptation of one prosthetic design for multiple tasks
 1. Usually interchangeable terminal devices
 - iii. There are many activity specific terminal devices, but the amputee should be taught to use the primary device for most tasks before multiple attachments are provided
- g. Multiple prosthesis
- i. Not one prosthetic design meets all the needs of the typical amputee, sometimes multiple prosthetic designs are used to accomplish the ADL, vocational, and avocational goals of the individual

3. Componentry
 - a. Hooks

Chapter 24 Figures



Fig. 1. Transradial External Powered.



Fig. 2. Body Powered Elbow and Myoelectric Hand.

Chapter 24: Amputations and Prosthetics

Brian Monroe, CPO

- i. Body powered
 - 1. Voluntary opening: cable excursion opens the hook and preset rubber bands or springs close the hook
 - a. Good line of site
 - b. Excellent dexterity for fine motor skills
 - c. Grip strength limited by the number of rubber bands, or spring tension, typically 2-6 lbs
 - d. Numerous designs from light duty to farming
 - 2. Voluntary closing: cable excursion closes the hook
 - a. Proportional grip strength
 - b. Increased grip strength; only limited by the amputees ability to generate gross body motion (healthy adult male can generate over 100lbs of grip strength)
 - c. Must maintain cable excursion to maintain grip on object
 - ii. External powered
 - 1. Uses some of the same advantages of the hook design but not limited by the harness and cabling
 - 2. Capable of generating up to 35lbs of pinch force
- b. Hands
- i. Passive
 - 1. Fingers can be bent into various positions to hold light objects
 - 2. Spring assisted closure: hand can be opened with sound limb and spring closes hand to hold light objects
 - ii. Body powered
 - 1. Most designs are not very functional due to the restraints of cabling and maintaining the cosmetic value of a hand
 - iii. External powered
 - 1. 3 jaw chuck grasp
 - a. Good grip strength (approximately 22 lbs.)
 - b. Ability to have both proportional grip strength and speed
 - c. Limited to only one grasp pattern
 - 2. Compliant grasp
 - a. All 5 fingers close around the object
 - b. Ability to have both proportional grip strength and speed
 - c. Typically less grip strength per finger than 3 jaw chuck grasp pattern, but a secure grip is achieved by all five fingers contacting the object
 - d. Thumb is manually positioned to achieve lateral prehension
 - e. Ability to program additional grasp patterns
- c. Wrists

- i. Body powered/passive
 1. Friction: the resistance to pronation or supination is set with an adjustment screw
 2. Positive locking: terminal device can be positioned and locked to maintain that amount of pronation or supination
 3. Flexion wrist: terminal device can be flexed or extended
 4. Ball and socket: terminal device can be positioned
 5. Quick disconnect: used to easily change terminal devices
 6. 4 function/5 function: through cabling and mechanics the wrist is capable of flexion/extension and pronation/supination
 - ii. External powered
 1. Typically electrical motor powers the terminal device into supination or pronation with the ability to have proportional control
 - d. Elbows
 - i. Passive
 1. Forearm is manually placed in some degree of flexion and either friction or a manual lock is activated to maintain the desired ROM
 - ii. Body powered
 1. Gross body motion powers elbow flexion
 - iii. External powered
 1. Battery is typically used to power elbow flexion and/or extension
 - e. Shoulders
 - i. There are no commercially available powered shoulder joints
 - ii. The prosthesis is manually positioned and is locked either with a manual switch or electric switch
 - 4. Complicated Pathway: injury that prevents good surgical closure and/or increased hospital stay
 - a. Pre-operative
 - i. If possible, consult with rehab team, educate the patient, psychological consult or amputee peer counseling, and maintenance of ROM and strength in proximal joints
 - b. Surgery
 - c. Inpatient therapy
 - i. Pain control
 1. Distinguish between residual limb pain, phantom sensation, and phantom pain (phantom pain is experienced by 80% of amputees)ⁱⁱⁱ
 2. Acute pain treated w/ narcotic for 3-4 days post op
 3. Various pain therapies dependent on cause

Chapter 24: Amputations and Prosthetics

Brian Monroe, CPO

- a. Dr. Ramachandran has reported a decrease in phantom limb pain using a mirror box to reflect the uninvolved side as the missing side.^{iv}
- ii. Wound care
 1. Skin and incision inspection
 - a. Teach signs of infection: redness, odor, change in amount or color of drainage, heat, swelling, low grade temperature
 2. Nutrition consult
 3. Have patient help with dressing changes
- iii. Maintenance of normal joint range of motion
 1. Active and active-assistive ROM at proximal joints initiated at 2nd post op day
 2. Isometric contractions at 5th day post op
 3. Isotonic contractions 7-10 days post op
 4. Maintain capsular, skin, and soft tissue mobility
- iv. Residual limb shrinkage and shaping
 1. Rigid dressing if there is good skin integrity
 2. Compression device when primary healing has started and application will not disrupt skin integrity
 - a. Ace wrap
 - b. Compressogrip™ shrinker
- v. Residual limb desensitizing
 1. Start with light touch and progress to deep massage
- vi. Instruction in proper limb hygiene
 1. Educate and get patient involved to decrease chances of limb neglect
- vii. Increasing muscle strength and endurance
 1. Maintain strength on the amputated side as well as contra lateral side
 2. Increase muscle endurance and general cardiovascular conditioning
- viii. Maximizing independence
 1. Change hand dominance and introduce one handed adaptive equipment if needed
 2. Functional Independence Measure (FIM)
- ix. Patient education
 1. Introduce 6 prosthetic options
 2. Realistic expectations of prosthetic rehabilitation
 3. Psychological consultation and/or amputee support group with similar levels of amputation
- x. Body image/body mechanics
 1. Psycho-social impact
- d. Outpatient therapy
 - i. Transferred from inpatient to outpatient when they are medically stable to go home

1. Good FIM scores
 2. Home/family support
 - ii. Continuation of the inpatient therapy model
 - e. Pre-prosthetic training (Fig. 4)
 - i. Introduce EMG training
 - ii. Target specific motions and muscle groups used to operate the prosthesis
 - iii. Monitor residual limb volume
 - f. Preparatory/definitive prosthesis
 - i. Fit the preparatory as soon as possible - “golden period” if fit with prosthetic device in the first 30 days following an amputation the rehabilitation success rate dramatically improves^v
 - ii. Fit definitive as soon as limb volume stabilizes (limb shaping and atrophy will continue for the first 6 months post op)
 - g. Repetitive and functional prosthetic training
 - i. Donning and doffing
 - ii. Grasp and release of same size objects
 - iii. Grasp and release of various size objects and densities
 - iv. Work in various heights and planes of the body
 - v. The goal is to encourage efficient reaching patterns^{vi}
 - vi. Assess function utilizing standard outcome measures: i.e. Functional Independence Measure (FIM) and Functional Assessment Measure (FAM)
 - h. Vocational training
 - i. Driver education
 - ii. Will patient be returning to the same vocation, altered job duties, or new vocation
 - iii. Access need for activity specific or adaptive attachments
 - i. Follow-up
 - i. Periodic follow-ups to address any issues with fit/maintenance and monitor the reintegration of the patient into the community
 - ii. Monitor body image and psycho-social issues
 - iii. Use subjective information to assess outcomes since there is currently no accepted amputee-specific standardized measure that has been validated.^{vii}
5. Uncomplicated Pathway: amputation with good surgical closure and no other injuries that would cause an increased hospital stay
 - a. Pre-operative
 - i. If possible consult with rehab team, educate the patient, psychological consult or amputee peer counseling, and maintenance of ROM and strength in proximal joints
 - b. Amputation surgery & Immediate Post Operative Prosthesis (IPOP) application (Fig. 5)
 - i. IPOP applied in the OR by prosthetist
 1. Can be external power or body powered

Chapter 24: Amputations and Prosthetics

Brian Monroe, CPO

2. Can be used on all levels, but best results at the Trans radial level
 3. Advantages
 - a. Decreased edema
 - b. Decreased postoperative pain
 - c. Decreased phantom pain
 - d. Improved patient rehabilitation
 - e. Increased prosthetic use
 4. Disadvantages
 - a. Decreased ability to monitor suture line
 - b. Patient needs to be cognitively intact
 - c. Best results in a hospital with multidisciplinary approach
- c. Acute inpatient therapy
- i. 1 day post op
 1. Harness applied
 2. Review signs of infection or looseness of IPOP
 - ii. 2nd day post op
 1. Start working on bimanual activities
 2. Active and active-assisted proximal joint ROM
 3. FIM assessment
- d. Outpatient therapy
- i. Transfer to outpatient when medically stable to discharge and when patient has demonstrated compliance and the cognitive ability to recognize if there is a potential problem with the fit
 - ii. Rehabilitation time line is dynamic and can be followed as inpatient or outpatient
 - iii. 3-5 days post op
 1. Start functional and repetitive tasks
 2. Address body symmetry issues
 3. Review IPOP precautions and signs of looseness
 - iv. 5-7 days post op
 1. Rigid dressing removed for limb inspection
 2. Reapply IPOP
 3. Continue functional and repetitive training
 4. Isometric contractions in the residuum started at 5th post op day
 - v. 7-10 days post op
 1. Start isotonic contractions in the residuum
 - vi. 14 days post op
 1. Remove rigid dressing
 2. Sutures are usually removed between 14 and 21 days post op
 - a. If sutures removed apply compression garment and mold taken for preparatory prosthesis

Chapter 24 Figures



Fig. 3. Activity Specific Transradial.



Fig. 4. Pre-prosthetic EMG training.

Chapter 24: Amputations and Prosthetics

Brian Monroe, CPO

- b. If sutures are left intact – reapply rigid dressing for another 5-7 days
 - c. Once sutures are removed start use of preparatory prosthesis
- e. Preparatory prosthesis
 - i. Used to assess control strategy, components, and to speed shaping of the residual limb
 - ii. Can be used from a few days to several months depending on complexity of amputation level and rate of limb shaping
- f. Definitive prosthesis
 - i. Used as soon as limb volume has stabilized and control strategy is established
- g. Vocational training
 - i. Depending on work environment patient can return to work at any stage of the rehab process
 - ii. Assess if any changes will need to be made in the work environment
 - iii. Determine if adaptive tools or additional terminal devices need to be used with the prosthesis
 - iv. Driver education
- h. Follow-up/outcome measure
 - i. Periodic follow-ups to address any issues with fit/maintenance and monitor the reintegration of the patient into the community
 - ii. Monitor body image and psycho-social issues
 - iii. There is no one functional amputee-specific measure that is recognized as the standard
 - 1. The Upper limb Prosthetic Academy’s State of Science Conference rated the current available outcome measures^{viii}

Chapter 24 Figures



Fig. 5. Immediate Post Operative Prosthesis.

References

1. Atroshi I, Rosberg HE. Epidemiology of amputations and severe injuries of the hand. *Hand Clin.* 2001;17:343-50.
2. Dillingham TR, Pezzin LE, MacKenzie EJ. Limb amputation and limb deficiency: epidemiology and recent trends in the United States. *South Med J.* 2002;95(8):875–883.
3. Jensen TS. et al. *Pain* 1985; 21:268-278.
4. Ramachandran VS, Rogers-Ramachandran D. Synaesthesia in phantom limbs induced with mirrors. *Proc Biol Sci.* 1996; 263(No.1369):377-86.
5. Malone JM, Fleming LL, Roberson J, Whitesides TE, Leal JM, Poole JU, Sternstein Grodin R. Immediate, early, and late postsurgical management of upper-limb amputation. *J Rehabil Res Dev.* 1984;21:33-41.
6. Atkins JD, Meier RH (eds). *Comprehensive Management of the Upper-Limb Amputee.* New York: Springer-Verlag, 1989, pp 48.
7. *Prosthetic Outcome Measures for Use With Upper Limb Amputees: A Systematic Review of the Peer-Reviewed Literature, 1970 to 2009.* Virginia Wright, PT, PhD.
8. *Summary and Recommendations of the Academy’s State of the Science Conference on Upper Limb Prosthetic Outcome Measures.* Laura A. Miller, PhD, CP, Shawn Swanson, OTR/L.

Multiple Choice Questions

1. In a dual control (split cable) body powered prosthesis:
 - A. Gleno-humeral flexion controls elbow flexion and bicipital abduction controls the terminal device
 - B. Shoulder depression, gleno-humeral extension, and abduction control elbow flexion
 - C. Gleno-humeral flexion and / or bicipital abduction control elbow flexion and the terminal device
 - D. Shoulder depression, gleno-humeral extension, and abduction control the terminal device
2. In a single control (Bowden) body powered prosthesis:
 - A. Gleno-humeral flexion and/or bicipital abduction controls only the terminal device
 - B. Gleno-humeral flexion and/or bicipital abduction controls only the elbow lock
 - C. Gleno-humeral flexion and/or bicipital abduction controls only elbow flexion
 - D. The amputee has independent control of the terminal device, elbow flexion, and elbow lock
3. An external powered prosthesis:
 - A. Requires increased harnessing
 - B. Is lighter than other prosthetic options
 - C. Uses gross body motions to power the prosthetic componentry
 - D. Typically uses a battery to power the prosthetic componentry
4. A voluntary opening hook:
 - A. Has proportional grip force
 - B. Is only available in light duty designs
 - C. Uses rubber bands to control the grip force
 - D. Must maintain cable excursion to maintain grip on an object
5. Body powered hands:
 - A. Have limited function because of the restraints of cabling while maintaining the cosmetic value of the hand
 - B. Allow for direct line of site when grasping an object
 - C. Are opened by the sound hand and have a spring assisted closure
 - D. Have an increased functional envelope as compared to external powered hands
6. An uncomplicated clinical pathway for amputation refers to:
 - A. An injury that prevents good surgical closure and/or increased hospital stay
 - B. An injury that results in amputation from a disease process and not a traumatic event
 - C. An injury that results in amputation from a war time injury and not a disease process
 - D. An amputation with good surgical closure and no other injuries that would cause an increased hospital stay
7. An Immediate Post Operative Prosthesis (IPOP) is:
 - A. Is applied after the “golden period”
 - B. Applied in the operating room
 - C. Is only for amputations at or above the elbow
 - D. Is only used for amputations with secondary healing

Multiple Choice Questions

8. The first cast change for an Immediate post Operative Prosthesis (IPOP) occurs:
 - A. When the definitive prosthesis is ready for fitting
 - B. When the patient transfers from in-patient to out-patient therapy
 - C. When ever there are signs of looseness or 5-7 days post op
 - D. When the sutures are removed
9. When should residual limb shrinking and shaping occur?
 - A. Once the suture line is completely healed
 - B. The same time the definitive prosthesis is fitted
 - C. Once the myoelectric prosthesis is fitted
 - D. Once primary healing has started and application will not disrupt skin integrity
10. An external powered compliant grasp hand:
 - A. Is able to be programmed for multiple grasp patterns
 - B. Has only one grasp pattern
 - C. Does not have proportional grip
 - D. Has increased grip strength as compared to other prosthetic hands
11. Which of the following is not part of the complicated clinical pathway?
 - A. Wound care
 - B. Maintain normal joint range of motion
 - C. Immediate post operative prosthesis (IPOP)
 - D. Residual limb shrinkage and shaping
12. Active and active-assistive range of motion at the proximal joints should begin:
 - A. Once sutures are removed
 - B. At the 2nd post op day
 - C. When primary healing has occurred
 - D. Once the amputee receives their definitive prosthesis
13. The "golden period" for prosthetic fitting refers to:
 - A. A prosthetic fitting with in the first 30 days of amputation
 - B. Prosthetic fitting during world war II
 - C. Successful integration of the prosthesis into the amputee's activities of daily living
 - D. A prosthetic fitting for congenital limb deficiencies in the first year of life
14. A voluntary closing hook:
 - A. Grip strength is limited by the number of rubber bands
 - B. Is only available in light duty designs
 - C. Uses external power to control the grip force
 - D. Allows the amputee to control the amount of grip force

**Multiple Choice Question Answer Key
Chapter 24**

1-C, 2-A, 3-D, 4-C, 5-A, 6-D, 7-B,
8-C, 9-D, 10-A, 11-C, 12-B, 13-A, 14-D