VA/DoD CLINICAL PRACTICE GUIDELINE FOR THE MANAGEMENT OF UPPER EXTREMITY AMPUTATION REHABILITATION

Department of Veterans Affairs
Department of Defense

QUALIFYING STATEMENTS

The Department of Veterans Affairs and the Department of Defense guidelines are based upon the best information available at the time of publication. They are designed to provide information and assist decision making. They are not intended to define a standard of care and should not be construed as one. Neither should they be interpreted as prescribing an exclusive course of management.

This Clinical Practice Guideline is based on a systematic review of both clinical and epidemiological evidence. Developed by a panel of multidisciplinary experts, it provides a clear explanation of the logical relationships between various care options and health outcomes while rating both the quality of the evidence and the strength of the recommendations.

Variations in practice will inevitably and appropriately occur when clinicians take into account the needs of individual patients, available resources, and limitations unique to an institution or type of practice. Every healthcare professional making use of these guidelines is responsible for evaluating the appropriateness of applying them in the setting of any particular clinical situation.

These guidelines are not intended to represent TRICARE policy. Further, inclusion of recommendations for specific testing and/or therapeutic interventions within these guidelines does not guarantee coverage of civilian sector care. Additional information on current TRICARE benefits may be found at www.tricare.mil or by contacting your regional TRICARE Managed Care Support Contractor.

Version 1.0 – 2014

Prepared by:

The Management of Upper Extremity Amputation Rehabilitation Working Group

With support from:

The Office of Quality, Safety and Value, VA, Washington, DC
&
Office of Evidence Based Practice, US Army Medical Command

Version 1.0 – 2014

Based on evidence reviewed through June 2013

Table of Contents

Executive Summary

Amputation presents a significant disability for the nearly two million Americans living with limb* loss. In approximately three percent of this population one or both upper limbs are involved [1] with nearly 70 percent of upper limb amputations resulting from trauma. [2] Traumatic injuries are also the most common cause of upper limb amputations within the Department of Defense (DoD) and Department of Veterans Affairs (VA). Other causes of amputations are from cancer, infections, and dysvascular conditions. From 2001-2014, more than 700 Service Members with some level of upper limb amputation (including partial hand and digits) were cared for in one of three military advanced rehabilitation facilities, comprising approximately 30 percent of the total amputation population treated. More than 32,000 Veterans with some level (including partial hand and digits) of upper limb amputation (18 percent of the total amputation population) were cared for in the Veterans Health Administration (VHA) since2000. [3]

Expertise for upper limb amputations is very limited across many healthcare disciplines, so the requests for an upper limb amputation clinical practice guideline by more than 75 percent of certified hand therapists [4] nationwide are not surprising. A tremendous amount of knowledge, advancement, and expertise has been acquired during the care of patients with upper limb amputation, not only the combat-related cohorts from Operations Iraqi Freedom, Enduring Freedom, and New Dawn, but also from managing the rehabilitation needs of aging Veterans with upper limb loss. With this clinical practice guideline, VA and DoD subject matter experts culminate more than a decade of research, unprecedented clinical experience, and funding of new technologies for the upper limb loss patient to translate these contributions into a standard of care, clinical practice, and ultimately improved health, quality of life, and satisfaction for this population of patients.

*For this Clinical Practice Guideline, limb and extremity are used interchangeably.

Introduction and Background

The clinical practice guideline (CPG) for The Management of Upper Extremity Amputation Rehabilitation (UEAR) was developed under the auspices of the VHA and DoD pursuant to directives for the VA. These entities define CPGs as:

"Recommendations for the performance or exclusion of specific procedures or services derived through a rigorous methodological approach that includes:

- Determination of approach criteria such as effectiveness, efficacy, population benefit, or patient satisfaction; and
- Literature review to determine the strength of the evidence in relation to these criteria."

This guideline is designed to address the key principles of rehabilitation and clinical care for patients with upper limb amputation. This CPG highlights the following goals to ensure quality care:

- Promote a patient centered interdisciplinary team approach
- Describe the prosthetic prescription process, prosthetic training, activities of daily living (ADL) and instrumental activities of daily living (IADL) training with and without a prosthesis, physical conditioning, and psychosocial rehabilitation to maximize the patient's function and quality of life
- Describe appropriate interventions to optimize the patient's physical function after an amputation (e.g., range of motion, flexibility, muscle strength and endurance, and cardiovascular fitness)
- Develop clinical pathways that are consistent with current evidence-based rehabilitation methods
- Provide primary care providers an algorithm to assist with the referral process
- Provide rehabilitation care providers with a structured framework of appropriate rehabilitation interventions to improve the patient's outcome and reduce practice variation
- Establish priorities for future research efforts that will generate evidence for practice improvement

Traumatic injuries account for nearly 70 percent of upper limb amputations in the United States [2] and are also the most common cause of upper limb amputations within DoD and VA. Extremity injuries occur from military combat (e.g., blast, shrapnel, and gunshot), motor vehicle accidents, and other training and industrial accidents. While improvements in immediate trauma care, advanced reconstructive surgical techniques, and rehabilitation have reduced the need for some amputations, Veterans and Service Members continue to be at significant risk for amputation. Of the total amputation population cared for within DoD advanced rehabilitation facilities and VA healthcare since 2001, approximately 30 percent in DoD and 18 percent in VA have involved one or both upper limbs. [3]

The successful rehabilitation of patients with upper limb amputations is influenced by a variety of factors that include, but are not limited to, level of amputation, cognitive impairment, physical conditioning, nutritional status, social support, psychological factors and motivation. To maximize successful outcomes and return patients to independent living in home, work and community

environments, these factors must be considered in the development of a rehabilitation program and care plan for the Veteran or Service Member with an upper extremity amputation. Most upper limb amputation patients are candidates for a prosthesis; however, some may not choose to use a prosthesis. For those patients, other approaches need to be considered to allow these patients to be functionally independent.

While the pathophysiology of traumatic amputations may be different than non-traumatic amputations, rehabilitation strategies and prosthetic component prescriptions for both should be centered around realistic patient goals with concentrated efforts directed to maximize function. The overall goal of amputation rehabilitation is to optimize the patient's health status, function, independence, and quality of life. Ongoing medical assessments and therapy interventions to address psychosocial, physical and functional limitations are necessary to achieve these desired end states.

Long-Term Goals of Upper Extremity Amputation Rehabilitation Care

The CPG Working Group defined goals of amputation rehabilitation care necessary to achieve success in the key domains of postoperative pain, physical health, function, psychological support and well-being, patient satisfaction, reintegration, and healthcare utilization. These are described in Table 1.

Table 1. Key Domains of Care and Goals of Amputation Rehabilitation

Domain	Goals
Postoperative pain	• Reduce residual limb pain, improve effectiveness of coping, and reduce interference with daily function • Reduce phantom limb pain • Minimize complications and side-effects associated with the use of narcotic pain medications
Physical health	• Reduce the risk of adverse effects due to use or non-use of an artificial limb • Prevent and decrease impact of overuse injuries in remaining extremities and residual limb • Improve and maintain physical health (e.g., residual limb care and tolerance; improve and maintain range of motion proximal to the amputation and throughout the body; core strengthening, postural stability, and balance; cardiovascular health, and increase strength and endurance) to maximize efficient use of a prosthesis
Function	• Improve functional independence with and without a prosthesis (e.g., independence and safety in self-care, work, recreational/leisure activities and mobility activities) • Improve quality of life and decrease activity restriction (e.g., optimize self-care, community integration, recreation, return to home and productive work environments)
Psychological support and wellbeing	• Reduce psychological comorbidities (e.g., depressive and anxiety disorders)

Domain	Goals
	• Improve quality of life • Decrease the mental/emotional disease burden • Enhance adjustment to disability through healthy body image and self-esteem development
Patient satisfaction	• Improve satisfaction with the level of skills and independence • For patients receiving prostheses, improve satisfaction with the prosthesis (comfort, functionality, and cosmesis) • Improve satisfaction with healthcare services and care providers
Community Integration	• Improve the discharge outcome (discharge to the least restrictive environment) • Improve vocational outcomes • Improve recreational participation • Maximize community participation
Healthcare utilization	• Optimize the length of rehabilitation stay • Optimize the time between prosthetic fitting patient goal attainment • Optimize Lifelong care and minimize the effects of long-term prosthesis use

Organization of This Clinical Practice Guideline

This guideline is organized to provide the reader with a quick access algorithm, a discussion of important patient care themes, and information pertaining to each phase of care in upper extremity amputation rehabilitation. The algorithm of care provides a step-by-step clinical decision making process as well as important interventions that occur within each phase of care. A subset of recommendations is provided within each core module and phase of care.

Core Modules

The core modules highlight essential elements of care encompassed within all phases of care following upper limb amputation. The core modules include:

- Core 1: The Care Team Approach
- Core 2: Comprehensive Interdisciplinary Assessments
- Core 3: Patient-Centered Care

Phases of Rehabilitation Care

There are four phases of care which create a framework for rehabilitation and long term management of patients with an upper limb amputation. The phases are not defined by fixed points in time. Rather, they often overlap to accommodate for the patient's recovery process based on an appreciation of the patient's needs, severity of injury, wound healing, pain tolerance, and psychological readiness. Additionally, progression through the phases of care does not necessarily occur sequentially in a linear direction. Phases are repeated as appropriate based on needs of the patient.

The four phases are:

- Phase 1: Perioperative
- Phase 2: Pre-prosthetic
- Phase 3: Prosthetic Training
- Phase 4: Lifelong Care

The Perioperative phase of rehabilitation commences when a patient has been initially evaluated in the clinical setting and has either undergone an upper limb amputation, or the decision has been made that amputation is necessary. In the vast majority of cases, the mechanism of injury resulting in upper limb amputation will be traumatic in nature. Complete interdisciplinary assessments of the patient's medical, functional, and psychological status should be performed as soon as it is clinically appropriate in order to establish a baseline level of function and prepare the patient for the ensuing rehabilitation plan and, ultimately, lifetime care. The continuum of this phase is to: ensure communication and coordination of care; provide proper medical, surgical, and psychological management; initiate rehabilitation; and facilitate protective healing of the residual limb. The end of the Perioperative phase occurs when residual limb wounds are free of infection and closed, sutures are removed, the patient has been medical cleared, and has maximized independence in self- care ADL using one-handed strategies and adaptive or durable medical equipment.

The goal of the Pre-prosthetic phase is to prepare the patient and his or her residual limb for initial prosthetic fitting. In this phase, the care team determines if the patient is a candidate for prosthesis and aids the patient in determining which type of prosthesis will be most beneficial. During this phase, wound closure and pain control continue to be monitored, ongoing rehabilitation interventions are performed, and continued psychosocial support is provided. The patient must be medically, surgically and cognitively cleared by the care team for a diagnostic socket fitting to occur. The Pre-prosthetic phase ends with the fitting of the preparatory prosthesis. This phase typically occurs in an outpatient or rehabilitation setting.

The Prosthetic Training phase marks a turning point in the rehabilitation of the patient who desires a prosthesis. Phases one and two provide a foundation for success in phase three. This phase commences upon delivery of an initial prosthesis and continues until the patient demonstrates a successful functional outcome with proper prosthetic use during desired functional activities. This phase involves continued physical rehabilitation interventions as appropriate, functional prosthetic training, return to vocational and avocational activities, and continued psychological support. Patient's will ebb and flow through this phase after receiving each new or different type of prosthesis. This phase may also begin as a result of a patient receiving a new terminal device programmed with a novel control scheme.

The last phase of upper limb amputation rehabilitation is Lifelong Care. This phase begins upon completion of the Prosthetic Training phase and continues throughout the remainder of the patient's life. The importance of this phase cannot be understated. During this phase the patient returns for annual routine follow-up assessments with the amputation care team. A comprehensive, interdisciplinary approach is used at each follow up regardless if the patient continues prosthetic use or not. The patient's functional independence is maximized through the use of available rehabilitation

services and emerging technologies in upper limb amputation rehabilitation. This is the focus of each routine follow up assessment.

About This Clinical Practice Guideline

Methods

The methodology used in developing this 2014 CPG follows the *Guideline for Guidelines*, [5] an internal document of the VA and DoD Evidence-Based Practice Working Group (EBPWG). This document provides information regarding the process of developing guidelines, including the identification and assembly of the Guideline Champions (Champions) and other subject matter experts from within the VA and DoD, known as the Work Group, and ultimately, the development of a UEAR CPG.

The Champions and Work Group for this CPG were charged with developing evidence-based clinical practice recommendations and writing and publishing a guideline document to be used by providers within the VA/DoD healthcare system. Specifically, the Champions for this guideline were responsible for identifying the key questions of greatest clinical relevance, importance, and interest for the management of patients with upper extremity amputations. In addition, the Champions assisted in:

1. Providing direction on inclusion and exclusion criteria for the evidence review
2. Assessing the level and quality of the evidence
3. Identifying appropriate disciplines of individuals to be included as part of the Work Group
4. Directing and coordinating the Work Group
5. Participating throughout the guideline development and review processes

The VA Office of Quality, Safety and Value, in collaboration with the Office of Evidence Based Practice, US Army Medical Command, the proponent for CPGs for the DoD, identified five clinical leaders as Champions for the 2014 CPG.

The Lewin Team (team), including DutyFirst Consulting and ECRI Institute, was contracted by the VA and DoD to support the development of this CPG and conduct the evidence review. The team held the first conference call in October 2012, with participation from the contracting officer's representatives (COR), leaders from the VA Office of Quality, Safety and Value and the DoD Office of Evidence Based Practice, and the Champions. During this call, the project team discussed the scope of the guideline initiative, the roles and responsibilities of the Champions, the project timeline, and the approach for developing specific research questions on which to base a systematic review about the management of UEAR. The group also identified a list of clinical specialties and areas of expertise that are important and relevant to the management of UEAR, from which Work Group members were recruited. The specialties and clinical areas of interest included: Internal Medicine, Nursing, Occupational Therapy, Physiatry, Physical Medicine & Rehabilitation, Physical Therapy, Prosthetics, Psychology, Recreational Therapy, Social Work and Surgery.

The guideline development process for the 2014 CPG update consisted of the following steps:

1. Formulating evidence questions (Key Questions)
2. Conducting the systematic review

3. Convening a face-to-face meeting with the CPG Champions and Work Group members
4. Drafting and submitting a final CPG about the management of CKD to the VA/DoD EBPWG

Appendix A provides a detailed description of each of these tasks.

Evidence Review

The recommendations presented in this CPG are based on a systematic appraisal of the published evidence on the rehabilitation and management of Veterans and Service Members with acquired upper extremity amputation. In areas where the evidence is particularly lacking, expert opinion served as the basis for the recommendations. Published evidence was identified through extensive searches of the following databases: MEDLINE, PreMEDLINE, EMBASE (via the OVID SP platform using the one-search and de-duplication features), the Cochrane Database of Systematic Reviews, the Database of Abstracts of Reviews of Effects, and the Health Technology Assessment Database. Searches were designed to identify unique reviews, trials, and technology assessments. Searches of the World Wide Web were also performed to capture relevant grey literature that has not been indexed to the databases listed previously. The searches covered an extended time period of January 2002 through June 2013, to ensure relevant studies were captured.

In general, full-length clinical studies or systematic reviews published in peer-reviewed journals were considered as evidence in this CPG. Abstracts alone, letters, editorials, and non-English language papers were excluded from the searches. To be included as evidence in this review, a study must have enrolled at least one adult 18 years or older with acquired upper extremity amputation. Studies that enrolled only able-bodied participants, and technical studies that did not include patients with amputation or report on patient outcomes, were excluded.

The methodological quality of all included systematic reviews and independent clinical studies was assessed using the U.S. Preventive Services Task Force (USPSTF) method. Each study was assigned a rating of Good, Fair, or Poor based on sets of criteria that vary depending on study design. Detailed lists of criteria and definitions of Good, Fair, or Poor ratings for different study designs appear in the USPSTF procedure manual. [5] The evidence from each included study was abstracted into evidence tables and narratively synthesized. This guideline focuses primarily on the following patient-centered outcomes: independence in ADL, prosthetic use, prosthetic satisfaction, satisfaction with body image and/or cosmesis, residual or phantom pain, quality of life, satisfaction with life, depression and other mood disorders, incidence of complications, reintegration, and return to work. The strength of the evidence was assessed along the following criteria: methodological quality, consistency of findings across studies, directness of the evidence (e.g., head-to-head comparisons provide the most direct evidence), and precision (i.e., the degree of certainty around an outcome's effect size).

Overall, the evidence base for this guideline consisted of 43 studies. The majority of the evidence addressed strategies to treat postoperative phantom and residual limb pain. A fair amount of evidence considered factors associated with successful, long-term prosthetic use at one or more years following rehabilitation. Very few studies considered rehabilitation at the pre-prosthetic or prosthetic training

phase. Inconsistencies of the evidence are discussed in the text describing the basis of a recommendation.

Evidence Assessment

In order for the clinician to be aware of the evidence base behind the recommendations and the weight that should be given to each recommendation, the recommendations are keyed according to the level of confidence with which each recommendation is made. The graded recommendations are based on two main dimensions: 1) net benefit of an intervention and 2) certainty of evidence associated with that net benefit. When evidence is limited, the level of confidence also incorporates clinical consensus with regard to a particular clinical decision. The strength of recommendation is based on the level of the evidence and graded using the USPSTF rating system (see Table 2. Strength of Recommendation Rating). The discussion following the recommendations for each annotation includes an evidence table identifying the studies that have been considered, the quality of the evidence, and the rating of the strength of the recommendation (SR).

Table 2. Strength of Recommendation Rating (SR) [5]

Grade	Definition	Suggestions for Practice
A	The USPSTF recommends the service. There is high certainty that the net benefit is substantial.	Offer or provide this service.
B	The USPSTF recommends the service. There is high certainty that the net benefit is moderate or there is moderate certainty that the net benefit is moderate to substantial.	Offer or provide this service.
C	The USPSTF recommends selectively offering or providing this service to individual patients based on professional judgment and patient preferences. There is at least moderate certainty that the net benefit is small.	Offer or provide this service for selected patients depending on individual circumstances.
D	The USPSTF recommends against the service. There is moderate or high certainty that the service has no net benefit or that the harms outweigh the benefits.	Discourage the use of this service.
I Statement	The USPSTF concludes that the current evidence is insufficient to assess the balance of benefits and harms of the service. Evidence is lacking, of poor quality, or conflicting, and the balance of benefits and harms cannot be determined.	If the service is offered, patients should understand the uncertainty about the balance of benefits and harms.

Grade of EO for Experts Opinion: To grade the recommendations for the guideline, the CPG Working Group used a variation of the USPSTF grading framework to provide for a grade of EO for "Expert Opinion." Given that evidence-based clinical practice guidelines have to be used in real practice for Veterans and Service Members, a grade of I for insufficient evidence may not provide useful guidance for supporting clinical decisions in practice. In particular, we considered certain instances in which

evidence suggests a Substantial or Moderate net benefit, but the certainty/strength of that evidence is Low. In those instances, rather than concluding that the evidence is insufficient to support a clinical decision, we relied on expert opinion to set forth a recommendation. A grade of EO does not imply that the evidence is strong (it is still Low). However, it does suggest that the magnitude of net benefit (Substantial or Moderate) is of sufficient clinical importance to make a recommendation, even if it is based on low certainty (weak evidence).

This CPG represents a synthesis of current scientific knowledge and clinical practice on the management of upper limb amputation rehabilitation. It attempts to be as free as possible of bias toward any theoretical or empirical approach to treatment.

This CPG is the product of many months of diligent effort and consensus building among knowledgeable individuals from the VHA and the DoD. An experienced moderator facilitated the multidisciplinary Working Group. The draft document was discussed in a face-to-face group meeting. The content and validity of each section was thoroughly reviewed in a series of conference calls. The final document is the product of those discussions and has been approved by all members of the CPG Working Group.

Patient Engagement

The recommendations included in this guideline are patient-centric. In an effort to ensure that the patient is at the core of any clinical decision, the Work Group identified a group of individuals from within the VA and DoD with upper limb amputations. Approximately 10 patients, currently receiving care from the VA and/or DoD health systems, were invited to join the Work Group for a discussion on their experiences. These individuals represented different age groups, sexes, race/ethnicities, and had various causes of upper limb loss. The group consisted of non-combat veterans who underwent elective and non-elective upper limb amputations as well as combat veterans from Vietnam, Afghanistan, and Iraq.

The Work Group developed a set of concise, thought-provoking questions in an effort to gather insights on each person's care and rehabilitation experience. These questions included:

- How critical do you feel your care team was to your rehabilitation?
- How were options for treatment presented to you throughout your care?
- To what extent did you feel empowered to make treatment decisions?
- Throughout each phase of your care, how often did you have contact with any member of your care team?
- How could your care and rehabilitation process have been improved?

In addition, the Work Group reviewed each practice recommendation with the participants in order to identify and address any potential gaps within the CPG. The discussion that ensued was fairly informal and designed to gather information about the patient's experience with their primary care providers and care team throughout their rehabilitation.

Several key insights were gleaned from this discussion and subsequently used to refine and clarify the guideline recommendations. In particular, participants noted that an interdisciplinary care team

approach, shared decision making, and education on emerging prosthetic technologies are critical to improving the patient experience during and following rehabilitation.

Several participants indicated that while they have been generally satisfied with their primary care providers, rehabilitation providers, or prosthetists, a truly comprehensive care team approach was essential but occasionally missing, in which all or most members of the team are fully abreast of the patient's progress and engaged in all aspects of his or her care. The Work Group used this information to further emphasize the importance of the care team and outlined the various individuals that should be involved, including the patient's family and/or caregivers.

Participants also described the importance of utilizing a shared decision making model, which allows providers and patients to identify rehabilitations goals, assess prosthetic needs, and make treatment decisions together. Some of the older participants explained that historically, very little was discussed in terms of goal setting between themselves and their providers. Often, rehabilitation and training, both with and without prosthesis, was primarily achieved through trial and error over time, rather than during the rehabilitation process. Today, shared decision making is more frequently used in a clinical setting, particularly due to VA and DoD commitment to providing patient-centered care.

Finally, participants expressed concern over a lack of communication between patients and providers regarding education and information on emerging prosthetic technologies. Several individuals noted that most of the information they receive comes from indirect sources (i.e., other people with amputations), rather than from their providers. The Work Group incorporated this feedback into the lifelong care phase.

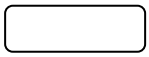
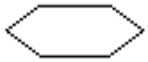
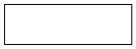
Participants for this discussion were identified and recruited by the CPG Work Group. Participants received modest compensation for their travel. The Work Group noted the value in incorporating patients during the development of this guideline and suggested that other CPG Work Groups follow this model.

Algorithm Development

This CPG includes an algorithm, which is designed to maximally facilitate clinical decision making for the management and rehabilitation of upper extremity amputations. The use of the algorithm format was chosen based on the understanding that such a format can allow for therapeutic decision making, and has the potential to change patterns of resource use. The algorithmic format allows the provider to follow a linear approach to critical information needed at the major decision points in patient rehabilitation, and includes:

- An ordered sequence of rehabilitation care
- Recommended observations
- Decisions to be considered
- Actions to be taken

A clinical algorithm diagrams a guideline into a step-by-step decision tree. Standardized symbols are used to display each step in the algorithm, and arrows connect the numbered boxes indicating the order in which the steps should be followed. [6]

	Rounded rectangles represent a clinical state or condition.
	Hexagons represent a decision point in the guideline, formulated as a question that can be answered Yes or No.
	Rectangles represent an action in the process of care.

This CPG is not intended to serve as a standard of care. Standards of care are determined on the basis of all clinical data available for an individual case and are subject to change as scientific knowledge and technology advances and patterns evolve. This CPG is based on information available at the date of publication, and is intended to provide a general guide to best practices. The guideline can assist care providers, but the use of a CPG must always be considered as a recommendation, within the context of a provider's clinical judgment, in the care of an individual patient.

Implementation

This CPG and algorithms are designed to be adapted to patient needs and resources. It is expected that this CPG will provide information useful for improving upper limb amputation care by reducing variability. Primary care providers and rehabilitation professionals may use the algorithms to determine best interventions and steps of care for their patients to optimize healthcare utilization and achieve the best outcomes related to rehabilitation following upper limb amputation. This should not prevent providers from using clinical expertise in the care of an individual patient. Guideline recommendations should facilitate, not replace, clinical judgment.

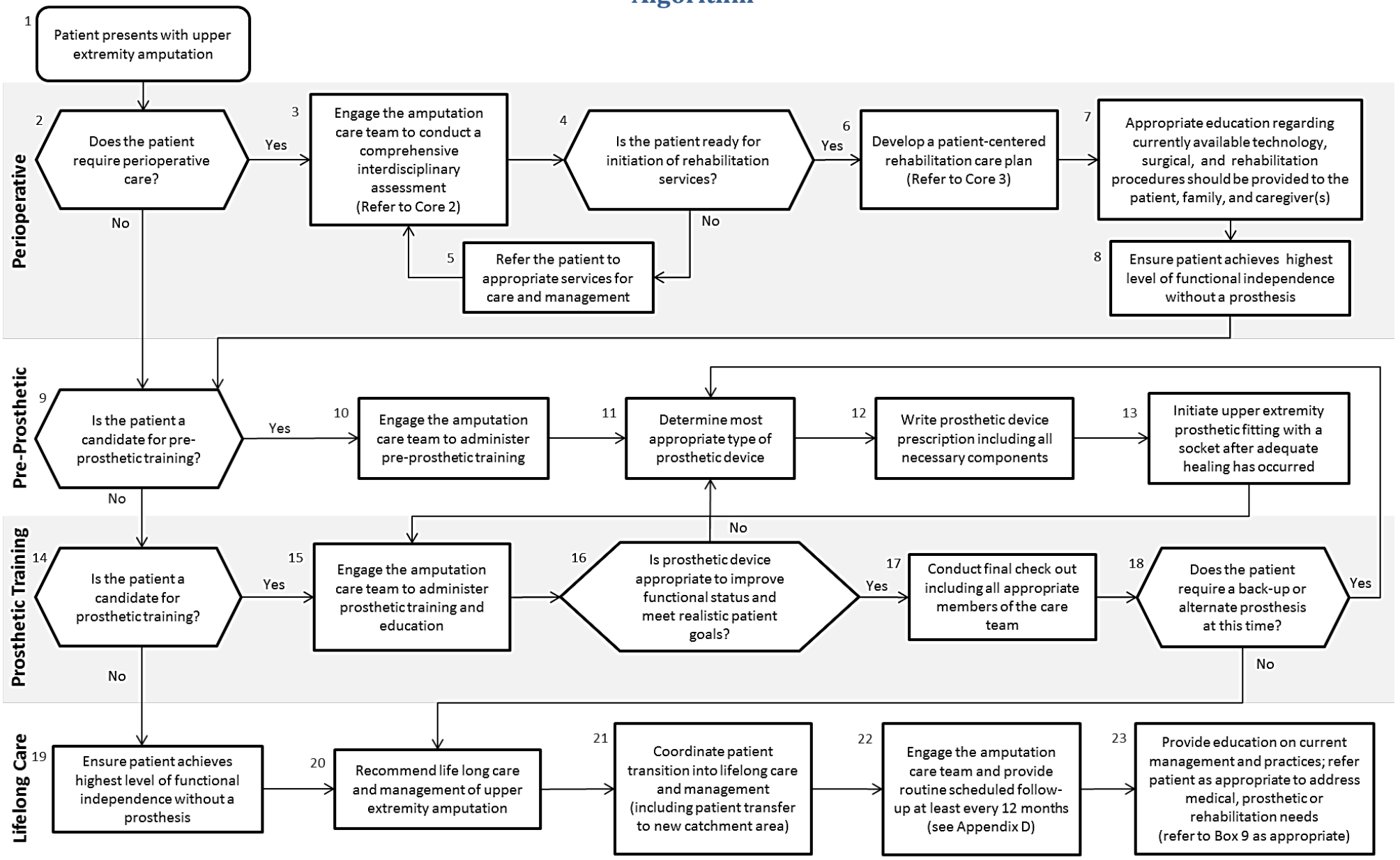
This CPG represents a first attempt in providing a structure for a rehabilitation process in upper extremity amputation that is evidence-based. As rehabilitation practice evolves, new technology and more research will improve rehabilitation care. This CPG can assist in identifying priorities for research efforts and allocation of resources. As a result of implementing a more unified approach to rehabilitation practice, followed by data collection and assessment, new practice-based evidence will emerge.

Guideline Working Group

Guideline Working Group Members*	
VA	**DoD**
Cindy Poorman, MSPT **Billie J. Randolph, PT, PhD** **Joseph Webster, MD**	**MAJ Jay Clasing, PhD, OTR, CPE** **Lisa Smurr Walters, MS, OTR, CHT**
Laurel Adams-Koss, OT	David Beachler, CP
Erin Butler, MSW	MAJ Jocelyn Blackwell, MD
David Drake, MD	**Corinne K.B. Devlin, MSN, RN, FNP-BC**
Christopher Fantini, MSPT, CP, BOCO	Louise Hassinger, CP
Francine Goodman, PharmD, BCPS	Heather Miller, MEd, CTRS
Jeffrey Heckman, DO	**MAJ Sarah Mitsch, OTR/L**
Patty Jackson, RN, CRRN	CDR George Nanos, MD
Gail Latlief, DO	LCDR Robert Selvester, MD
Peggy Merchak, MA, OTR, CHT	Jorge Torres, APN
Elsie Moore, LICSW	
Linda Resnik, PT, PhD	
Stacey Pollack, PhD	
Jay Pyo, DO	
Alicia White, PT, DPT	
The Office of Quality, Safety and Value Carla Cassidy, MSN, ANP **M. Eric Rodgers, PhD, FNP, BC** René M. Sutton, BS, HCA	**Office of Evidence Based Practice,** **US Army Medical Command** Ernest Degenhardt, COL USA (Ret.) MSN, RN, ANP, FNP **Corinne K.B. Devlin, MSN, RN, FNP-BC**
ECRI Institute	**The Lewin Group**
Jim Reston, PhD Stacey Uhl, MS	Cliff Goodman, PhD **Hillary Kleiner, MPH** **Mariam Siddiqui, BS** **Erin Gardner, BS** **Sneha Rangarao, MPH** Paul Wallace, MD

*Bolded names are members of the core editing panel. Additional contributor contact information is available in Appendix M.

Algorithm


Perioperative
Pre-Prosthetic
Prosthetic Training
Lifelong Care
1
Patient presents with upper extremity amputation
2
Does the patient require perioperative care?
Yes
No
3
Engage the amputation care team to conduct a comprehensive interdisciplinary assessment (Refer to Core 2)
4
Is the patient ready for initiation of rehabilitation services?
Yes
No
5
Refer the patient to appropriate services for care and management
6
Develop a patient-centered rehabilitation care plan (Refer to Core 3)
7
Appropriate education regarding currently available technology, surgical, and rehabilitation procedures should be provided to the patient, family, and caregiver(s)
8
Ensure patient achieves highest level of functional independence without a prosthesis
9
Is the patient a candidate for pre-prosthetic training?
Yes
No
10
Engage the amputation care team to administer pre-prosthetic training
11
Determine most appropriate type of prosthetic device
12
Write prosthetic device prescription including all necessary components
13
Initiate upper extremity prosthetic fitting with a socket after adequate healing has occurred
14
Is the patient a candidate for prosthetic training?
Yes
No
15
Engage the amputation care team to administer prosthetic training and education
16
Is prosthetic device appropriate to improve functional status and meet realistic patient goals?
Yes
No
17
Conduct final check out including all appropriate members of the care team
18
Does the patient require a back-up or alternate prosthesis at this time?
Yes
No
19
Ensure patient achieves highest level of functional independence without a prosthesis
20
Recommend life long care and management of upper extremity amputation
21
Coordinate patient transition into lifelong care and management (including patient transfer to new catchment area)
22
Engage the amputation care team and provide routine scheduled follow-up at least every 12 months (see Appendix D)
23
Provide education on current management and practices; refer patient as appropriate to address medical, prosthetic or rehabilitation needs (refer to Box 9 as appropriate)

Recommendations

Recommendation	GRADE
Core 1: The Care Team Approach	
1. An interdisciplinary amputation care team (care team) approach, including the patient, family and/or caregiver(s), is recommended in the management of all patients with upper extremity amputation.	EO
2. Care teams should communicate on a regular basis to facilitate integration of a comprehensive treatment plan.	EO
Core 2: Comprehensive Interdisciplinary Assessments	
3. Comprehensive interdisciplinary assessments and reassessments should be completed during each of the first three phases of care (perioperative, pre-prosthetic and prosthetic training).	EO
4. Annual comprehensive interdisciplinary screening should be conducted for all patients with an upper extremity amputation throughout lifelong care.	EO
5. Functional status measures should be utilized during assessments and reassessments throughout all phases of care to document outcomes and monitor the efficacy of rehabilitation.	EO
Core 3: Patient-Centered Care	
6. A shared decision making model, incorporating patient goals, should be used throughout all phases of rehabilitation to ensure patient-centered care.	EO
7. A comprehensive, interdisciplinary, patient-centered rehabilitation plan should be developed as early as possible and updated throughout all phases of care based on patient's progress, changes in functional status, emerging needs, and goals.	EO
8. Patient-centered physical and functional rehabilitation interventions should be initiated based on the rehabilitation plan and the patient's physical and psychological status.	EO
9. Various types of pain following upper limb loss should be managed appropriately and individually throughout all phases using pharmacological and non-pharmacological treatment options.	EO
10. The care team should provide appropriate education and informational resources to patients, family and caregiver(s) throughout all phases of care.	EO
11. The care team should facilitate early involvement of a trained peer visitor.	C
Perioperative Phase	
12. The decision for amputation should be made based upon accepted surgical and medical standards of care.	EO
13. Communication must occur between the surgical and non-surgical members of the care team in order to optimize surgical and functional outcomes.	EO
14. The care team should ensure that the patient is optimized for rehabilitation to enhance functional outcomes.	EO
15. Following amputation, the care team should ensure that the patient has achieved his or her highest level of functional independence without a prosthesis.	EO
Pre-Prosthetic Phase	
16. The care team should ensure that patients undergo pre-prosthetic training to help determine the most appropriate type of device to achieve functional goals.	EO
17. Once the appropriate type of prosthesis is identified, the care team should write a prosthetic prescription including all necessary components.	EO

Recommendation	GRADE
18. Initiate upper extremity prosthetic fitting as soon as the patient can tolerate mild pressure on the residual limb.	EO
Prosthetic Training Phase	
19. Upon delivery of the prescribed prosthesis, or change in the control scheme or componentry, the care team must engage the patient in prosthetic training and education.	EO
20. The care team should frequently reassess the patient's prosthetic fit and function throughout the prosthetic training phase and modify as appropriate.	EO
21. The final check out of the prosthesis should take place with appropriate members of the care team to verify that the prosthesis is acceptable.	EO
22. The care team should offer active prosthesis users at least one back up device to ensure consistency with function.	EO
23. Prescription of activity specific or alternate design prostheses may be considered, dependent upon the patient's demonstration of commitment, motivation, and goals.	EO
Lifelong Care	
24. Upon completion of functional training, and to ensure continuity, the care team should coordinate patient transition into the lifelong care phase.	EO
25. The care team should provide routine, scheduled follow-up contact for patients with upper extremity amputation at a minimum of every 12 months, regardless of prosthetic use or non-use.	EO
26. Upon notification of patient relocation to a new catchment area, the care team should communicate with the receiving care team and coordinate transition of patient care.	EO
27. The care team should provide education to the patient, family, and caregiver(s) regarding advancements in technology, surgical, and rehabilitation procedures related to the management of upper extremity amputation.	EO

Core 1: The Care Team Approach

Care Team Approach

Recommendation

1. An interdisciplinary amputation care team (care team) approach, including the patient, family and/or caregiver(s), is recommended in the management of all patients with upper extremity amputation. [EO]

Discussion

The care team approach is vital to successful outcomes for all patients with upper extremity amputation. It requires a physician leader with specialized knowledge in upper limb amputation care and effective interpersonal communication skills to coordinate care and share information across multiple disciplines including medical, surgical, rehabilitation and prosthetic.

The care team approach is a physician-led, patient-centered, multidisciplinary approach to provide a comprehensive treatment plan and ensure lifelong management. The care team approach for patients with upper extremity amputation is unique due to varying patient factors and the myriad of medical, surgical, rehabilitation and prosthetic specialists involved, including:

- Rehabilitation physicians
- Anesthesiologists
- Surgeons (hand specialists, orthopedic surgeons, plastic surgeons)
- Mental and behavioral health specialists
- Case managers
- Nurses
- Occupational and physical therapists
- Driver rehabilitation therapists
- Certified prosthetists
- Recreation therapists
- Social workers
- Trained peer visitors
- Others

All members of the care team, including the patient, are equally important to maximize the medical, surgical and functional outcomes following upper limb amputation. Members of the care team must work in concert to achieve the patient's functional goals.

Advancements in the medical, surgical, rehabilitation and prosthetic management for patients following upper extremity amputation have led to improvements in pain management, surgical and rehabilitation outcomes and advancements in technology for prosthesis componentry with augmented control systems. These advancements are the result of experts in the field working collaboratively with a common goal, to provide the highest quality of care for those who have sustained upper limb amputation.

Care Team Communication

Recommendation

2. Care teams should communicate on a regular basis to facilitate integration of a comprehensive treatment plan. [EO]

Discussion

Patients who sustain upper limb amputation present with complex and diverse issues that require clear and effective communication by providers. Each care team member must utilize appropriate communication skills to ensure shared understanding of the situation and a shared course of action across the continuum. The care team requires a physician leader with specialized training and skills in standardized vernacular for communication with the medical, surgical, rehabilitation, and prosthetic providers.

Timeliness of communication is crucial to optimize functional outcomes and to assist patients in achieving treatment plan goals. In order to effectively communicate with care team members, each provider must have access to other care team members and is required to maintain an understanding of the patient's past medical history including cause of amputation and comorbid conditions, an updated problem list with current issues and an updated list of goals and functional progress. Each care team member should have access to updated patient demographic information.

Core 2: Comprehensive Interdisciplinary Assessments

Recommendation

3. Comprehensive interdisciplinary assessments and reassessments should be conducted during each of the first three phases of care (perioperative, pre-prosthetic and prosthetic training). [EO]

Discussion

A comprehensive, interdisciplinary, baseline assessment facilitates the optimization of a patient's condition, guiding the formulation of a customized treatment plan, to promote the best surgical and rehabilitative outcomes.

Providers should avoid focusing too much attention on the amputated limb at the expense of missing other significant medical issues and comorbidities. As traumatic injuries are the most common cause of amputation in the upper limb, these individuals frequently have additional injuries that require lifelong care. This is especially true in Veterans and Service Members. Combat and other traumatic amputations are commonly associated with multiple other comorbid injuries. It is important to appreciate how commonly these associated injuries occur and the potential impact of these injuries on outcomes such as functional independence, satisfaction, and quality of life. Frequently associated injuries include: traumatic brain injury (TBI), fractures and other musculoskeletal injuries, soft tissue injuries and burns, peripheral nerve injuries, abdominal injuries, hearing loss and tinnitus, vision impairment or loss, genitourinary injuries, as well as other mental health conditions such as post-traumatic stress disorder (PTSD), depression, and adjustment disorder.

Routine medical follow-up should include an assessment of the issues listed above, as appropriate. Some of these issues are more prevalent and significant in the early recovery period following the traumatic event whereas others develop later and have the potential for progressive worsening over time. Individuals with trauma-related amputations typically sustain injuries at a relatively young age and have a long life expectancy, emphasizing the need for longitudinal medical care. Although vascular diseases are a less common cause of amputation in the upper limb, medical conditions such as peripheral vascular disease and diabetes mellitus still need to be addressed when present.

Greater investigational research is necessary to determine predictors of prosthesis use in a patient with an upper extremity amputation. Studies focused on patients with lower extremity amputation suggest that advancing age is a negative predictor for most outcome measures. It must be noted that comorbidities such as diabetes, cardiovascular disease, and cerebrovascular disease were frequently present in these populations, reflecting chronic systemic diseases common to an aging population. Therefore, baseline pre-amputation functional capability, general health status, and socioeconomic status may also be important predictors of prosthetic use and functional ability. [7]

It is recommended that a comprehensive assessment of a patient's pre-amputation and post-amputation medical and psychological status is necessary to better predict and manage a patient's rehabilitation outcome.

The recommended components of the comprehensive assessment are summarized in Table 3; a brief discussion on each follows. Additionally, a summary of assessments and interventions through-out all rehabilitation phases is found in Appendix B. (See Appendix B: Summary of Assessments and Interventions in Rehabilitation Phases.)

Table 3. Components of the Comprehensive Assessment

Component	Description
Present Health Status	• May assess for: o Infection (using laboratory and radiographic studies) o Anemia o Electrolyte imbalances o Nutrition o Liver and kidney function o Cardiac and pulmonary function o Bowel and bladder function o Metabolic function o Neurologic function o Burns, musculoskeletal injuries and bone integrity o Prevention of secondary complications such as venous thrombosis, embolism, heterotopic ossification, joint contracture, and pressure ulcers
Level of Function	• Assess the patient's level of function including: o Hand dominance o Range of motion (ROM) and flexibility o Gross motor strength and skills o Sensation o Fine motor skills o Balance o Functional mobility o Endurance/general conditioning o Level of assistance to perform ADL and IADL o Home environment/need for modifications o Community mobility and driving o Community integration (e.g., recreation, leisure and sport interests)
Modifiable/Controllable Health Risk Factors	• Assess patient's awareness of strategies to reduce the impact on morbidity and mortality
Pain Assessment	• Conduct assessment and monitoring of perioperative pain, phantom limb pain, residual limb pain, and phantom limb sensation • Assess efficacy of any ongoing pain intervention • Assess any pain in the non-affected limb(s) and trunk
Behavioral and Cognitive Health	• Complete a Behavioral Health Assessment to include: o Depression o Anxiety o Post-traumatic stress symptoms o Substance abuse disorders o Major life stressors • Screen the patient to determine ability to participate in rehabilitation

Component	Description
	• Assess cognitive function including: o Intellectual functioning and attention/concentration along with working memory and speed of processing o Executive functioning o Learning and memory: short- and long-term, auditory and visual, recall, and recognition o Self- (and possibly family-) reported cognition and emotional functioning o Barriers to learning or communication • A cognitive assessment should utilize: o Standardized tests o Self-reporting o Behavioral descriptions o Subjective estimations from family and others o Careful history taking o Recognition of other possible comorbid factors (e.g., depression, brain injury, dementia or stroke) o Acknowledgment of the limitations and sources of variability and error in measuring psychometric performance • Screen ability to learn, adapt to, and utilize a prosthesis
Patient's Personal, Social, and Cultural Contexts	• Assess for any personal, social, cultural and financial factors that may influence rehabilitation to include: o Patient's beliefs, values and opinions that shape who he or she is and how he or she may adapt or cope after amputation o The level of family or caregiver support available to the patient o Cultural factors o Spiritual support and/or individual religious beliefs o Influences of the patient's age and gender o Accessibility to resources and services o Financial limitations or constraints
Learning Assessment	• Language barriers that require a translator • Education and literacy level • Patient's preferred learning style
Residual Limb Assessment	• Acute assessment: o Edema and shape of residual limb o Wound closure (dehiscence) and drainage o Excessive redness or induration o Temperature of surrounding tissue o Protection from external trauma • Follow-up assessment: o ROM o Strength o Skin Integrity/Breakdown o Shape o Sensitivity/Pressure tolerance
Contralateral Limb and	• Assess for the presence of:

Component	Description
Trunk	o Deformity o Range of motion limitations o Abnormal skin or soft tissues o Vascular health issues • Quantify any motor or any sensory deficit • Note dominance and functional gross and fine motor skills • Assess for presence of overuse syndromes
Prosthetic Assessment (if applicable)	• May evaluate and discuss several aspects of prosthesis use including: o Prosthesis fit to include ability to don and doff the device o Prosthesis operational function and ability to use o Maintenance of the prosthesis o Acceptance/rejection of the prosthesis o Appropriateness of the prosthesis prescription (for employment, ADL and leisure)
Vocational Rehabilitation	• A vocational assessment should include: o Level of education o Work history o Desired vocation o Desire to return to college o Desire to begin a business • May offer a referral to any of the following as appropriate: o VA Vocational Rehabilitation o VA Benefits Administration Program o VA Compensated Work Therapy Program o Community or state vocational rehabilitation agencies

Present Health Status

Individuals who have undergone upper extremity amputation represent a patient population with wide-ranging medical needs. These medical needs can include issues directly related to the amputation itself, traumatic injury of other body parts, as well as pre-amputation medical condition and secondary complications or comorbidities associated with amputation. A baseline medical evaluation, including laboratory and radiological studies, should be completed to screen multi-organ and body system function (see Table 3 above).

Heterotopic Ossification

Heterotopic ossification (HO) is defined as abnormal formation of lamellar bone in nonosseous tissue. It has been commonly defined and observed in patients after total hip arthroplasty, spinal cord injury, and traumatic brain injury. Although HO is not a new or unique phenomenon and has been described throughout historical texts, reports on the incidence and management of HO in patients with amputations have been limited. It was not until recently that HO has been better defined in patients with amputation as a result of combat trauma. [8] HO in the residual limbs of patients with amputation can be identified with careful palpation of the residual limb, or identified through radiographic imaging.

Basic scientific research has shed light on the cellular and molecular basis for this osteogenic process, but many questions remain unanswered. The recent experience of the military amputation centers with

traumatic and combat-related amputations has reported a greater than 50 percent prevalence of HO in residual limbs of blast induced amputations. As a result it is extremely important to screen for HO in these patients.

Level of Function

To appreciate the patient's current level of function, the care team should initially obtain a subjective history of the patient's prior level of function. This history should include the patient's pre-amputation: 1) level of independence in ADL and IADL; 2) vocational roles and responsibilities or educational pursuits; 3) recreational, sport, and leisure interests; 4) hand dominance and; 5) an inventory of any assistive and/or adaptive devices (e.g., grab bars, shower handles, shower or tub bench, long handled reacher, etc.).

The comprehensive objective assessment of the patient's current level of function should be completed by multiple members of the care team. The purpose of the assessment is to determine the patient's physical, neurologic, and functional abilities and needs and is performed on the affected an unaffected limbs as appropriate. Assessment of the patient's current level of function includes: range of motion (ROM); gross motor strength and skills; sensation; fine motor skills; balance; functional mobility; and endurance and general conditioning. Additionally, current level of function should include and the level of assistance required for the patient to complete ADL and IADL tasks. ADL generally refers to dressing, bathing, grooming, toileting, personal hygiene, feeding and mobility within the home. [9,10] IADL is a broad topic area and includes but is not limited to: home management tasks (e.g., meal planning preparation, clean-up, routine housekeeping, yard work, seasonal home care); laundry; shopping (e.g., community mobility, money management); child care; pet care; work; and individual recreational, leisure or sport activities. A list of outcome measure tools is available in Appendix C: Outcome Measures, to aid providers in completing a functional assessment.

When appropriate, an assessment of the home environment should be conducted by an occupational or physical therapist to determine any safety, functionality, and accessibility needs to return to daily living activities in the home. Home evaluation and modifications are extremely important for the success of the patient in returning to his or her roles. Ideally, assessment of the home should be performed preoperatively or postoperatively to prepare the home environment for patient discharge after hospitalization.

Community mobility refers to a person's ability to move in and around the community using public or private transportation (e.g., walking, riding a bike, driving, or taking a taxi or plane). [11] A driving evaluation or public transportation assessment should be pursued when appropriate for a patient with an upper limb amputation. The driving evaluation is conducted by a driving evaluation specialist who will assess driving abilities, provide necessary driver's training, and identify any necessary vehicle modifications to ensure safe driving.

Community integration refers to a patient's ability to live, work, and enjoy his or her leisure time in the community setting. [10] This includes not only accessibility to the community environment but also engagement in social roles that the patient wishes to participate. The ability for a patient to engage in

community tasks and roles after injury is associated with individual intrinsic abilities or skills and factors within the environment.

The assessment of the patient's prior and current level of function allows the care team to: 1) develop an appropriate treatment plan (see Core 3: Rehabilitation and Discharge Plan); 2) establish specific and realistic ADL, work and recreational goals to improve quality of life after limb loss; 3) determine the potential need for home or other environmental adaptations to maximize function; 4) project appropriate timelines for progression through phases of rehabilitation; 5) project an appropriate patient disposition following acute hospitalization and; 6) determine prognosis for maximum functional independence with or without a prosthesis to better prepare for long term care needs. Current level of function must be re-assessed during routine follow-up clinical visits to appreciate functional progress throughout the phases of care. Based on assessment findings, modifications are made to the comprehensive rehabilitation plan and patient-driven functional goals are adjusted as appropriate.

Modifiable/Controllable Risk Factors

Modifiable health risk factors (e.g., smoking cessation, body weight management, hypertension control, substance abuse, and psychosocial issues including body image) should be assessed and education and treatment strategies, to reduce their impact on morbidity and mortality, should be offered to the patient, ideally prior to surgery.

Pain Assessment

There are several different types of pain that may be experienced after amputation, including:

- **Immediate post-surgical pain** – is experienced after any surgical procedure where skin, muscle, bone, and nerves are cut. Immediate post-surgical pain after amputation should be managed aggressively as part of the post-surgical management plan.
- **Post-amputation pain** – the various factors that contribute to post-amputation pain, such as RLP, PLP, and associated musculoskeletal pain, should be considered and alleviated when developing the treatment plan for pain. Table 4 summarizes the distinction between residual limb pain and phantom limb pain.
    - ***Residual limb pain (RLP)*** – occurs specifically in the residual tissue and structure of the amputated limb. It is an expected and predictable symptom immediately post-amputation due to the massive tissue disruption of the surgery itself. After immediate post-amputation assessment and treatment, resolution of these symptoms should also occur in a predictable manner with a predictable wean off of all acute treatment interventions. Chronic or emergence of new RLP later in a patient's care can be due to poor prosthetic socket fit, bruising of the limb, chafing or rubbing of the skin, and numerous other largely mechanical factors. Other factors for RLP can include inherent vascular, neurologic, or musculoskeletal factors to include ischemia due to poor profusion, post-amputation neuromas, or heterotopic ossification, respectively, among other considerations.
    - ***Phantom limb pain (PLP)*** – occurs when pain is perceived in the missing limb that has been amputated. It is the most difficult part of post-amputation pain to manage and is treated distinctly compared to RLP. Up to 40 percent may report PLP to be significantly bothersome at one year after amputation. The mechanism for phantom limb pain and sensations is not

well understood, although existing theories implicate central nervous system processing as well as peripheral nerve mediation.

- ***Phantom limb sensations (PLS)*** – are non-painful sensory perceptions of the phantom limb and are likely to be experienced by most patients and may be present throughout their entire life. PLS can be described as paresthesias, normal anatomy, proprioception of the missing body part, temperature gradients, and other non-painful sensations in the missing portion of the limb.
- ***Associated musculoskeletal pain*** – occurs in body regions other than the amputated limb, such as the back, shoulder or contralateral limb and may be related to overuse/compensatory motions of the intact limbs and trunk, fit and use of the prosthesis, design of the prosthetic socket, residual limb interface, and/or other medical comorbidities. Aggravating factors include abnormal biomechanical stresses to joints and other musculo-tendinous structures, and advancing age.

- **Chronic pain -** may be mediated by neuropathic as well as nociceptive pain mechanisms. Chronic pain symptoms, regardless of mechanism, can be additionally influenced by cognitive, behavioral, and social factors. Chronic pain patients have much higher rates of depressive disorder comorbidities and pain, which often overlap.

Table 4. Residual Limb vs. Phantom Limb Pain

Residual Limb Pain (RLP)	Phantom Limb Pain (PLP)

• Pain occurs in the portion of the amputated limb that is still physically present
• May have allodynic qualities (pain from non-noxious stimuli such as touch), particularly near the skin flap scar or neuromas
• Is expected from the surgical trauma and should be aggressively managed perioperatively
• Later, can be due to
  o Mechanical factors including
  ▪ Poor prosthetic socket fit
  ▪ Bruising of the limb
  ▪ Chafing or rubbing of the skin
  o Poor perfusion, ischemia
  o Heterotopic ossification
  o Neuromas (common cause)
• Can be managed by addressing the cause(s) and adding multimodal analgesic therapy if necessary
	• Pain is perceived in the amputated or absent part of the body
	• Has been reported to occur in 60 percent to 70 percent of patients and to be significantly bothersome at one year after amputation in up to 40 percent of patients
	• Is uncommonly experienced immediately after surgery
	• Can be episodic, lasting from seconds to days, or continuous
	• Has unclear mechanism(s) that may include:
	  o Abnormal regeneration of primary afferent neurons
	  o Abnormal central somatosensory processing or central sensitization
	  o Ectopic peripheral nerve activity
	  o May be triggered or exacerbated by various factors including
	  o Chronic pre-amputation pain
	  o Phantom limb sensations
	• May be related to the intensity and duration of preoperative pain
	• Is often managed with multimodal pharmacologic and non-pharmacologic therapies

Residual Limb Pain (RLP)	Phantom Limb Pain (PLP)
	• Is more difficult to control than residual limb pain

Adequate pain control is important throughout all phases of rehabilitation. Residual limb and phantom limb pain occur more commonly and with greater intensity in those with upper extremity amputation compared to those with lower extremity amputation. [12] Pain control and pain interference should be assessed and re-assessed at each rehabilitation visit. This is important because residual limb pain (RLP) and phantom limb pain (PLP) frequently evolve over time. The management of a patient's pain can impact the patient's function, use of a prosthesis, and quality of life. The patient assessment must include patient education on the differences between PLP, RLP, and phantom limb sensations (PLS). It is also important that the patient be assured these symptoms are common and that numerous and distinct treatment and management strategies exist for each.

Pain should be routinely assessed and re-assessed using standard tools for pain. The most commonly used tools involve numeric scales (0 to 10), visual analogue scales (VAS), or picture scales such as the Wong-Baker FACES. In addition to assessing pain location and intensity, it is also important to assess pain frequency and duration as well as aggravating and alleviating factors. The assessment should further include a determination of how much pain is affecting function, sleep, and participation in therapy. Under-treated pain may lead to poor compliance with prosthetic fitting and/or training. The degree to which pain interferes with activities may be a function of the pain location. In one study, it was found that back pain interfered more significantly with daily function than the same level of intensity of PLP. These findings have implications for understanding the meaning of pain intensity levels, as well as for the assessment of pain intensity in persons with amputation-related pain. [13] In another study, evidence suggested that RLP, PLP, and back pain intensity ratings, as a group, may account for 20 percent of the variance in pain interference. The pain intensity ratings associated with each individual pain site made a statistically significant contribution to the prediction of interference with ADL even after controlling for the pain intensity of the other two symptoms. [14]

New or worsening pain symptoms may warrant new diagnostic evaluation and work-up rather than simply attributing the symptoms to the patient's chronic condition. The emergence of new or worsening pain symptoms may be simply a result of prosthesis factors. Additionally, conditions unrelated to prosthesis use, neurologic and musculoskeletal pain syndromes and overuse syndromes are also common. Overuse syndromes frequently occur in the contralateral limb in those with unilateral amputations; however they can also develop in the proximal joints of the amputated residual limb. These later painful conditions are very common in this population and the pain may be even more debilitating than the patient's residual limb or phantom limb pain. [12] Self-reported quality of life has also been shown to be lower in patients with these chronic pain symptoms. [15]

The existence of other comorbid conditions such as arthritis, osteoarthritis, spinal stenosis, diabetes, or vascular disease must always be considered when assessing pain. For patients with trauma related amputations, it is particularly important to assess for previously unidentified injuries. Input from the care team members, such as nursing staff, occupational therapist and physical therapists can be valuable in characterizing the pain and arriving at a diagnosis and treatment plan. Particular attention

should be paid to patients who report pre-amputation pain or severe pain as the result from burn, gangrene, or thrombosis, as these conditions are associated with a greater risk of chronic pain, post-amputation. [16]

A thorough pain assessment should also include an examination of potential psycho-social influences on pain. For example, greater catastrophizing by the patient and less family support has been shown to be predictive of greater pain severity, physical disability, and psychosocial dysfunction. [17-19] Table 5 provides the assessment of pain control in different phases of rehabilitation.

Table 5. Pain Control in Phases of Rehabilitation

Phase	Pain Control
I. Preoperative	Assess for existing pain
II. Postoperative	Assess and aggressively treat residual and phantom limb pain
III. Pre-prosthetic	Assess for specific treatable causes of residual limb or phantom limb pain and apply specific treatments appropriate to the underlying etiology If no specific cause can be determined treat with non-opioid medications and other non-pharmacologic, physical, psychological, and mechanical modalities
IV. Prosthetic training	Assess for specific treatable causes of residual limb or phantom limb pain and apply specific treatments appropriate to the underlying etiology If no specific cause can be determined treat with non-opioid medications and other non-pharmacological, physical, psychological, and mechanical modalities
V. Lifelong care	Assess and treat associated musculoskeletal pain that may develop

Behavioral and Cognitive Health Assessment

Behavioral Health Assessment

There are some significant differences in the recovery process between patient's with upper limb amputation and those with lower extremity amputations. The upper extremity provides the ability to perform fine motor tasks and experience the world through the use of the hand. After upper limb loss there is a decline in functional abilities and activities when using the hand. Upper limb prostheses are more complicated to operate than lower extremity prostheses and are not as easily concealed under clothing. Active use of an upper limb prosthesis is more visible to self and others. There is a lack of proprioception so the patient must watch the prosthesis in action, possibly making it more difficult to consider it part of self. Prosthesis mastery is more difficult to attain and patient expectations regarding ease of use may not match reality, possibly leading to increased frustration, depression and resistance to therapy. Although, most patients with amputations will cope and adapt adequately, it is usually a lengthly process and setbacks are not uncommon.

The behavioral health assessment should include screening for depression, anxiety, post-traumatic stress symptoms, and substance abuse disorders. There is evidence that a relatively high percentage of patients experience such problems. [20-24] Levels of depression and anxiety problems appear to be relatively high for up to two years post-amputation and then decline to normal population levels. [22] Post-Traumatic Stress Disorder (PTSD) symptoms are more common and severe for individuals whose

trauma involves combat-related injury (e.g., many traumatic amputation victims). [23] PTSD is seen in up to 40 percent of individuals who have undergone amputation as a result of trauma. [25]

Assessment should also address the current major stressors the patient is facing as well as his or her familial/social network, as these factors are likely to influence rehabilitation. There are a number of studies indicating that social support enhances psychosocial adjustment, overall functioning and pain management for patients. [22,24,26-29] The provider should also assess common effective and ineffective coping strategies. There is evidence that specific coping strategies for patients may enhance psychosocial adjustment and pain management while other strategies may diminish it. Active/confrontive problem-solving coping strategies enhance functioning, while passive/avoidant, disengaging strategies diminish it. [27,28] It seems prudent that counseling interventions explicitly address coping strategies and encourage strategies demonstrated to be more effective. Finally, substance use patterns and abuse and/or dependence should also be assessed. Substance abuse is a method of dysfunctional coping.

While current psychological symptoms are most relevant, providers should also assess for a history of psychiatric problems for both the patient and his or her family, as such histories increase the risk for current or future problems for the patient. Assessment may include brief symptom checklists such as the Beck Depression Inventory-II, [30,31] the Beck Anxiety Inventory, [32,33] or the Post-Traumatic Stress Checklist (PCL) [34] in order to acquire a quantitative measure of symptom severity. Quantitative indications of global functioning and/or disease burden over time can be obtained from outcome measures such as the SF-36. [35,36] The patient's personality type has also been shown to influence adaptation. The Millon Behavioral Health Inventory (MBHI) [37] provides identification of an individual's coping and personality style and recommendations on how to work with that specific type of patient.

Increasingly, the concepts of motivation and "readiness" are recognized as important issues in chronic disease and chronic pain management. [38,39] It is important to assess a patient's "readiness" to be actively involved and focused on treatment. Readiness and motivation may change over time as the patient progresses through the stages of adaptation, so he or she should be assessed intermittently throughout treatment and motivational enhancement interventions applied as needed. [39]

Initial and ongoing assessments should attempt to understand how the patient views the amputation and its impact. It is not unusual for patients to have an unrealistic view or expectations of how prostheses work. In the early stages of rehabilitation, denial can be seen in the form of over-optimism. The provider should assess social and body image anxiety and/or discomfort, which are not uncommon, particularly among younger and female patients. [21,22,24,40] The loss of a limb distorts the body image; lowers self-esteem; and increases social isolation, discomfort, and dependence on others. They are associated with activity restriction, depression, and anxiety. The activity restriction may be a mediating factor (amongst others) for depression. [22] Overall, activity level, including the presence of excessive activity restriction, and satisfaction with the prosthesis should be assessed as well. Activity level is reciprocally related to depressive and anxiety symptoms (e.g., decreased activity is often associated with such symptoms). The activity restriction may be a mediating factor (amongst others) for depression. [22] Moreover, excessive activity restriction compromises functional outcomes.

Satisfaction with the artificial limb may mitigate body image problems. The appearance of the prosthesis affects the patient's ability to disguise the disability, and reduces the amputation-related body image concerns and perceived social stigma.[41] With advances in the cosmetic appearance of prostheses cosmetic covers can be developed which are remarkably similar to the contralateral limb.

The patient's mental health status should be reassessed routinely at follow-up appointments during active rehabilitation, and throughout lifelong care. Depression, anxiety and other mental health issues may impact functioning. During the follow-up screening the care team should assess the patient's level of activity, support network, risk of isolation, suicidal or homicidal ideation, ADL, use of alcohol/drugs, sleep habits, and diet. In addition, the patient's level of cognitive functioning and his or her knowledge and use of positive coping skills should be assessed.

If the patient screens positive for behavioral health issues, he or she should be referred for follow-up with the primary mental health provider or to the behavioral and/or mental health clinic. A follow-up assessment provides the best information to recognize changes and related needs to minimize the risk of complications. Lifelong care should include monitoring the patient for psychosocial adjustment. [42]

Cognitive Health Assessment

Patients with an upper extremity amputation who have been traumatically injured may be at higher risk for cognitive deficits secondary to comorbid traumatic brain injury. The care team should ensure to complete a cognitive health screening and obtain pertinent patient history of brain injury as soon as possible. This information is necessary to determine the patient's cognitive abilities and any potential impact on participation in rehabilitation. A clear understanding of the patient's cognitive health allows the care team to optimize the rehabilitation plan and design effective treatment strategies taking the patient's cognitive abilities into consideration.

If screen findings clinically indicate a more in-depth cognitive evaluation is necessary, the patient should be referred to appropriately trained and certified individuals for further cognitive testing. Additionally cognitive testing should include: careful history taking, standardized tests, self-reporting, behavioral descriptions and subjective estimations from family and caregivers, recognition of other possible comorbid factors (e.g., depression, brain injury) and acknowledgment of the limitations and sources of variability and error in measuring psychometric performance.

A neuropsychological evaluation is usually able to distinguish between normal and impaired function, identify cognitive strengths and deficits, and address diagnostic questions related to cognitive dysfunction. However, a neuropsychological evaluation does not permit definitive determination of the cause of the impaired function. [43] Neuropsychological referrals should be specific and guided by preliminary mental status assessment by the care team. Neuropsychological assessments should focus on the referring question and not provide specific medical advice.

Assessment of Patient's Personal, Social, and Cultural Contexts

The amputation of a limb is experienced as a traumatic loss that impacts multiple interpersonal, physical and financial dimensions of a patient's life as well as the family members. All of these factors influence the effectiveness of rehabilitation. Context refers to interrelated conditions in which a person or object

exists. As such, multiple factors create the context in which a person lives and it is important for the care team to understand these dynamics.

To assess a patient's context, the care team should review assessments from other disciplines involved in the care and take advantage of informal conversations with the patient. [44] The care team should screen the patient for any personal, social, cultural and financial factors that will directly influence participation in rehabilitation care. Within these contexts are the resources which the patient may depend on to adjust to individual and social roles after the loss of a limb. It is important that the care team obtain an understanding of the following and how each may impact engagement in rehabilitation and influence lifelong care:

- Patient's beliefs, values and opinions that shape who he or she is and how he or she may adapt or cope after amputation
- Level of family or caregiver support available to the patient
- Cultural factors
- Spiritual support and or individual religious beliefs
- Influences of the patient's age and gender
- Accessibility to resources and services
- Financial limitations or constraints

Contextual factors may change throughout the adaptation and rehabilitation process. Periodic reassessment is warranted during the course of the care and management in order for the care team to make appropriate modifications, identify resources, and meet the patient's changing needs.

Learning Assessment

The following specific areas should be assessed:

- Language barriers that require a translator
- Educational level including the highest level of formal education achieved and literacy level using the Rapid Estimate of Adult Literacy in Medicine (REALM) [45]
- Patient's preferred learning style whether it is written materials, group discussion, demonstrations, internet, role playing, lectures, self-directed, games, videos, audio tapes, photographs and drawings, or models

Learning is a process involving interaction with the external environment [46] and results in a behavior change with reinforced practice. [47] An assessment of the patient's learning capabilities will assist in developing tailored educational efforts to suit the patient's needs. A learning assessment evaluates this process by establishing learning goals and activities for the patient who has had an amputation.

Residual Limb Assessment

The comprehensive assessment of the residual limb during the acute stage should include the evaluation of the patients' residual limb edema, shape, wound drainage and closure, areas of redness or induration at the wound, any palpable areas of tenderness and changes in skin temperature surrounding wound. The care team should assess wound healing using a standardized approach (such as the approach described in Table 6 below).

Table 6. Categories of Wound Healing *(adapted)* [48,49]

Category	Description
Category I	Primary; healed without open areas, infections or wound complications; no wound healing intervention required
Category II	Secondary; small open areas that can be managed and ultimately healed with dressing strategies and wound care Additional surgery is not required May be possible to stay with the original plan with some portion of the wound intentionally left open
Category III	Skin and subcutaneous tissue involvement (no muscle or bone involvement); requires minor surgical revision
Category IV	Muscle or bone involvement; requires major surgical revision but heals at the initial amputation "level"
Category V	Requires revision to a higher amputation level

During the patient's follow-up assessments, the residual limb evaluation should include: residual limb range of motion (ROM), strength, shape, signs of alteration in skin integrity, or skin breakdown, and increase/decrease in sensitivity or tolerance to pressure.

Contralateral limb and trunk

During initial and follow-up evaluations, it is important to include the contralateral limb as part of the comprehensive assessment. Inspection of the contralateral limb for any signs of deformity to include atrophy, hypertrophy, skin integrity, or pressure areas is important when considering the physical rehabilitation plan as well as prosthesis prescription. Evaluation of the dermatomes will suggest whether further sensory testing is indicated; results are important to consider as they may influence prosthetic prescription and may be indicative of overuse injuries. Manual muscle testing and observation of gross motor movements and ROM are noted as deficits in these areas and can quickly impact function with the remaining upper limb. Fine motor coordination is of particular importance after loss of the dominant upper limb as this has a significant functional impact on performance of daily activities. If the circulatory system is compromised, vascularity should also be assessed. Patients who utilize an axillary harness may also experience temporary circulatory and sensory deficits during wear. Observe the color of the skin with and without an axillary harness (if utilized) to determine if there is any compromise to the circulatory system. The prosthetist should be notified for potential prosthetic harness modification or adjustment, if necessary.

The patient with a traumatic amputation may have an isolated amputation without any additional involvement of the contralateral extremity. However, it is common, especially in the polytrauma patient who has been injured in combat, to have multiple traumas that can result in injuries to the contralateral limb. These injuries may cause impairment in neurological function, perfusion, or skin integrity and may create patterns of complex scarring and soft tissue injuries. It is also important to consider injury to the central nervous system and its resultant adverse impact on the function of the contralateral limb.

Overuse injuries often develop in the contralateral limb and trunk as a result of repetitive use and or poor body mechanics when performing necessary functional tasks. The patient should be educated

about the potential to develop overuse injuries as well as the causes of overuse injuries, particularly when there is multiple limb involvement.

Optimization of the overall functional status of the patient after extremity amputation relies upon preservation of the contralateral limb and compensation for neuromusculoskeletal impairments through the use of education, rehabilitation strategies, and optimization of the prosthesis.

Prosthetic Assessment (if applicable)

As a standard of practice, the care team should routinely evaluate functionality of the prosthesis, including ease of movement, and make appropriate modifications as necessary during the prosthetic training and lifelong care phases. The care team should observe for any sign of symptoms that the prosthesis needs to be modified to include:

- Ongoing pain in the residual limb or pain associated with a prosthetic harness
- Skin breakdown
- Change in the ability to don and doff the prosthesis
- Change in limb volume (weight gain or loss)
- Change in pattern of usage

The provider may evaluate and discuss several aspects of prosthesis use including, but not limited to:

- Prosthetic fit to include ability to don and doff device
- Prosthetic operation, function, and usefulness
- Maintenance of the prosthesis
- Acceptance/rejection of prosthesis
- Appropriateness of prosthetic prescription (e.g., for employment, ADL, recreational, leisure and sport activities)
- Educate patient and family on current technologies that may enhance function

A review of the patient's prosthesis by the care team can determine if the prosthesis fits properly and if there are mechanical issues that need to be serviced. Also, patient goals change with differing life stages and occupations, interests, and social opportunities. The routine or annual assessment is a good time to focus on alterations in work activities, family duties and leisure activities which may lead to fluctuations in use of a prosthesis. A change in the patient's goals or in his or her ability to control the prosthesis should be evaluated to determine whether the current prosthesis is the best option and if additional training in use of prosthesis will maximize function and use. This is also a time when new prosthetic developments can be discussed with the patient to help him or her achieve better outcomes and satisfaction while using the prosthesis for ADL.

Several studies attempted to address the factors that most contribute to acceptance or abandonment of prosthetic use. Two systematic reviews [42,50] and three individual studies [51-53] suggest that dissatisfaction with comfort and function are the prime factors for rejection or abandonment. All of these studies concluded that a patient with upper limb amputation would choose not to wear his or her prosthesis if it had mechanical problems, was uncomfortable to wear, was financially constraining, or did not assist the patient with ADL.

Vocational Rehabilitation

Regardless of a patient's level of functioning, it is vital that the patient feel he or she has meaning and purpose. Numerous authors have examined the vocational reintegration of persons with amputations and report the return to work rate as between 66-74 percent. [54-57] However, only one of the studies separated out upper limb loss from lower limb loss, finding an unemployment rate of 22.8 percent in persons with upper limb amputations. [57] Successful return to work appears to be related to several variables:

- Age – the younger are more likely to return to work
- Gender – women have a higher rate of unemployment
- Less comorbidities
- Less residual or phantom limb pain
- Comfort of the prosthesis
- Prior education level
- Attitude – reported by patients as the most important factor in returning to work [57]
- Job skills

If a patient is capable and interested in working, a baseline vocational assessment should be obtained and continuously updated throughout the rehabilitation phases. This subjective assessment should include: level of education, work history, desired vocation(s), desire to return to college, and or desire to begin a business. Appropriate vocational assistance should be provided to help the patient achieve vocational goals and/or learn new vocational skills.

The literature supports the involvement of vocational counselors and vocational rehabilitation as being important factors in assisting a person with an amputation in returning to work. Millstein et al. found that 75 percent of persons with limb loss change their occupation following their amputation. [57] Patients may be referred to VA Vocational Rehabilitation, a national VA Benefits Administration program (to find or be trained in a career), the local VA Compensated Work Therapy Program, or a community or state vocational rehabilitation agency. In addition, the patient may pursue programs and grants to start a business. Additional resource identification is based on the patient's age, ability, and interest in paid or volunteer work, college/technical school, or self-employment/entrepreneurship.

Return to work for the person with an upper limb amputation can be especially challenging. It is important that a qualified rehabilitation provider evaluate the patient’s existing or new work environment to enhance safety, functionality, and accessibility. Recommendations for necessary accommodations to promote and maximize independence with completion of work related tasks and work activities evolve from the worksite assessment. Unique considerations upon the patient’s return to work include:

- Potential loss of hand dexterity and fine motor skills
- Need for unique methods of computer access and interface
- Potential limitations in ability to perform heavy manual labor

Voice recognition software, alternate keyboards, alternate pointing devices, document holders, headsets, Bluetooth devices, and voice recorders improve the patient's ability to complete work related tasks that require fine motor such as computer operation and phone use.

Annual Assessments

Recommendation

4. An annual comprehensive interdisciplinary assessment should be conducted for all patients with an upper extremity amputation throughout lifelong care. [EO]

Discussion

An annual assessment is an opportunity to identify new or continuing patient needs. An interdisciplinary team approach should be maintained and the evaluation should align with the comprehensive assessment components. The assessment addresses new or developing needs in the areas of medical care, rehabilitation services, and prosthetic restoration. A patient's needs evolve over time as there are changes in his or her goals, activity level, and residual limb. As a result, the prosthesis may need to be adapted or the patient may need additional training or provision of adaptive equipment to maximize function. Non-prosthetic users may also have a change in function and must be evaluated to determine the medical and rehabilitative management that will provide the best quality of life. The overall goals of the assessment are to assist the patient in maintaining functional performance and independence as well as minimizing secondary complications. Appendix D includes the essential elements of the annual assessment and this topic is addressed further in the lifelong care section. (See Appendix D: Essential Elements of the Annual Contact.)

Outcome Measures

Recommendation

5. Functional status measures should be utilized during assessments and reassessments throughout all phases of care to document outcomes and monitor the efficacy of rehabilitation. [EO]

Discussion

Advances in upper limb prosthetic design, control, and provision, combined with pressure to require more objective justification in the costs in providing these services, have intensified the need for clinicians to perform outcomes measures assessments. The care team must be aware that there is no universal functional outcome measure to assess all upper extremity amputation cases. [58,59] Depending on a patient's prosthetic training activity level, certain outcome measures may be applicable. Appendix E lists various outcomes measures that can be used by clinicians to assess functional status of someone with an upper limb amputation. Appendix E can be used to supply clinicians with information to help them choose the best measures of physical function for their own "toolkit" that are appropriate for their patients and their facility. (See Appendix C: Outcome Measures.)

Although outcome measure assessments are not completed for every patient who has undergone an upper limb amputation within the VA/DoD system, periodic assessments will ensure that the care team is considering all of the patient's needs and goals. Therapists responsible for artificial limb training will routinely evaluate a patient's progress by reviewing functional tasks, dexterity skills, and ability to complete various ADL such as cooking. A patient's own stated goals should also be assessed and reassessed and used as a functional outcome measure. Some general requirements for an upper limb measurement tool are: easy to quantify, easy to administer, relate to ADL, and able to track improvement and function over time. A standardized approach has not been implemented and there are variations in practice among therapists, which are not generalizable.

There are a significant number of outcome measures available, which can make it difficult to select appropriate measures for the upper limb amputation population. Several reviews of outcome measures have examined the content and psychometric properties of available measures for use in upper limb prosthetics. [47,60,61] The review focuses on physical function and does not include measures designed to assess important domains such as social participation or satisfaction with the prosthesis.

Areas of assessment other than physical function should not be overlooked and are also important to assess and monitor. These areas include, but are not limited to, residual limb pain, phantom limb pain/sensation, skin health, and overall satisfaction with quality of life.

Core 3: Patient-Centered Care

Shared Decision Making

Recommendation

6. A shared decision making model, incorporating patient goals, should be used throughout all phases of rehabilitation to ensure patient-centered care. [EO]

Discussion

The shared decision making model is the collaboration between patients and caregivers to come to an agreement about a healthcare decision. The process requires the cooperation of at least two parties to participate in treatment decision making, information sharing, a treatment decision (which may be to do nothing), and agreement on the decision by both parties. [62] It is essential to ensure clear communication and shared decision making between the patient and care team. The medical, surgical and rehabilitative management plan should be presented to the patient and care team prior to, and during, each phase of care with the focus on optimal patient outcomes supported by evidence-based practice. The quality of care and best patient outcome will ultimately be determined as the patient is provided with all the information and education to his or her best understanding. Communication of the care plan should be shared through the patient's primary language that is culturally appropriate and at the patient's literary and educational level. The care plan should also be made accessible to the patient with additional needs such as physical, sensory or learning disabilities.

A behavioral health and/or cognitive assessment may determine the patient's inability to participate in a shared decision making process. If the patient is unable to participate in this decision making process, similar considerations must be made to ensure proper communication with the family, significant other and/or caregiver.

Rehabilitation and Discharge Plan

Recommendation

7. A comprehensive, interdisciplinary, patient-centered rehabilitative and discharge plan should be developed as early as possible and updated throughout all phases of care based on the patient's progress, changes in functional status, emerging needs, and goals. [EO]

Discussion

Rehabilitation plan

Rehabilitation is important to enhance the patient's functionality and improve individual health and vocational prospects. [63-65] Successful rehabilitation relates to both prosthetic functional performance and a patient's overall level of function in his or her community.

As the medical and surgical care plan is executed during the acute, or initial, phase of upper limb amputation management, a comprehensive, interdisciplinary, patient-centered, holistic rehabilitation treatment plan should be developed. This rehabilitation treatment plan may serve as a "blueprint" for optimal patient outcomes and ensure that the care team is working together with the patient,

family/significant other and/or caregiver. The rehabilitation treatment plan with assessment of patient condition, interventions, and goals, should indicate and support the next anticipated phase of care. It is not uncommon for treatment phases to overlap. Moreover, patients will progress through care phases at variable speeds. Therefore, the care team must carefully and frequently coordinate their efforts to assist the patient through the current phase while simultaneously preparing for the next phase of care.

The patient-centered rehabilitation plan should include:

- Evaluations from all members of the care team
- Input from the patient and family/caregiver(s)
- Treatment plan, which must address all identified realistic patient-centered treatment goals, rehabilitation, medical, psychological, and surgical problems
- Indication of the next anticipated phase of rehabilitation care based on discharge criteria
- Identification of and plans for discharge at the initiation and throughout all phases of the rehabilitation process

Development of the treatment plan evolves from the findings of the Comprehensive Interdisciplinary Assessment. Concentrating on only one aspect of care is not sufficient for optimal treatment outcomes. Rehabilitation treatment goals should be written, measurable, specific, and achievable. This level of communication, to include shared decision making, information and education, preparation, planning and execution, can ensure that patient goals and successful outcomes are met throughout all phases of care. Care team members should work together to coordinate the recommendations and interventions to improve the quality and holistic nature of a patient's care. This may be accomplished through regularly scheduled care team meetings that offer team members opportunities to share observations, discuss complex patient issues, bring in other needed specialties, and develop stronger working relationships.

Involvement of the patient and family/significant other and/or caregiver in the rehabilitative care plan is critical. Educating the patient and family using the shared decision making model and realistic goals helps to manage expectations and prevent patient and care team frustration. Any updates or changes to the rehabilitative care plan can be life altering; therefore it is imperative that the patient's family/ significant other and/or caregiver are informed and educated to provide the appropriate emotional and psychosocial support to ensure success of the rehabilitative care plan and the patient's goals/outcomes. The failure to address any identified patient or patient support issues potentially compromises the achievement of patient-centered treatment goals and the provision of holistic care. A collaborative approach will influence the patient to become independent in his or her ADL and initiate processing of psychological and emotional challenges associated with extremity loss.

The rehabilitative treatment plan should also identify realistic patient-centered treatment goals. This plan facilitates optimal independence in ADL and provides a framework to help the patient progress through the physical, psychological and emotional challenges of upper extremity loss. This method opens the opportunity for the patient and care team to update and modify the rehabilitative treatment plan throughout all phases of upper extremity amputation care to ensure enhanced patient outcomes and better establish a timeline for each phase of care.

Discharge plan

The Royal College of Physicians [66] recommends that discharge criteria include the following:

- Independence in ADL
- Safe, functional independence with adaptive equipment as appropriate
- Initial home adaptations already in place and a program for further adaptations agreed upon
- Satisfaction with level of independence with or without prosthesis

The rehabilitation treatment plan should identify and address plans for discharge at the initiation and throughout all phases of the rehabilitation process. The discharge plan should include:

- Evaluation and required modifications of the home, work and community environments
- Determination of needs for home assistance
- Location of rehabilitation
- Social support/financial resources
- Transportation or driver training and vehicle adaptation
- Durable medical equipment (DME)/specialized equipment needs

Findings from the comprehensive interdisciplinary assessment regarding the patient's prior and current functional level, home environment, occupational history, social history and community environment can help the care team ensure all the resources and adaptive equipment are ordered/provided prior to the patient's discharge. Discharge and disposition planning can elucidate the need for home assistance versus optimal location and setting of rehabilitation. Identifying an appropriate social support system may enhance the opportunity for emotional adjustment and community integration. Disposition planning can also identify/predict the patient's ability to live with financial independence and provide early intervention for those who require additional financial resources. Accessible transportation, driver training and vehicle adaptation may also be required to allow the patient to continue to participate in the rehabilitation care plan, as well as enhance his or her community integration. Early determination of durable medical equipment (DME) and specialized equipment needs, such as environmental control units, can minimize the duration of the initial hospitalization and ease the patient's transition to an independent living situation and ability to reintegrate into the community.

Expert opinion and major accrediting bodies (The Joint Commission [TJC] and the Commission on Accreditation of Rehabilitation Facilities [CARF]) require the establishment of interdisciplinary treatment plans. Frequent evaluation and modification of the treatment plan assists with efficient progress through the rehabilitation phases of care. This may provide useful standards for the measurement of progress and for identifying (long-term) problems.

Rehabilitation Interventions

Recommendation

8. Patient-centered physical and functional rehabilitation interventions should be initiated based on the rehabilitation plan and the patient's physical and psychological status. [EO]

Discussion

Patient-centered physical and functional rehabilitation interventions should include:

- ADL retraining and consideration of adaptive equipment, modified or altered strategies, and one handed techniques
- Residual limb management (e.g., volume, pain, sensitivity, skin integrity, and care)
- Progressive range of motion (ROM) exercises
- Postural exercises and progressive strengthening
- Cardiovascular endurance
- IADL interventions, home and driving modifications, assistive technologies, and community integration

Additionally, considerations of the patient's psychological or behavior health needs are relevant to successful physical and functional rehabilitation interventions. A summary of the rehabilitation interventions provided below can be found in Appendix B: Summary of Assessments and Interventions in Rehabilitation Phases.

ADL

Once the care team completes the baseline assessment (see Core 2: Comprehensive Interdisciplinary Assessments) the occupational therapist initiates patient training in functional ADL. At the onset of rehabilitation, the initial focus is to retrain the patient to perform basic self-tasks such as hygiene, bathing, dressing, grooming, toileting and eating in order to maximize the patient's independence and combat any potential feelings of dependency and helplessness after upper limb loss. Regaining independence in self-care ADL is critical for patients with bilateral upper limb amputations. Regardless of the level of amputation, patients learn new strategies, alternate methods, and one-handed techniques to regain function.

Occupational therapists may also introduce adaptive equipment and assistive device options to facilitate independence. It has been reported that a patient with one hand can typically perform 90 percent of his or her daily activities; however, with increased effort and use of adaptive equipment or other unique tools, the one handed patient can be fully independent. [51] There are a number of adaptive equipment and assistive device options available some of which may include:

- Non-slip grip materials
- Rocker knives
- One handed nail clippers and nail brushes
- Zipper pulls
- Button hooks
- Universal or quadriplegic cuffs
- Modified long handled sponges, wash mitts
- Pumps for bottles
- T-shirts with modified Velcro sleeves
- Elastic shoelaces or lace locks
- Multipurpose jar, bottle, and can openers

Additionally, Appendix E, Table E-1 provides a list of technique options, equipment and considerations to maximize independence after bilateral upper limb loss. (See Appendix E: Activities of Daily Living.)

Hand dominance

Hand dominance is a factor that influences the long-term use of the prosthesis. Cerebral dominance is adaptable and learned motor patterns can be retrained. Loss of a dominant hand or arm requires that

the contralateral side be trained to perform the fine motor tasks which are no longer possible or efficient with or without the use of prosthesis.

Rehabilitation therapists should address functional use of the remaining limb to achieve fine motor tasks previously performed by the dominant hand, including writing, computer use, and manipulating tools. Motor training of the non-dominant side is most beneficial during the pre-prosthetic phase of rehabilitation, as the person with extremity loss will be totally dependent upon the remaining limb during this time. However, if circumstances or patient motivation do not allow for retraining with the remaining limb during the early phases, it should not be excluded or ignored as a goal during the lifelong phase.

Residual limb management

Acute residual limb management should focus on post-operative wound healing, limb protection, edema control, residual limb shaping, pain management and decreasing hypersensitivity of the limb. One of the key factors that will determine optimal and ideal prosthesis acceptance is wound healing and wound management. Regardless of the patient's prognosis for prosthesis use, management of wound healing is essential to successful postoperative outcomes. If closure does not progress or is not achieved, continued active management by the surgeon and a specialized wound care team is required to enhance progress and prevent complications.

Once a patient's limb has been surgically closed with minimal drainage, edema control, residual limb shaping and pain management can be achieved through an immediate post-operative wound dressing and figure of eight compressive wrap. The limb should be protected from external trauma if an open wound is present to reduce potential complications such as delayed wound healing and the patient should be provided education in the importance of limb protection. Residual limb skin and tissue integrity should be monitored at each dressing change. As wound drainage diminishes, the patient may progress to early application of a compression sleeve or shrinker over the surgical dressing for continuous wear. Once post-operative sutures are removed the patient may be issued an appropriately sized silicon liner to wear during the day and should be instructed to continue to wear the shrinker when not wearing the liner and during sleep. Both shrinkers and liners provide a continuous force compression to the residual limb.

Areas of hypersensitivity on the residual limb should be addressed through desensitization techniques which include massage, use of desensitization media, and progressive loading are of the residual limb. The care team should teach the patient to engage the residual limb in active mobilization and stretching to reduce pain, prevent contractures at proximal joints, and improve prosthetic function and use.

As the residual limb matures and edema diminishes, the underlying heterotopic ossification (HO) may become relatively more prominent. Despite this, HO is more often asymptomatic and in some cases may actually serve a useful purpose, such as to facilitate prosthesis suspension for those with short and/or proximal residual limb length. When symptomatic HO emerges, this may present as new or worsening residual limb pain and skin breakdown. It may also lead to trial of multiple and complex socket designs and even prevent optimal prosthesis fit and function. Sometimes the osseous overgrowth displaces or entraps a nerve and causes neurogenic pain in the residual limb, which may or may not be amenable to

minimally invasive interventions or oral medications. When nonsurgical measures such as physical activity modifications and prosthesis modifications fail to provide relief, surgical excision may be considered. Potter et al. reported the results of HO surgical excision in 19 residual limbs of 18 traumatic amputations. The mean time since injury was 8.2 months (range 3 to 24 months). All patients had failed conservative management for persistent skin breakdown and prosthetic use. At early follow-up, 16 patients (17 limbs) showed no radiographic evidence of recurrence. All 19 limbs were eventually successfully fitted with prosthesis after the surgery. Four of the 18 patients experienced wound complications requiring return to the operating room. [8] HO excision is a complex surgical procedure and can be approached as a "re-amputation" of the limb.

Primary prophylactic regimens (e.g., non-steroidal anti-inflammatory drug [NSAIDs] and local irradiation), which have proven to be effective in preventing and limiting HO in other patient populations, have not been adequately studied in patients with amputations and generally are not feasible in the setting of acute traumatic amputation.

Patient education and careful assessment of the patient and condition of the residual limb should be taken when HO is identified. All factors must be considered in the management, or non-management, of HO identified in the patient's amputated limb.

In long term residual limb management, it is important to remember that compromised soft tissue integrity in the residual limb hinders the patient's ability to progress in prosthetic wear, or any other additional training. Compromised tissue integrity may result from a rash, or debris left buried within the residual limb after a traumatic amputation. The care team should educate the patient about signs of irritation that may be due to the type of soap used, improper application of lotions or creams, poor socket hygiene, or perspiration while in the socket. [67] If the amputation was traumatic, then the patient should be reminded that there may be residual dirt, debris, or other fragmentary objects buried within the residual limb which may be the catalyst for open wounds or skin irritation. [68]

After prosthetic fitting, the patient and caregiver should be educated about the importance of frequent residual limb inspection as well as observable signs and symptoms associated with poor residual limb tolerance. Inspection of the residual limb should become part of the patient's daily routine. Upon removal of the prosthesis, the residual limb should be thoroughly inspected for any skin redness, irritation, and breakdown. Erythema normally appears within a few minutes after removing the prosthesis and should fade quickly. Erythema that is present upon removing the prosthesis, or that does not significantly diminish within 20 minutes, is concerning and should be evaluated. If prolonged tissue irritation is observed, the patient must be instructed not to re-don the device and to report any complications immediately to the prosthetist or other identified member of the care team. Table 7 describes the management of the residual limb in each phase of care.

Table 7. Residual Limb Management Throughout Phases of Care

I. Perioperative	• Preoperative: o Desensitization exercises, skin hygiene, and description of types of pain o Explain and differentiate between residual limb pain, phantom pain, and phantom sensation • Postoperative: o Donning/doffing of compressive wrap or shrinker, if appropriate o Desensitization exercises, skin hygiene, and description of types of pain
II. Pre-prosthetic	• Care of residual limb • Use of shrinker and or silicon liner
III. Prosthetic training	• Donning/doffing of prosthetic system • Use of shrinker when out of the prosthesis • Management of sock ply, if appropriate • Skin checks and skin hygiene • Observe pressure points and protect contralateral limb
IV. Lifelong care	• Routine residual limb evaluations and skin checks

Progressive range of motion

Limitations in range of motion of the upper quadrant may lessen prosthetic functional parameters. Daily maintenance of range of motion should be addressed early in rehabilitation and patients should perform daily self-stretching exercises to maintain joint flexibility. Low load prolonged stretch to the shoulder flexors, abductors, rotators, and scapular protractors and retractors is a priority, as well as maintaining motion in any remaining elbow or wrist joints. When manual assisted stretching is needed, the use of proprioceptive neuromuscular facilitation techniques may be beneficial for the patient.

Postural exercises and strengthening

Therapeutic intervention should include muscle strengthening. If applicable, patients should engage in scapular stabilization exercises as soon as medically cleared to promote control of the prosthesis and maintain integrity of the residual limb. Patients should begin shoulder stabilization exercises with isometric movements and progress through full range of motion activities.

If applicable, patients should strengthen the contralateral limb and lower extremities as they are needed to assist with transfers, mobility, and ADL. Patients should also engage in core stabilization exercises as soon as medically cleared to promote distal mobility, improve balance, and avoid compensatory upper extremity techniques which may result in injury. [69]

The patient's awareness of body symmetry and sound posture is critical in order to prevent incorrect postures that lead to cumulative trauma and overuse injuries of the amputated upper limb, intact upper extremity, neck, shoulders, and/or spine. The care team should engage the patient in core exercises and challenge weight bearing early to strengthen the trunk and protect the spine. A progressive yet

aggressive strengthening program for the upper quadrant range of motion should be initiated early to prepare the patient for the weight and strength demands that he or she will encounter. During upper body strengthening proper scapular positioning and correct exercise form is necessary to protect joints and properly strengthen key muscle groups. All major muscle groups proximal to and part of the residual limb should be strengthened to include: periscapular muscles, rotator cuff muscles, and any other proximal musculature of the residual limb. The patient should be instructed in a maintenance program for upper body strengthening and educated about the benefits of long term strengthening to prevent injury.

Cardiovascular endurance

Patients may develop decreased cardiovascular capacity while recovering secondary to immobility; therefore, patients should engage in cardiovascular reconditioning to decrease comorbidities and increase independence with ADL. Additionally, there are increased energy demands associated with prosthetic use, and weight management after any type of amputation is important for prosthetic fit and function. A general cardiovascular conditioning program should be introduced once a patient is medically stable and pain is controlled. Cardiovascular endurance is provided through physical, occupational and recreation therapies during the earliest phases of care. Cardiac precautions, patient goals, and physical clearance should be taken into consideration when developing an appropriate cardiovascular treatment plan. Cardiovascular activities may include, but are not limited to, any of the following with modifications to the activity as needed: cycling, walking, jogging, rowing, elliptical, seated elliptical, upper body ergometer, and swimming. Patients should be educated in the benefits of long-term cardiovascular activities as they assist with stabilizing body weight and maintaining limb volume, which will improve long-term prosthetic wear.

IADL

As patients regain independence in basic self-care ADL, improve ROM, strength and cardiovascular endurance, IADL is addressed. Learning new or alternate strategies to perform IADL may be necessary to enhance function after limb loss. Upon completion of a driving evaluation (see Core 2: Level of Function) the patient may begin driver's training to relearn driving with use of any necessary vehicle modifications to ensure safety. Modifications or use of specialized adaptive equipment may improve accessibility and safety within the home. Use of voice activation systems, hands free devices, voice recognition software, and one handed keyboards improve independence in operation of computers and phones. For a patient who has undergone a bilateral amputation, environmental control units may be useful to improve independence in operating appliances such as lights or a television. Unique showering and drying systems are also commercially available to improve ease for a patient who has undergone a bilateral upper limb amputation. Additionally, veterans may apply for Home Improvement and Structural Alterations (HISA) grants or adaptive housing funds for necessary home modifications. Assistive technology specialist should be consulted to assess for assistive technology devices to enhance independence in the home, at work, or participation in recreational and leisure activities.

Community integration

Community integration is an integral part of the rehabilitation process for any patient who has undergone an upper limb amputation. A community integration program may be introduced once the

patient is medically cleared to participate in a community outing. The patient must also be psychologically ready, willing to participate, and have some input into where the outing will take place. In early community outings, patients tend to manage better in small, one- on-one trips, such as to a local mall or restaurant. As patients' emotional and physical well-being stabilizes with the smaller outings, they should progress to larger, more complex, patient-specific outings as appropriate. Eventually, allowing the patient to become a more active participant in the planning and execution of the outing will encourage confidence and carry-over of community integration skills in the patient's personal life.

Community integration serves as a supportive tool for patients with amputations to explore various activities outside a clinical setting and to acquire lifelong skills. It also challenges the patient to learn to cope and/or adapt physically, psychosocially, and cognitively to every day experiences. Recreation, such as adaptive sports, leisure activities and outlets are important at all ages. Patients can often participate in and excel at sports and activities they have never tried, improving self-esteem and allowing them to network with others. Through sports and leisure activities there may be less risk for isolation and more opportunity for sense of purpose and ability to receive and/or provide peer support.

Behavioral health and psychological support

Male gender and nonvascular amputation are predictors of positive psychological adjustment. Negative influences include low social support, poor perceived health, and high social discomfort. [40] Educational level and pre-amputation salary (the higher, the more successful), a good social network, and an extroverted nature are also important factors. [70] Patients who have lost extremities as a result of war injuries usually have more complex problems because of the variety of traumatic experiences to which they have been exposed. [71] Early family member involvement and contact with other patients with amputations are important for the patient's psychological adjustment. [65]

In the early stages of adaptation, the patient may readily engage in rehabilitation while delaying dealing with the emotional aspects of adaptation. As therapy progresses, defense mechanisms weaken, and medication use drops, the priorities for the patient may also change. Conversely, some patients may feel overwhelmed by the whole amputation experience, and not want to participate in their physical recovery. If this is the case, the care team should try to be encouraging, without being demanding. In some cases, this approach may add stress to the patient, causing the patient to shut down and avoid all concomitant therapy. Patients with chronic complex medical problems should be encouraged to be active collaborators in their treatment and receipt of medical interventions. Motivational enhancement interventions attempt to validate and normalize the patient's intermittent feelings of discouragement and feeling trapped. These strategies are non-confrontational and help patients increase their awareness of and focus on their identified reasons for working so hard in rehabilitation. The patient's successful amputation rehabilitation will require considerable ongoing effort, as well as optimal adherence with medical and rehabilitative prescriptions.

Patients who are do not engaged in activities or have a general disinterest in participation in activity since loss of an upper limb may benefit from a community integration program where exposure to other peers may greatly benefit the patient. Continued involvement in support groups is also beneficial as the patient interacts with others with similar amputations and can learn from peers. In addition to the

emotional reactions (denial, mood disturbances, fear of the future) the rehabilitation team must remain aware of the patient's needs and how demands within his or her environment impact everyday life function.

In later stages of adaptation and rehabilitation, it is important to assist the patient in formulating a plan of action for a life as an individual with amputation. This may include assessment of future aspirations and goal setting. Ideally, the patient should be encouraged to begin taking active steps towards goals so the team can assist as difficulties arise and to ensure proper training to enhance function with and without a prosthesis.

Pain Management

Recommendation

9. Various types of pain experienced after upper extremity loss should be managed appropriately and individually throughout all phases using pharmacological and non-pharmacological treatment options. [EO]

Discussion

The etiology of pain in a patient with an upper limb amputation is likely to be multi-factorial and requires coordination of care by a physician led care team throughout all phases of rehabilitation. It is important that the care team provide accurate, verbal and written educational information to patients, caregivers and family members regarding the likelihood of post-amputation pain syndromes. It is essential to identify sources of pain in order to facilitate aggressive treatment and enhance the patient's participation in rehabilitation, community integration and quality of life. A multidisciplinary approach to pain management is advocated.

There are many pharmacologic options for managing pain following amputation despite the paucity of evidence to support one agent over another. Table 8 lists the pharmacologic therapies to consider for post-amputation pain management. If pharmacologic therapy is offered, providers and patients should understand the uncertainties of the short- and long-term efficacy and safety of treatment, and require the patient to have regular follow-ups to reassess risks and benefits and modify treatment as indicated. These follow-ups could be done in-person or through the use of virtual and connected care.

Table 8. Pharmacologic Therapies to Consider for Post-amputation Pain

Route / Method	Examples
Oral	Antidepressants, Tricyclics; (e.g., amitriptyline) [2] Antiepileptics; (e.g., gabapentin) [2] Opioids, such as tramadol [2] and morphine [1] Memantine [3] Mexiletine [3]
Intravenous	Ketamine [1] Opioids; e.g., morphine [1]
Myofascial Intravenous	Bupivacaine [2]
Nerve Block	Anesthetics; e.g., bupivacaine [2], ropivacaine [2]
Neurosclerosis	Phenol [2]

(1) Insufficient evidence; results from more than one small trial consistently suggested efficacy
(2) Insufficient evidence; results from one small trial suggest efficacy or results were inconsistent among more than one small trial
(3) Insufficient evidence; results suggest lack of efficacy in one or more small trials

The patient and the care team should also be aware of the multitude non-pharmacologic treatments, and therapeutic strategies that can be employed based on the type of pain. Due to the complexity of these pain syndromes following upper limb amputation, pharmacologic therapy should be used adjunctively with non-pharmacologic interventions for a multimodal therapeutic approach to yield the best outcome. The following modalities should be considered:

- **Pharmacological**: antiepileptics (e.g., gabapentin), tricyclic antidepressants (TCA), serotonin-norepinephrine reuptake inhibitors (SNRIs), non-steroidal anti-inflammatory drugs (NSAID), dextromethorphan, and long-acting opioids
- **Epidural analgesia**: use of patient controlled analgesia (PCA), or regional analgesia may be considered in the perioperative period, although the benefit is unproven
- **Non-pharmacological**: socket modifications, transcutaneous electrical nerve stimulation (TENS), desensitization, mirror therapy, scar mobilization, relaxation, and biofeedback.

RLP and PLP are commonly experienced following upper extremity amputation and may be difficult to control. Post-surgical pain following an upper limb amputation can usually be controlled with pain medication and subsides fairly rapidly as the swelling goes down, tissues begin to heal, and the wound stabilizes as part of the natural healing process. The treatment of PLP has received considerable attention in the literature. More than 60 different treatment strategies have been suggested as being effective in treating PLP, including a variety of medical, surgical, psychological, and alternative options. However, there is little support for any one approach. The role of pre-amputation analgesia and various other analgesic interventions have shown mixed results in small studies. It remains to be determined whether other methodological approaches will result in any therapeutic advantages. [72,73] PLS should be considered normal sequelae and only treated if it manifests as PLP and proves to be disruptive to functional activities and quality of life. There is good evidence that psychological and/or multidisciplinary interventions enhance outcomes for chronic medical conditions, particularly chronic pain. [74]

Response to therapy is often unpredictable and inadequate, therefore, a prophylactic approach to pain management prior to rehabilitation interventions should be considered. Results of a large survey of U.S. Veterans (2,694 respondents) with upper or lower extremity post-amputation pain revealed that, despite the use of a variety of therapies, only one percent of the 512 treated patients had clinically important lasting benefits, and only 8.4 percent were considered by the authors to have obtained any real benefit. [75]

Patient Education

Recommendation

10. The care team should provide appropriate education and educational resources to the patient, family and caregiver(s) throughout the phases of care. [EO]

Discussion

Appropriate education should include, at a minimum, information relating to:

- Level of amputation
- Role of the care team members
- Pain management
- Procedural/recovery issues
- Potential psychosocial consequences
- Sequence of amputation care
- Postoperative management of wound
- Residual limb management
- Patient safety
- Prevention of complications
- Expectation for functional outcomes
- Overuse syndromes
- Prosthetic types and options
- Peer support groups
- Non-profit resources
- Emerging technology

The education process can be divided into four stages: assessment, planning, implementation, and documentation. Once the patient's educational needs are identified, a plan is implemented to assure that the patient receives all of the information needed to achieve the educational goals. Patient education is best provided using multiple means of instruction. Appropriate verbal, written, and physical demonstration methods should be utilized accordingly. All aspects of the patient education process should be documented in the patient's record in order to monitor efficacy and progress.

There are no randomized controlled trials on the effectiveness of pre-procedural educational interventions for adult patients undergoing amputation. However, reviews of research examining the efficacy of pre-procedural interventions reveal that such interventions are generally effective. [76,77] Improvements have been observed in a variety of outcomes including patient satisfaction, pain reduction, pain medication use, pre- and post-surgical anxiety, and behavioral recovery. [63] In circumstances where surgery is urgent, patient education is often unavoidably delayed until the postoperative period.

The patient should be consulted and given appropriate advice and adequate information on rehabilitation programs, prosthetic options, and possible outcomes, with realistic rehabilitation goals. [63,78] Figure 1 lists the Joint Commission (TJC) standards for providing patient education on rehabilitation techniques.

Figure 1. Patient Education Minimum Standards

Patient Education Regarding Rehabilitation Techniques*

Healthcare organizations should:

- Provide information and educate on skills that improve the patient's health, toward both recovery and overall well-being
- Assess a patient prior to teaching and construct a plan that's based on the patient's needs
- Demonstrate the correct use of medical equipment to the patient
- Provide information on potential food and drug interactions specific to the illness or condition
- Counsel on nutrition intervention and modified diets
- Inform the patient about further treatment and rehabilitation techniques
- Provide the patient's background to home healthcare specialists and other medical care providers the patient may see during follow-up

*The Joint Commission's minimum standards

The patient, family, significant other and/or caregiver(s) who have been properly educated about all phases of the rehabilitation treatment plan of care are more likely to have a greater level of trust in the care team and may have improved outcomes during all phases of care. Using the shared decision making process, the patient is also more likely to have realistic expectations if he or she understands the processes included in recovery time, the course of rehabilitation, and the sequence of events necessary for healing after upper limb amputation. If the patient is undergoing a planned amputation or revision, as opposed to one as result of a traumatic event, the patient and care team should discuss the optimal level of amputation, as it relates to the preservation of life and limb, to enhance the patient's potential for future use of prosthesis and attain maximum independent functionality.

Education in pain management will need to be addressed early in the patient's rehabilitation, as appropriate, as pain may manifest itself in various ways throughout each phase of rehabilitation. It is important that the care team engage the patient in shared decision making and educate the patient as to how pain affects function as well as how it may serve as a critical indicator for limb complication. This knowledge can help the patient and the care team to apply the best clinical practices and standards of care for the management of residual limb pain, phantom limb pain, phantom limb sensation and pain associated with degenerative conditions and overuse syndromes.

Patient education on the post-operative wound management and residual limb management is critical in the preparation for limb acceptance of a prosthesis. Furthermore, the importance of the prosthesis-to-limb interface, type of prosthesis suspension, and the volumetric fit of the prosthesis cannot be understated during the care team's discussion with the patient.

Patient interventions have most often included some combination of procedural and sensation information giving, instruction in cognitive-behavioral coping strategies, and elicitation of patient anxieties and fears. It is difficult to assess the relative effectiveness of different strategies, because multiple strategies are often "packaged" as one intervention and outcome measures may lack the sensitivity or specificity to detect the outcome of interest. Overall, there appears to be slightly more benefit from coping skills instruction over information giving, although both have been shown to be effective. [76]

The patient, and family/caregiver(s), should be informed of all appropriate options pertaining to upper limb prostheses. Some prosthesis options require that the patient possess certain physical capabilities to

successfully operate the device. There are up to six options (or combinations thereof) that a patient can utilize in various settings including:

- No prosthesis
- Semi-prehensile cosmetic prostheses
- Body-powered prostheses
- Externally powered prostheses
- Hybrid prostheses
- Task specific prostheses

(Advantages and disadvantages of each design are described in Appendix F: Advantages and Disadvantages of Prostheses.)

Involvement in some type of support program can often be beneficial for both the patient and the family/caregiver(s). Support programs allow the patient with extremity loss to interact with others with a similar condition and who face similar challenges. [79,80]

The care team should provide the patient with education about available community resources and non-profit resources to facilitate successful recovery as the patient reintegrates into the community after limb loss. Nonprofit organizations for disabled Veterans and non-Veterans provide recreational opportunities and other types of support. Amputee Coalition (Knoxville, Tennessee) is a non-profit organization that provides numerous resources, outreach, and education for individuals with limb loss. There are a number of veteran's service organizations that support wounded Veterans. Publications such as InMotion magazine (Amputee Coalition, Knoxville, Tennessee) and Challenge magazine (Disabled Sports USA, Rockville, Maryland) can be great resources as well.

A patient with an upper extremity amputation may experience complications related to overuse injury of the contralateral limb. Strategies to manage safety and prevention of complications after upper limb amputation are other aspects of education that should be offered by the care team. The patient's overuse injuries must be addressed and managed proactively through established standards of care, and the patient must be educated about early symptoms of the onset of overuse syndromes, which may have a significant impact on the patient's daily functioning.

The patient will require continuing education regarding updates in rehabilitative techniques, advances in medical technologies and emerging research. The patient and the care team need to work collaboratively to ensure that the patient receives continuing education and outreach for the optimal management of his or her upper extremity amputation. The patient must be referred to the appropriate members of the care team that can facilitate this educational opportunity and dissemination of valuable information, throughout his or her lifetime.

Peer Support

Recommendation

11. The care team should facilitate early involvement of a trained peer visitor. [C]

Discussion

Fear of lack of acceptance by friends and family, loss of function, and alteration in body image are a few common reactions that patients experience prior to having, or after having, an upper limb amputation. An appropriate peer visitor can model healthy adaptation in all these areas. Patients with an amputation report that peer support programs are often very helpful and provide a sense of hope in recovery and for a life with a sense of normalcy. Peer support provides an opportunity for patients to relate to one another and/or to disclose relevant emotions and experiences. Peers can communicate with the patient that coping with and adapting to an amputation is possible. Peer support interventions can be categorized into two types: individual peer support and peer support groups. Support programs, either individual peer support visitors or peer support groups, allow the patient with an extremity loss to interact with others with a similar condition, and who face similar challenges. [79,80]

Patient peer support and visitation allows the patient one-to-one interaction with another person with an extremity loss. These meetings can take place on an inpatient or outpatient basis, and may begin perioperatively. A peer visitor can provide emotional support as well as be a source of information and resources. Sometimes simply meeting another person with a limb loss can make the patient's ability to cope with an upper limb amputation easier.

Strengthening the family, significant other and/or caregiver through emotional support and education strengthens the patient. Peer visitation may also be considered for the family. A properly trained spouse has been used in some institutions to deliver peer support to family members. It is important to remember that patient specific discussion should be avoided unless permission has been granted by the patient.

Peer visitors should go through a training program such as the one offered by the Amputee Coalition (AC). The training involves visitation strategies, education tasks, emotional support, and other skill sets to ensure a non-biased approach to the patient care discussion. Peer certification programs provide some standardization and consistency to the individual peer support program.

Peer visits work best when the age, gender and type of amputation are considered and matched. [80] A young woman with a shoulder disarticulation amputation will have different needs and concerns in contrast to an elderly man with a transradial amputation. Therefore, the best match would be same-gendered patients with similar levels of amputation.

Peer support groups provide an opportunity for patients to meet others with similar amputations, obtain information about the condition and receive emotional support. Patients who participate in a peer support groups may feel empowered, experience reduced social isolation, and receive validation for their feelings and experiences.

Potential patient benefits from participating in support groups are:

- Improving coping skills and sense of adjustment
- Talking openly and honestly about their feelings
- Reducing distress, depression or anxiety
- Developing an understanding of what to expect from an amputation

- Getting information on various treatment options

Support groups can be social, recreational or educational. The AC has developed a structured educational curriculum for support groups called Promoting Amputee Life Skills (PALS) Program. This self-management group program includes topics such as: an overview of self-management, pain management, building positive mood, managing negative mood, interacting with family and friends, working with the health team/community resources, building healthy habits, relapse prevention, and maintaining progress. When Wegener et al. compared existing support group activities, the PALS program participants showed an overall improvement in self-efficacy, state-of-mind, and functional limitations. The study also found that the odds of being depressed were 50 percent lower in persons involved in the PALS self-management program. [81]

Connecting the patient with an upper limb loss to a peer visitor, support groups or educational program may be accomplished through face-to-face programs or through telecommunication technology. Peer visits can be conducted in person, via telephone conversation, e-mail, or instant messaging. Moreover, while initial introductory visits between a new patient and the peer visitor are best done in person, follow-up visits can be done easier and more frequently using phone and e-mail options. For patients who are not located at a reasonable distance from a peer center, or live in a low patient population density, Clinical Video Tele-health (CVT) visit (real-time video conference) may also be used to broaden the patient's access to a peer support group or education program.

Perioperative Phase

Decision for Amputation

Recommendation

12. The decision for amputation should be made based upon accepted surgical and medical standards of care. [EO]

Discussion

The informed consent process is essential to any surgical intervention and is required by law. The discussion prior to surgery is usually the first contact between the patient and the surgeon who will conduct the operation. This discussion is the opportunity to form a trusting relationship and open communication to address any patient's fears, wishes, and concerns. The surgeon must make the patient aware of the risks and benefits of each viable treatment option. The patient should be encouraged to ask questions and to express his or her own personal desires, verbalize a good understanding of the options, and agree to a treatment plan before undertaking upper extremity amputation. Special consideration must be given in cases where the patient is unable to consent to surgery.

The decision regarding amputation should be made based upon accepted surgical and medical standards of care. The surgeon should be familiar with the multiple approaches available for the various levels of amputation, muscle balancing strategies, and wound closure techniques. [48] (See Appendix G: Surgical Considerations) Emerging and advanced surgical techniques may be performed in a specialized setting under the care of experienced surgeons. Combined with sophisticated medical and rehabilitation care, amputation surgeries can also serve as a refined reconstructive procedure to prepare the residual limb not only for motor function but also for sensory feedback and cosmesis.

The presence of severe trauma, critical extremity ischemia and/or overwhelming infection generally requires that amputation surgery be performed urgently. An urgent amputation may also be required when vessel occlusion and subsequent extremity tissue necrosis results from using vasoconstrictor agents to treat infections (sepsis).

In trauma cases in which the immediate threat to life is not serious, a period of conservative management may observed to monitor the evolution of the patient's condition. In certain cases this period may allow for restoration of collateral circulation in the extremity and help to avoid amputation or minimize the segment to be removed. Emergency repair of torn blood vessels by the vascular surgeon can make extremities viable and even help to avoid amputation. Providers should be aware that extensive reconstructive surgery to preserve an extremity may result in a painful, non-functional, and less efficient and effective limb than an amputated limb with a prosthesis. Conversely, the opposite of this statement can also be true. An upper limb with very minimal function can sometimes be more useful than an amputation with a prosthesis. Therefore, careful consideration should be made with respect to the decision about limb salvage versus amputation. [82,83]

When considering amputation as a treatment for cancer, the care team should involve the Orthopedic Oncology or General Surgery Oncology teams (if available) to add more subject matter expertise in the patient and care team decision making process.

Elective, or delayed, amputations may be considered in situations when the affected extremity is considered non-functional secondary to the loss of compensated vascular, neurologic, or musculoskeletal function resulting in significant decline in patient health, quality of life, and patient wellbeing. It is in the best interest of the patient and care team that the patient undergoes a comprehensive mental health assessment to ensure that patient is of sound decision making capacity and has been determined to be able to make a well informed decision regarding elective or delayed amputation.

With any amputation surgery, thought should be given to the surgical technique that will result in the highest level of functional ability, including consideration of available prosthesis treatment options. (See Appendix G: Surgical Considerations.) This can be best accomplished through early consultations and collaboration with other members of the care team with subject matter expertise (prosthetist, Physiatrist, etc.) that will provide the best opportunity for the patient to achieve the maximal level of postsurgical function and outcome.

Care Team Surgical Communication

Recommendation

13. Communication must occur between the surgical and non-surgical members of the care team in order to optimize surgical and functional outcomes. [EO]

Discussion

Although the primary goal of amputation is removal of the diseased, damaged, or dysfunctional portion of the limb, the surgery must also result in a residual limb that is optimized for motion, motion control, and proprioceptive feedback to achieve the most successful outcomes. In general, maximum preservation of length is desirable in the upper limb amputation. With increasing length and preservation of joints, the patient becomes more capable of positioning the residual limb and/or prosthetic device in space, allowing optimal functional result and leading to improved outcomes. There may be instances when preserving maximal limb length in an amputation would actually hinder functional outcomes with a prosthesis, thereby limiting functional independence. These should be thoroughly discussed with the surgeon and care team.

In a traumatic amputation, the scope of injury will often determine the level of amputation, while in cases of vascular disease, the level of amputation is often dictated by the amount of blood flow and tissue viability. However, it is important for the surgeon to understand the requirements and capabilities of available prostheses for each amputation level, allotransplantation and/or other evolving treatments, and direct opportunities for limb length preservation when available. (See Appendix F: Advantages and Disadvantages of Prostheses, Appendix G: Surgical Considerations, and Appendix H: Emerging Technology for further information.) Figure 2 provides generally accepted surgical guidelines and levels

of amputation; Appendix G provides greater detail of surgical considerations by level of amputation. (See Appendix G: Surgical Considerations.)

Figure 2. Surgical Levels and Considerations

Generally accepted surgical considerations and levels:

- Do not perform "guillotine" style amputation
- Complete the amputation within the zone of injury to maximize length
- Preserve at least 5cm of humerus length to preserve a transhumeral amputation level
- Preserve at least 5cm of ulnar length to preserve a transradial amputation
- Special consideration must be taken in cases of disarticulation at the elbow or wrist level, partial hand amputation, and with other complex or unusual cases
- Perform myodesis for all primary function muscles. Myoplasty and myofascial closure may be utilized to secure secondary muscles and to contour muscles for final amputation closure
- Skin grafts and dermal substitutes may be used to allow amputation closure, if a primary fasciocutaneous closure is not available

Patient Optimization for Rehabilitation

Recommendation

14. The care team should ensure that the patient is optimized for rehabilitation to enhance functional outcomes. [EO]

Discussion

The perioperative phase of care largely encompasses not only the surgical management but also the immediate post-surgical management plan through the acute inpatient rehabilitation care. As reviewed in the above section, all efforts in the surgical and post-surgical management are conducted to ensure optimal and functional patient outcomes outlined in the rehabilitation care plan. Residual limb length, pain management, wound care, joint and weight bearing limitations and other issues affect overall patient outcomes. Once the pre-operative and intraoperative management plan has been establish and the patient is recovering from amputation of the upper limb, there is a need to progress through a seamless transition through post-operative recovery.

Early and aggressive pain management with interventional, pharmacologic and non-pharmacologic methods can also expedite post-surgical recovery and advancement through the perioperative phase of care. (See Core 2: Pain Assessment and Core 3: Pain Management). Non-pharmacologic methods can include limb shaping with compressive socks and/or shrinkers, desensitization techniques, scar massage, mirror therapy, and other more conventional therapeutic pain relief modalities. These factors are important in minimizing duration of hospitalization and prevent further deconditioning.

An important factor that will determine optimal and ideal prosthesis acceptance is wound healing and wound management. Regardless of the patient's prognosis for prosthesis use, management of wound healing is essential to successful postoperative outcomes. If wound closure is not progressing or is not

been achieved, continued active management will be required by the surgeon and a specialized wound care team. (See Core 2: Residual Limb Assessment and Core 3: Residual Limb Management.)

The patient and the care team should be committed to a surgical plan for an amputation that results in the optimal limb length that provides the best opportunity to return lost function with and without the most appropriate prosthetic device(s). There are multiple conventional, custom and experimental designs for prosthetic limb options. (See Appendix F: Advantages and Disadvantages of Prostheses.) The care team should provide patient and family education about prosthetic options to help establish the evolving rehabilitation plan, patient centered goals and optimize functional outcomes.

In addition, the patient and care team should focus on comprehensive functional independence. (See Core 2: Level of Function.) This perioperative phase of care may be the initial moment when the care team assesses specific DME needs due to loss of function as a result of the loss of the upper limb. Furthermore, the care team will need to address and train the patient for ADL independence. This may involve new learning and training as it applies to single hand manipulation of ADL tasks as well as hand dominance training/re-training.

Other therapeutic activities and physical conditioning should be conducted to enhance cardiovascular health, musculoskeletal condition, upper body strengthening.

In the occurrences where hospital discharge is soon after the amputation, early emphasis on cardiovascular conditioning and upper body strength training may also prevent early onset of overuse injuries and medical comorbidities that commonly affect patients with an amputation.

Functional Independence without a Prosthesis

Recommendation

15. Following amputation, the care team should ensure that the patient has achieved his or her highest level of functional independence without a prosthesis. [EO]

Discussion

The perioperative phase of care sets the stage for the patient's functional independence and may impact quality of life and community integration. Historically, there is a lower patient satisfaction rate for upper limb prostheses and a high rejection rate. Although more research is needed to determine the factors that impact these facts, it also elucidates the need to address functional independence in the earliest phases of care.

As mentioned previously, early identification and provision of adaptive equipment, home modification and adaptive skills training to successfully complete ADL and IADL tasks will ensure rapid transition through the phases of care and promote early functional independence.

Functional and physical performance evaluations of the contralateral upper extremity are completed as appropriate for each patient to determine his or her baseline function. Typically, the intact upper limb will be responsible for performing all fine motor and dexterity tasks for vocational and leisure purposes. When appropriate, hand dominance retraining and one-handed techniques are ideally

initiated during the late perioperative or pre-prosthesis phases. This includes immediate introduction of the residual non-dominant extremity for basic self-care ADL, training in self-feeding, toileting, and oral hygiene (See Core 3: Rehabilitation Interventions).

Functional independence without the use of a prosthesis is commonly understood as the transition point and advancement of a patient to the next phase of care.

Pre-Prosthetic Phase

Pre-Prosthetic Training

Recommendation

16. The care team should ensure that patients undergo pre-prosthetic training to help determine the most appropriate type of device to achieve functional goals. [EO]

Discussion

The duration of the pre-prosthetic phase is dependent upon the affected limb's volume, sensitivity, range of motion, physical condition of the residual limb, presence of pain, and the patient's emotional and psychological status.

Though it is currently impossible to replace all of the lost functions of any part of the upper limb that has been amputated, it is possible for a patient to potentially restore a significant amount of function when prescribed an appropriate prosthesis. A patient's potential restored function depends on several factors including: [84]

- Adequate physical condition to wear and operate a prosthesis including:
    - Level of amputation
    - Condition of residual limb (i.e., skin integrity, sutures and staples removed)
    - Proximal joint and contralateral limb strength
    - Sensation
    - Range of motion (ROM)
    - Presence of multiple limb amputations
- Goals/motivations and willingness to move forward with prosthetic training
- Living conditions/social support
- Cognitive status and the ability to understand and apply knowledge to the fitting and use of a prosthesis
- Access to appropriate healthcare (with an experienced prosthetic team)
- Importance of cosmetic appearance and self-image
- Functional requirements
- Vocational requirements
- Financial coverage

Interventions started postoperatively by the care team continue during this phase and include wound care, controlling extremity volume with compression wrapping or shrinkers, desensitization training, and scar management. For those with transradial, or longer, amputations, initiating gradual weight-bearing on the residual limb during this phase may reduce residual and phantom pain and prepare the limb for prosthetic usage. [85]

A comprehensive assessment should be conducted by the care team to determine the most appropriate types of prostheses to prescribe. Education on the various types of available prostheses should be

provided to the patient and his or her family and/or caregiver(s) by the care team prior to the initiation of a prosthetic prescription. (See Appendix F: Advantages and Disadvantages of Prostheses.)

During the pre-prosthetic phase, preparatory training should be initiated as necessary depending on the type of prosthesis being considered for the patient. Powered prosthetic systems create less shear force and end-bearing forces on the residual extremity; hence, they can be used sooner post-amputation and allow for earlier fitting of a prosthesis. Patients can begin electrode site identification and training necessary for the operation of a myoelectric prosthesis even before the wound is closed. When considering a myoelectric prosthesis, the therapist and prosthetist work closely to identify the best possible electrode placement and the most effective control scheme for each patient's particular abilities and needs. The care team should also implement a program to test and train the patient's muscles for use of a myoelectric prosthetic device through single and dual channel activation as well as muscle pattern training (e.g., co-contraction, pattern recognition programming).

Potential users of body-powered prostheses must be instructed in the various body motions that will be utilized to control opening and closing the terminal device and/or operating the elbow, including its locking mechanism, if applicable (see Appendix I: Control Strategies for Body-Powered and Externally Powered Prostheses). The care team should develop and apply simulation tasks and challenge weight bearing tolerance through training the patient in the use of body-powered motions. Targeted muscle strengthening should begin at this time. These gross motions include: shoulder flexion, shoulder abduction, shoulder extension, scapular protraction, scapular retraction, scapular depression, and occasionally chest expansion with more proximal transhumeral or higher amputations.

Prosthesis Prescription

Recommendation

17. Once the appropriate type of prosthesis is identified, the care team should write a prescription for the device, including all necessary components. [EO]

Discussion

Prescriptions for upper extremity prostheses should be based on a collaborative decision between the patient and the care team. After the care team has conducted a pre-prosthetic assessment and all appropriate prosthetic options have been discussed with the patient, family and/or caregiver, a prescription for the appropriate upper limb prosthesis and pre-prosthetic training is written by the primary physician of the care team. A comprehensive prescription for an upper extremity prosthesis should include:

- Design (e.g., preparatory vs. definitive)
- Control strategy (e.g., passive, externally powered, body powered, task specific)
- The anatomical side and amputation level of the prosthesis
- Type of socket interface (e.g., soft insert, elastomer liner, flexible thermoplastic)
- Type of socket frame (e.g., thermoplastic or laminated)
- Suspension mechanism (e.g., harness, suction, anatomical)
- Terminal device (TD)

- Wrist unit (if applicable)
- Elbow unit (if applicable)
- Shoulder unit (if applicable)

Prescriptions for upper limb prostheses written with a standard format provide a clear reference to monitor compliance on the part of the rehabilitation team, including the prosthetist. This standard also provides information for future evidence-based research, including those that examine outcome measures. Utilizing a standard format will allow for a comparative analysis between successful and unsuccessful outcomes and, ultimately, identify key factors to fitting upper limb prostheses. In addition, this analysis may objectively help determine what, if any, predictive factors would inform the rehabilitation team on what type of design may work best for particular patients. The standard prescription also provides a "checks and balance" measure in the approval process for the third party payer of the device, whether the VA, DoD, or a private insurance provider.

Based on pre-prosthetic assessment and training, the care team may prescribe a preparatory prosthesis to allow the patient to experience various types of prosthetic components/controls (see Appendix J: Preparatory Prosthesis Recommendations) to determine the prescription of the definitive prosthesis. If a patient is only interested in a passive prosthesis, then it is not necessary to go through the process of utilizing a preparatory prosthesis, since the function of the device for dynamic use will be minimal.

The primary differences between the preparatory and definitive prostheses are the materials used to make the device. The preparatory prosthesis is made of lower cost, thermoplastic materials and utilizes components on a trial basis. The definitive prosthesis is made with sturdier, more expensive material, such as laminated fiberglass or carbon fiber, designed to endure several years of use, and features components that are purchased for the specific needs of the user. The definitive prosthesis may also include a custom or semi-custom outer skin, which is not part of a preparatory design. The preparatory and/or definitive prostheses should be prescribed by the care team physician after a successful trial of a preparatory prosthesis.

Prosthetic Fitting

Recommendation

18. Initiate upper extremity prosthetic fitting as soon as the patient can tolerate mild pressure on the residual limb. [EO]

Discussion

The most important aspects of a prosthesis are the achievement of an intimate fit and the associated comfort of the prosthetic socket. They are interrelated; without either, the prosthesis will ultimately be rejected or abandoned by the patient, negatively impacting their potential for improved function in various activities.

In order to best attain an optimal outcome relating to the fit and comfort of the final (definitive) prosthesis, fitting of a diagnostic socket is strongly encouraged. The socket design prescribed for the prosthesis requires anthropometric measurements and/or a negative impression or digital image of the

residual limb. Diagnostic sockets are made from inexpensive, clear, thermoplastic material and allow the prosthetist and patient the opportunity to monitor and test socket fit and comfort prior to fabricating a full prosthesis. Patients with recent amputations often require frequent modifications to the socket to accommodate residual limb volumetric changes. The residual limb must be fully mature and limb volume must be stable before fabricating a definitive socket. In some cases, such as a desire for a passive prosthesis, it may be possible to go directly from a successful diagnostic socket fitting to fabrication and fitting of a definitive prosthesis.

Prosthetic Training Phase

Prosthetic Training and Education

Recommendation

19. Upon delivery of the prescribed prosthesis, or change in the control scheme or componentry, the care team must engage the patient in prosthetic training and education. [EO]

Discussion

There is very limited clinical evidence regarding prosthetic training and most techniques are based on clinical judgment and expertise. [86] Despite this, there is a belief that lack of or poor training may be one of several contributing factors to the high rejection or disuse rates of upper extremity prostheses in patients with upper limb amputation. [59,87] The absence or insufficiency of training may be the result of rapid advances in prosthesis technology, limited expertise of the treatment team, or poor communication among providers, as well as between providers and patients, regarding device operation. [87,88] In a study of 44 upper extremity amputation patients using myoelectric prostheses, Silcox et al. found that prosthetic training had no influence in acceptance of a myoelectric prosthesis, but training did improve utilization of the device as compared to those who did not received training. [89] Resnik et al. identified the importance of clinician training prior to the provision of advanced technology prostheses. [87] Many studies that attempt to understand contributing factors related to prosthesis rejection have limited generalizability due to little use of standardized tools for comparison of data between subjects, [42] as well as variances in training techniques and the unique comorbidities that may exist in cases of trauma induced amputation.

As discussed earlier in this guideline, the opportunity to trial various socket interfaces and components with a preparatory prosthesis offers the patient an opportunity to explore capabilities during activities with different types of components (see Appendix J: Preparatory Prosthesis Recommendations). Ultimately, this leads to better decisions in component and design selection for the definitive prosthesis, and will also improve patient satisfaction and overall functional outcomes.

Trialing various components does not necessitate trialing of different types of prostheses. The patient should be proficient in using one type of prosthetic device, or demonstrate one to be inappropriate, before receiving training in use of an alternate prosthesis or exploring components of an alternate prosthesis. Simultaneous training/trialing of different types of prostheses (e.g., body-powered versus external powered) should not occur until the patient demonstrates competent control of at least one type of device. This minimizes the need for multiple fittings of the same, or new, interface with subsequent prostheses. This also provides the patient the opportunity to gain some experience with the prosthesis and what may be desired in an alternate device. This approach facilitates a more appropriate, cost-effective method to achieve the patient's personal goals.

Whether preparatory or definitive, once the prosthesis is fabricated, ready for use, and a prescription for training is completed, the prosthetist educates the patient, family/caregiver and rehabilitation providers on:

- The proper terminology related to the prosthesis and its parts
- Proper operation of the prosthesis
- The particular prosthetic control strategy utilized
- Functional and mechanical limitations of the prosthesis
- Any precautions related to the device
- Appropriate care of the prosthesis

This education serves to enhance communication, prevent personal injury while using the device, reduce user frustration, maximize the efficiency of the training sessions, and minimize or prevent any undue mechanical damage to prosthetic parts due to inappropriate use of the device, such as lifting weight beyond the maximal capacity of the components.

The importance of early prosthetic training of patients by an occupational or physical therapist, who specializes in rehabilitation after limb loss, cannot be understated. [68,88,90,91] Providing an initial prosthesis and sending the patient home to practice on his or her own, is not an adequate process for the patient to learn to fully use or accept the prosthesis. Prosthetic training should be provided within one to two days of fitting a patient with a new preparatory prosthesis or, in cases where a preparatory prosthesis was not fitted prior, a new definitive prosthesis. [67] If a new component, such as a new terminal device or replacement elbow unit, is required and prescribed for an existing prosthesis, there may be additional training required, but only if the component(s) has/have significantly different functional features than that of the patient's existing device. If any part of the control system is changed, formal training associated with this change is recommended to assess and assure safety with, and functional use of, the device.

The average length of prosthetic training for patients with below elbow amputation, and those with above elbow amputation was reported by Dakpa and Heger to be three to five weeks, respectively; however, the frequency and duration of visits was not identified. [88] Atkins reports that with one to two hours a day of instruction, a patient can obtain proficiency in controlling a prosthesis in approximately five hours with a transradial prosthesis, ten hours with a transhumeral level prosthesis, twelve hours for a patient with bilateral transradial prostheses, and twenty hours for a patient with bilateral transhumeral level prostheses. [90] Patients with more complex injuries or comorbid conditions may require more training time than these estimates.

The initial focus of prosthetic training is to cultivate successful experiences, manage patient expectations, and encourage future acceptance and use. [92] The care team provides education and training to the patient and care giver about methods to don and doff the device (if applicable), importance of daily residual limb inspections, daily care of the prosthesis and an appropriate progressive wear schedule. Prosthetic training begins with familiarization of components and learning to safely control and operate the device. For safety of the patient and those around them, the patient should master basic operation of the prosthesis prior to initiation of functional training.

Donning/doffing prosthesis

Early independence in putting on, and taking off, the entire prosthesis is an important goal for the patient to achieve. The prosthetic system may include: residual limb socks, prosthetic donning liner or sleeve, alcohol based lubricant gels or powder for donning, prosthetic socket and harnessing as appropriate. [68] As discussed by Smurr et al., commonly used methods to don and doff prosthesis with a harness include coat method and pull-over method. [68] There are various methods to don and doff a self-suspending prosthesis (i.e., harnessing not needed), such as use of lubricants, powder or donning sleeve.

When donning a myoelectric prosthesis, some designs may include use of a donning sleeve and vacuum versus suction seal. The sleeve is used to achieve proper alignment of the residual limb with the electrodes for prosthetic control. A vacuum versus suction seal is typically used for prosthetic suspension with elbow disarticulation or transhumeral prostheses because it creates suction or semi-suction fit of the prosthesis on the residual limb. Air is removed from the socket through the valve for suspension and is released when the valve is removed to take off the socket. For an individual with bilateral upper limb loss, donning and doffing methods vary based on level of amputation. Donning trees may be built and used to help the patient gain independence in this task.

Device wear schedule

It is imperative that the patient be educated in a proper prosthesis wear schedule after receiving the device. The schedule is progressive in nature to allow for gradual increase in residual limb tissue tolerance to the socket and weight of prosthesis. Initially the prosthesis should be worn for no more than 15 to 30 minutes, two to three times daily. [67,68]

The care team should provide education to the patient and/or caregiver about the signs and symptoms associated with poor residual limb tolerance and the importance of frequent, at least daily, residual limb inspection. After limb inspection, if no signs of poor fit are evident, the patient may increase the wearing time by 30-minute increments, two to three times daily. [67,68] Inspection of the residual limb should become part of the patient's daily routine even after he or she has progressed to all day wear and use of the prosthesis.

Poor residual limb tolerance to prosthesis may be a result of poor prosthetic fit or due a variety of other issues. If the residual limb soft tissue integrity is compromised, subsequent prosthesis wear and training is hindered. (See Core 3: Residual Limb Management.)

Residual limb management and care of prosthesis

The patient should receive training in proper residual limb hygiene (see Core 3: Residual Limb Management) and prosthetic care. The inside of the socket should be cleaned frequently using mild odorless soap, warm water and a damp towel. This should be followed by the use of a damp towel and clean warm water to wipe any excess soap from within the socket. The prosthesis should be air dried or dried using a towel. Rubbing alcohol may be used to clean the inside of the socket if an odor develops. Myoelectric prosthesis cannot be immersed in water as they are not water resistant. Residual limb socks should be washed using mild odorless soap and warm water and allowed to air dry. Cosmetic covers for

prosthesis stain easily and can be cleaned using a glove cleansing cream which is provided by the prosthetist.

Familiarization in components and demonstration of proper and safe use

For safety purposes it is recommended that the prosthesis remain in the rehabilitation clinic until the patient is able to independently demonstrate a clear understanding of the wear schedule, safe use of components, operational maintenance and care of the prosthesis, and proper management of the residual limb. Additionally, educating the patient and caregiver on proper component terminology facilitates communication with the care team regarding fit and function of the prosthesis and helps to empower the patient to take ownership of his or her new prosthesis. It is also important to provide written instructions regarding initial wear schedule, care, and limitations of the device when the patient takes it home.

Controls training

The goal of controls training is to teach the patient to successfully and correctly operate the prosthesis, minimize compensatory motions during use, and to grasp objects with the appropriate amount of force. [67,68] To do this, the patient must learn to operate the individual components of the prosthesis issued and to optimally preposition the prosthesis when possible to minimize compensatory body positions during use. Prepositioning involves manually or actively positioning the prosthesis prior to actually carrying out a task. Additionally, the patient should be taught about proportional control with body-powered and external power systems. Proportional control allows the patient to control the speed and force of a given movement by using the appropriate intensity (strength) and duration of a given input command. Good proportional control can be exemplified in activities which involve grasping delicate items using the terminal device (e.g., opening the terminal device just enough to grasp a Styrofoam cup with just enough force to avoid crushing or breaking the cup). Proportional control improves efficiency of use and reduces the likelihood of damage or harm during active grasp with a terminal device. Lastly, progressive proprioceptive training with the prosthesis should be incorporated as well. The therapist should utilize a hierarchical progression to train the patient in control of the prosthesis. (See Appendix K: Control Training for Body-Powered and Externally Powered Prosthetics.)

Functional training

Functional training aims to teach the patient to properly integrate use of the prosthesis to safely perform bimanual activities, maximize independence and reduce caregiver burden. Appendix E Table E-2 provides a sample list of functional bimanual ADL and IADL tasks to help guide the therapist and patient through functional prosthetic training sessions. (See Appendix E: Activities of Daily Living.) The prosthesis does not have to be used all the time; a functional patient may use the prosthesis for part of the day or only for certain activities, such as cooking.

The rehabilitation team should work closely with the patient, as they perform training tasks, to optimize all available functional features of the prosthesis within the mechanical limits of the device. The patient should be encouraged to optimize body mechanics during activity performance with and without use of prosthesis and explore alternative methods to perform necessary functional activities where body

mechanics are easily compromised to reduce the patient's potential of developing an overuse injury over the long-term.

Reassess Prosthetic Fit and Function

Recommendation

20. The care team should frequently reassess the patient's prosthetic fit and function throughout the prosthetic training phase and modify as appropriate. [EO]

Discussion

As a standard of practice, the care team should routinely re-assess functionality and ease of movement of the prosthesis. Appropriate modifications should be made as necessary to the device or adjustments should be made to the device prescription during the prosthetic training phase. (See Core 2: Prosthetic Assessment.) Patients who use a prosthesis should be advised to report any of the following symptoms as they are signs that the prosthesis needs to be modified:

- Ongoing pain in the residual limb or associated with a prosthetic harness
- Skin breakdown
- Change in the ability to don and doff the prosthesis
- Change in limb volume (weight gain or loss)
- Change in pattern of usage

The care team must monitor the patient's goal progression and function as changes in the patient's physical condition, social status, vocation, and/or technological advancements in prosthetic components, can influence changes in their fitting needs. Different components or types of prostheses should be considered to assist the patient in meeting functional goals. New goals may require changes to the design of an existing prosthesis, consideration of a different terminal device, or warrant the prescription of a completely new prosthesis.

Additionally, the care team must remain abreast of advancements in upper extremity prosthetic technology and maintain consistent long-term follow-up with the patient in order to provide ongoing assessment of the patient's needs and goals and provide appropriate guidance and treatment to achieve identified goals. [84]

Prosthesis Checkout

Recommendation

21. The final check out of the prosthesis should take place with appropriate members of the care team to verify that the prosthesis is acceptable. [EO]

Discussion

The definitive prosthesis should be prescribed by the care team physician after a successful trial of a preparatory prosthesis. A successful trial includes sound fit, comfort and use of the prosthesis, as determined by the patient, therapist and prosthetist. The residual limb must be fully mature and limb volume must be stable before fabricating a definitive socket. Stable limb volume is critical for use of

myoelectric devices because there must be an intimate fit between the residual limb and socket for operation. Myoelectric control signals will be adversely affected if the socket is too tight or becomes too loose due to changes in limb volume or soft tissue composition. The definitive prosthesis prescription should be given towards the completion of prosthetic training, and once specific prosthetic components have been identified as valuable by the patient and care team.

The final delivery of the definitive prosthesis should take place in the clinic setting, with the core amputation team present and in agreement that the prosthesis is acceptable. The team should include, at a minimum the patient, prescribing physician, prosthetist, occupational or physical therapist, and patient's family and/or caregiver, if applicable. Any written material related to the operation, function, safety guidelines, as well as the contact information of the care team members, should be reviewed and issued to the patient and family or caregiver, along with the prosthesis, during checkout and delivery of the definitive prosthesis. Additional prosthetic training may continue with the therapist, as needed after the definitive prosthesis is received by the patient.

Additional Prosthesis

Recommendation

22. The care team should offer active prosthesis users at least one back up device to ensure consistency with function. [EO]

Discussion

It is strongly advocated that the care team physician prescribe at least one back up prosthesis prior to discharge from training to any patient who uses upper extremity prostheses. This is particularly important for active and rugged users/wearers. The second prosthesis, in addition to serving a primary role in certain settings (if it is of a different design/type than the first prosthesis), can serve as an alternate device if the first prosthesis breaks down or requires maintenance. In some cases the primary device may require a simple repair that the prosthetist has trained the patient to perform. The patient may utilize the secondary prosthesis to perform the repairs, eliminating the need for a visit to the prosthetist's office. Other issues may require a visit to the prosthetist but can be repaired that same day, while the patient waits. Still, other problems, such as catastrophic component or material failure, may require complete overhauls to the interface or components, possibly leaving the patient without the device for days or weeks. Given these scenarios, it is essential that each patient has at least one additional prosthesis to ensure continued use in daily functional activities and quality of life, should such repairs be needed. [84,93]

Activity Specific Prosthesis

Recommendation

23. Prescription of activity specific or alternate design prostheses may be considered, dependent upon the patient's demonstration of commitment, motivation, and goals. [EO]

Discussion

There is no single prosthetic device that can replace all of the complex functions lost secondary to the amputation of any part of the hand or arm. Therefore, the prescription of multiple terminal devices and alternate prosthetic devices is recommended in cases where a patient is an active user of a prosthesis, or participates in activities that require specialty prosthesis for active participation. It is encouraged, whenever possible, to advocate for use of a multi-purpose terminal device, or a prosthesis which can easily be adapted for participation in multiple activities, rather than have a different prosthesis for each activity of interest. However, in various situations some patients may utilize more than one of type of upper limb prosthesis. For example, a patient may have a body-powered prosthesis used for gardening or heavy yard work and an externally powered myoelectric controlled prosthesis to perform light duty, work-related tasks. [84] The patient may also wish to participate in activities that require specialty devices. Some examples include: activities requiring waterproof components (e.g., swimming, kayaking), activities requiring enhanced durability (e.g., rock climbing, weightlifting), and activities requiring special grasping capabilities or specialized suspension systems (e.g., competitive sporting activities). In addition to enhanced function with the activity specific prosthesis, the patient's ability to participate in the particular activity or activities can improve psychosocial well-being. The design and fitting of an alternate prosthesis should be considered only after either of the following occurs:

- A satisfactory result has been achieved with the initial prosthesis. A satisfactory result means that the patient is proficient in using the particular type of prosthetic device they are trialing and has indicated realistic expectations and satisfaction with the function of the prosthesis.
- It is determined that a patient's existing prosthesis is inappropriate or ineffective in meeting the patient's particular activity goal(s).

Lifelong Care

Patient Transition

Recommendation

24. Upon completion of functional training, and to ensure continuity, the care team should coordinate patient transition into the lifelong care phase. [EO]

Discussion

The lifelong phase of care begins after the completion of acute rehabilitation or once the initial prosthetic fitting and functional prosthetic training is completed. Typically the patient has reached a desired level of function and stability from both a medical and rehabilitation perspective. This phase of care lasts for the remainder of the patient's life.

Lifelong follow-up care and services for a patient with upper limb amputation requires a dynamic process to ensure that the patient's needs are matched with the most appropriate technology, whether the patient is an active prosthetic user or not, to continue optimal function in the home and community. Advancements in medical science and prosthetic technology will continue for the patient's lifetime and the potential benefits of these advances for each patient should be reassessed by the care team on a routine basis.

Providers should recognize the importance of the follow-up assessment and the need to re-evaluate the patient's goals and, therefore, should engage the patient and significant others in shared decision making regarding long-term care and management. Healthcare professionals should provide patients with upper extremity amputations timely referrals as indicated for both the prevention and treatment of complications. Additionally, providers should be aware of the comorbid injuries (e.g., burns, fractures, TBI) that commonly coexist in patients with upper limb amputations and provide appropriate referrals and lifelong management for these conditions.

In addition to follow-up care in an amputation clinic, lifelong care must include primary care and referral to additional specialty services when needed. The transition from the DoD to the VHA system is usually complete by the beginning of the lifelong care phase, but ongoing interaction and collaboration with the patient's prior military healthcare providers should occur. The patient's medical needs will change as the patient ages and experiences lifestyle changes. While the patient with upper limb amputation may typically remain more stable in the lifelong care phase, these patients will continue to benefit from case management or involvement of a lead care coordinator regarding resources in the community and advancements in health care services.

Follow-up Contact

Recommendation

25. The care team should provide routine, scheduled follow-up contact for patients with upper extremity amputation at a minimum of every 12 months, regardless of prosthetic use or non-use. [EO]

Discussion

Currently, there are no clinical trials that provide direct evidence for the need for lifelong care or for the timing and frequency of follow-up care. However, based on expert clinical experience, patients should be encouraged to have access to ongoing primary care and an interdisciplinary amputation care team. Moreover, access to these services is imperative as the patient ages and experiences changes not only in body habitus but may also develop chronic disease(s) or exacerbations in chronic disease processes. Moreover, there is no research evidence to support the impact of routine clinical follow-up care, education programs, or interventions such as referral to specialty care on reducing morbidity and improving functional outcomes; however, there are many reasons to justify lifelong follow-up care, which include:

- The patient's medical condition will change over time (due to the aging process and internal and external factors) requiring new or modifications to existing medical care, rehabilitation and prosthetic services
- Comorbid conditions can appear or progress over time
- Without lifelong, routine specialty care contact, patients with upper extremity amputations can lose their functional independence
- Patients with amputations are at risk for secondary complications in the residual and non-amputated limb. The development of overuse syndromes and other painful musculoskeletal conditions frequently occurs in patients with upper limb amputations
- Patients with amputations are at risk of requiring revision surgery for the amputated extremity or amputation of other extremities
- The shape and volume of the amputated residual limb will change over the life of the patient. Long-term prosthetic use commonly results in complications such as skin breakdown and pain
- Prostheses have limited life spans and need to be evaluated on regular basis for needed repairs or replacement
- Patients may benefit from advances in technology or other treatment options as they become available.

All annual follow-up evaluations should include an assessment of the patient's medical history for existing or new medical conditions/complications. (see Appendix D: Essential Elements of the Annual Contact). Upper extremity amputation-related complications, including pain and skin issues, should be evaluated, treated, and provided follow-up as needed. Education regarding secondary amputation prevention should be provided and an assessment of risk factors performed and explained to the patient. [81] Further reevaluation of the patient's functional status, goals, and potential prosthetic abilities should also be included during the patient visits.

As part of the annual assessment it may be found that a prosthesis needs an update on components especially when new devices become available. Long-term prosthetic users may also choose to add additional functions to their prosthetic needs such as a change or update of a terminal device, additional sports- or work- related terminal devices, or change from body-powered to myoelectric or vice versa. Changing components in a prosthesis alters the function and feel of the device. Even though the patient may have long-term experience with prosthetic use, the differences in fit and function will require additional training to enhance acceptance and long-term use. Providing the patient with updated

training with new components will also enable the patient to obtain complete operational control of the device with the functional applications.

Persons who use an upper limb prosthesis will require an adjustment period to accommodate to the differences between the old and new devices. Ensuring that the patient receives training with a therapist is always necessary. Training enhances the adjustment process and enables a patient to optimize the improvements and function of the updated device. Prosthetic training for a previous user who is adjusting to a change in components may frequently be abbreviated. However, learning is patient dependent and may also take the same period of time as initial training, depending upon the complexity of the device and the changes that have been incorporated into the prosthesis.

Acceptance and function of upper extremity prostheses by the patient is always at risk. The risk for disuse or rejection is even greater if the patient does not have a good understanding of the operation and control of the prosthetic device. Moreover, change may frequently be difficult for some patients to accept. Thus these patients often return to using their old version of the prosthesis, which is more familiar in use, fit and function.

Patient Relocation

Recommendation

26. Upon notification of patient relocation to a new catchment area, the care team should communicate with the receiving care team and coordinate transition of patient care. [EO]

Discussion

Coordinated care remains a key to optimizing life after amputation for patients who relocate to a new area. Transitional care is the process that facilitates how patients are seamlessly moved from one type of care setting to another. The setting may be from a more complex system to a less complex system (or vice versa). Transitional care planning ensures that the patient is part of the process and receives seamless continuity of care. The hand-off is a tool utilized to transfer the patients care from one healthcare provider, team, or setting to another. Transitional planning has been mandated by the Centers for Medicare and Medicaid Services (CMS), The Joint Commission (TJC) and other federal agencies as the standard of care. [94]

The care team should initiate the warm hand-off to the receiving facility when they learn of a patient's intent to move to the catchment area of another amputation care team. Certainly, this process is fostered by open communication and familiarity with the patient and the willingness to share such intent with the care team. The hand-off ensures that potential barriers to care (e.g., physical environment, family, time, and transportation) are averted by ensuring successful planning and communication between the releasing and receiving member(s) of the care team or facility. [95] The actual hand-off should occur as close as possible to the patient's actual discharge from the leaving facility and subsequent enrollment at the receiving facility. For the benefit of patient and care team alike, a discrete date of discharge should be identified and established, after which the sending facility is no longer responsible for coordination or provision of routine care of the patient.

The initial comprehensive assessment at each transition of care is critical if the receiving new care team is to effectively assume the care of the patient. An initial comprehensive assessment is designed for the new team to become familiar with the patient. Done properly, the assessment should identify strengths, capacities, and resources of the patient and juxtapose them against weaknesses, challenges and needs. It includes evaluation of several realms of a patient's experience: physical, mental, emotional, prosthetic, pain, environmental, relational (particularly as it relates to systems of support outside of the amputation care team), changes in functional goals, as well as a variety of other needs. Naturally, many of these components may change with a move from one catchment area to another. A change in physical or mental function, resources, or relational issues may have precipitated the move. Conversely, those or other realms—social supports, environmental concerns, and others—necessarily change as a result of a move. Without a fresh comprehensive assessment, changes cannot be identified and addressed, possibly setting the patient up for failure in their new environment.

While all members of the care team are vital to the successful transition of the patient, case managers provide a collaborative expertise that assesses, plans, implements, coordinates, monitors and evaluates options and services to meet the patient's unique upper limb care needs. Case managers ensure that hand-offs are successfully completed during transitional care planning. [94]

Offering Education on Rehabilitation Advancements

Recommendation

27. The care team should provide education to the patient, family and caregiver(s) regarding advancements in technology, surgical and rehabilitation procedures related to the management of upper extremity amputation. [EO]

Discussion

The evolution of the upper limb prosthesis has not progressed with the speed or success of lower extremity prostheses. However, advances are now starting to be apparent in the mechanical properties, control and attachment of the upper extremity prosthesis. In addition, hand and arm transplantation offers an alternative, but is not yet ready for widespread use due to the risks involved.

The care team needs to remain current on the changes that are occurring within the field of upper limb amputation technology and procedures in order to provide the patient with the best possible options. Clinician and patient goals will help to determine the possibilities available to assist in attaining the best functional outcomes and quality of life.

According to Biddess & Chau, prosthetic technology played a significant role in limb abandonment. [42] Patients who reject a prosthesis were less satisfied with all aspects of prosthetic design including appearance, comfort, function, ease of control, reliability and cost. Excessive weight and heat were concerns for both prosthetic wearers and rejecters who reported that they were more functional and comfortable without the prosthesis. [42]

This research demonstrates the need for treating clinicians to remain current on the state-of-the-art technology and updated procedures so that they can provide patients with all the options available to

them. This study confirmed that patients want and need to be involved in selecting their prosthesis based on their goals, and this continues into the lifelong care phase. [42] As new technology and procedures develop, patients should be reevaluated to see if their needs and goals have changed. (See Appendix H: Emerging Technology for emerging technology available at the writing of this document.)

Future Research

Due to the paucity of research in the areas pertaining to upper limb amputation, efforts should be made to standardize and collect treatment and outcomes data across both the VA and the DoD in order to conduct practice-based evidence and comparative effectiveness studies. Moreover, a need exists for enhanced data infrastructure within our current systems to enable this type of health services research.

Although not an exhaustive list, the panel also recommends that research be conducted to address the following specific questions:

- How much, and what type of training is required for clinicians to optimally treat patients with upper limb loss?
- What are the ideal pain management strategies to minimize pain and maximize function in patients with upper limb loss throughout the rehabilitation process?
- What are the effects of recreational activities on self-image and long-term quality of life for patients with upper limb loss?
- What pre-prosthetic exercise protocols are most effective to prepare patients with upper limb loss to use prosthetic devices (body-powered, myoelectric, hybrid, or cosmetic)?
- What is the optimal time period in which pre-prosthetic training should be initiated and does the time between amputation and the first prosthesis fit and training have an effect on the acceptance and use of a definitive prosthesis with patients with upper limb loss?
- What factors of training (e.g., timing, intensity, frequency, etc.) are associated with use or abandonment of prosthesis with patients with upper limb loss?
- What prosthetic factors (cosmesis, weight, ease of use of terminal devices, etc.) are associated with use or abandonment of prosthesis with patients with upper limb loss?
- Which myoelectric and body-powered prosthesis components (wrist rotator, harnessing system) and terminal devices are associated with the best functional outcomes (with each type of available prosthesis – body-powered or myoelectric) with patients with upper limb loss?
- In the long-term management of persons with upper limb loss, do routine clinical follow-up, education programs, and intervention such as referral to specialty care for comorbid injuries and conditions reduce morbidity and improve functional outcomes.
- Following upper limb loss, what are the factors associated with successful, long-term prosthetic use (1, 3 and 5 years after discharge)?
- Following upper limb loss, what are the best strategies for improving long-term functional outcomes and successful community and vocational reintegration?
- What is the impact of advances in technology and treatment advances such as limb transplant, targeted muscle reinnervation, and osseo-integration on the long-term functional outcomes of individuals following upper limb loss?

Appendix A: Guideline Development Process

Introduction

The methodology used in the development of the Rehabilitation Management for Upper Extremity Amputation (UEAR) Clinical Practice Guideline (CPG) (Version 1.0 - 2014) follows the *Guideline for Guidelines*, an internal working document of the Veterans Health Administration (VHA) and Department of Defense (DoD) Evidence-based Practice Working Group (EBPWG). [5] This document provides information regarding the process of developing guidelines, including the identification and assembly of the Guideline Champions (Champions) and other subject matter experts from within the VA and DoD, known as the Work Group, and ultimately, the submission of a new CPG.

The Champions and Work Group members for this CPG were charged with developing evidence-based clinical practice recommendations and publishing a guideline document to be used by providers within the VA/DoD healthcare system. Specifically, the Champions for this CPG were responsible for identifying the key evidence questions of greatest clinical relevance, importance, and interest for rehabilitation of a patient with an upper extremity amputation. In addition, Champions assisted in:

- Conducting the evidence review, including providing direction on inclusion and exclusion criteria
- Assessing the level and quality of the evidence
- Identifying appropriate disciplines to be included as part of the Work Group
- Directing and coordinating the Work Group
- Participating throughout the guideline development and review processes

The VA Office of Quality, Safety and Value, in collaboration with the Medical Center Command of the DoD, identified five clinical leaders as Champions for the 2014 UEAR CPG. The Lewin Group (Lewin) and their sub-contractors ECRI Institute and Duty First Consulting, held the first conference call for this Guideline in October 2012, with participation from the contracting officer's representatives (COR), leaders from the VA and DoD evidence-based guideline development program, and the Champions. During this call, the project team discussed the scope of the guideline initiative, the roles and responsibilities of the Champions, the project timeline, and the approach for developing evidence questions for a systematic review on the management of UEAR. During this call, the team also identified a list, from which the Work Group members were recruited, of clinical specialties and areas of expertise that are important and relevant to UEAR. The specialty areas included were dietetics, family practice, behavioral health, internal medicine, nursing, occupational therapy, orthopedics, prothestists, pharmacy, physical therapy and primary care.

Methodology

The evidence review and synthesis portion of the guideline development process for the 2014 VA/DoD UEAR CPG consisted of the following steps:

1. Formulating evidence questions (key questions)
2. Conducting a systematic review of the literature
3. Convening a three and a half day face–to-face meeting with the CPG Champions and Work Group members

4. Drafting and submitting a final CPG on rehabilitation management for upper extremity amputation to the VA/DoD EBPWG

The following is a detailed description of each of these steps.

Key Question Formulation

The CPG Champions were tasked with identifying key evidence questions to guide the systematic review of the literature on rehabilitation management of upper extremity amputation. These questions, which were developed in consultation with Lewin and ECRI Institute, addressed clinical topics of the highest priority for VA and DoD populations regarding UEAR. The key questions follow the population, intervention, comparison, outcome, timing and setting (PICOTS) framework for evidence questions, as established by the Agency for Healthcare Research and Quality (AHRQ). [96] Table A-1 provides a brief overview of the PICOTS typology.

Table A-1. PICOTS Framework [96]

P	Patients, Population or Problem	A description of the patients of interest. It includes the condition(s), populations or sub-populations, disease severity or stage, comorbidities, and other patient characteristics or demographics.
I	Intervention or Exposure	Refers to the specific treatments or approaches used with the patient or population. It includes doses, frequency, methods of administering treatments, etc.
C	Comparison	Describes the interventions or care that is being compared with the intervention(s) of interest described above. It includes alternatives such as placebo, drugs, surgery, lifestyle changes, standard of care, etc.
O	Outcome	Describes the specific results of interest. Outcomes can include short, intermediate, and long-term outcomes, or specific results such as quality of life, complications, mortality, morbidity, etc.
(T)	Timing, if applicable	Describes the duration of time that is of interest for the particular patient outcome, benefit, or harm to occur (or not occur).
(S)	Setting, of applicable	Describes the setting or context of interest. Setting can be a location (such as primary, specialty, or inpatient care).

The Champions and evidence review team carried out several iterations of this process, each time narrowing the scope of the CPG and the literature review by prioritizing the topics of interest. Table A-2 contains the final set of key questions used to guide the systematic review for this CPG.

Table A-2. Key Evidence Questions for the UEAR CPG

Key Evidence Questions	
Perioperative Phase	
1.	What factors used to determine elective amputation level (i.e., limb length consideration, myoplasty vs. myodesis, nerve function, skin integrity etc.) and perioperative exercises are associated with maximal functional outcome, with or without prosthesis?
Postoperative Phase	
2.	In adults with UE amputations, what are the most effective strategies to treat postoperative, phantom and residual limb pain?

Key Evidence Questions
3. In adults with UE amputations, do those who receive immediate post-op peer visits (others with amputations) have better functional outcomes than those who do not?
Pre-Prosthetic Training Phase
4. In adults with UE amputations, what pre-prosthetic rehabilitation protocols are most effective to improve patient function with ADL (i.e., dressing, bathing, grooming, toileting, hygiene, and eating) without the use of a prosthesis?
5. In adults with UE amputations, what pre-prosthetic exercise protocols are most effective to prepare a patient to use an upper extremity prosthesis (body-powered, myoelectric, hybrid, or cosmetic)?
6. In adults with UE amputations, what adaptive equipment or assistive devices maximize independence with ADL i.e., dressing, bathing, grooming, toileting, hygiene, and eating) without use of a prosthetic in the short-term (i.e., after amputation but before receiving prosthesis)?
7. In adults with UE amputations, what is the optimal time period in which pre-prosthetic training should be initiated? Is the "golden window" really true?
8. In adults with UE amputations, does the time between amputation and the first prosthesis fit and training have an effect on the acceptance and use of a definitive prosthesis?
Prosthetic Training Phase
9. In adults with UE amputations, which device (body-powered, myoelectric) should an individual be trained on first and how does this affect training of next device?
10. In adults with UE amputations, what factors of training (e.g., timing, intensity, frequency, etc.) are associated with use or abandonment of prosthesis?
11. In adults with UE amputations, is type of prosthesis originally trained on associated with use versus abandonment of newer prosthesis?
12. In adults with UE amputations, what prosthetic factors (cosmesis, weight, ease of use of terminal devices, etc.) are associated with use or abandonment of prosthesis?
13. In adults with UE amputations, what patient characteristics (age, marital status, education level, dominant hand v. non-dominant hand) are associated with use or abandonment of prosthesis?
14. In adults with UE amputations, which myoelectric and body-powered prosthesis components (wrist rotator, harnessing system) and terminal devices (Grieffer, sensor hand, electric terminal device, or ilimb and all are not compatible) are associated with the best functional outcomes (with each type of available prosthesis – body-powered or myoelectric)?
Lifelong Care Phase
15. In the long-term management of persons following upper extremity amputation, do routine clinical follow-up, education programs, and intervention such as referral to specialty care for comorbid injuries and conditions reduce morbidity and improve functional outcomes?
16. Following upper extremity amputation, what are the factors associated with successful, long-term prosthetic use (1, 3 and 5 years after discharge)?
17. Following upper extremity amputation, what are the best strategies for improving long-term functional outcomes and successful community and vocational reintegration?
18. Following upper extremity amputation, does long-term rehabilitation therapy maintain functional abilities and improve independence in ADL compared to no therapy services?
19. What is the impact of advances in technology and treatment advances such as limb transplant, targeted muscle reinnervation, and osseo-integration on the long-term functional outcomes of individuals following upper extremity amputation?

Systematic Review Methodology

The methods guiding this systematic review are described below. In part, these methods follow the guidelines for conducting a systematic review set forth by the AHRQ in the *Methods Guide for Effectiveness and Comparative Effectiveness Reviews*. [97] The methods also follow the guidance set forth by the VA/DoD *Guideline for Guidelines* document. [5] The systematic review of the literature consisted of several distinct steps, including:

1. Defining the inclusion and exclusion search criteria
2. Developing a search strategy (i.e., search logic using MeSH (Medical Subject Headings) terminology and key words)
3. Screening the results based on abstracts and titles (i.e., identifying relevant studies and excluding duplicate records)
4. Reviewing the full text of remaining studies and abstracting relevant data points (i.e., population, comparator, results, etc.)
5. Assessing the internal and external validity of abstracted studies
6. Summarizing the evidence
7. Interpreting the results

Criteria for Study Inclusion/Exclusion

The inclusion and exclusion criteria are described in detail below.

Inclusion criteria

- Clinical studies published on or after January 1, 2002, and systematic reviews published on or after January 1, 2007
- All studies must be published in English
- Abstracts were not included. Similarly, letters, editorials, and other publications that were not full-length, clinical studies were not accepted as evidence
- All studies must have enrolled at least 1 upper extremity amputee
- All studies must have enrolled adults 18 years or older. In studies that mixed adults and children, at least 85 percent of the enrolled patients must have been 18 years or older

Exclusion criteria

- Studies that enrolled only able-bodied participants
- Technical studies that did not include patients with an amputation or report on patient outcomes

Search Strategies

The search strategies listed in Tables A-3 and A-4 were used to capture studies pertaining to all of the Key Questions for this report. Search sets were arranged into broad subject groups pertaining to amputation site, prosthesis design, treatment stage, activities of daily living, demographic variables, rehabilitation, and pain control, among other concepts. These search results were further refined to capture specific patient outcomes, study designs, publication types, and to exclude out-of-scope citations. The strategies are presented in OVID syntax and were used to search EMBASE, Medline, and PsycINFO. Similar strategies were used to search PubMed, CINAHL and ancillary databases.

Table A-3. Topic-specific Search Terms

Concept	Controlled Vocabulary	Keywords
Patient Population		
Upper Extremity Sites	**MeSH** arm arm injuries	arm arms elbow*

Concept	Controlled Vocabulary	Keywords
	elbow elbow injuries finger finger injuries forearm forearm injuries hand hand injuries upper extremity wrist wrist injuries **EMBASE** arm injury elbow injury finger injury fingers hand injury thumb injury wrist injury **PsycINFO** arm (anatomy elbow (anatomy) fingers (anatomy) hand (anatomy) shoulder (anatomy) thumb	finger* forearm* hand hands phalang* phalanx shoulder* thumb* upper extrem* upper limb* wrist*
Amputation Categories	**MeSH** amputation amputation stumps amputation, traumatic amputees **EMBASE** amputation stump limb amputation traumatic amputation	amputation level* bone lengthening elective amput* arm shaping hand shaping limb shaping
Amputation Sites	**EMBASE** arm amputation finger amputation hand amputation thumb amputation	amputat* amputee*
Artificial Limbs/Prosthetics	**MeSH** artificial limbs **EMBASE** arm prosthesis elbow prosthesis electric limb prosthesis	artificial* myoelectric prosthes* prosthetic* robot*

Concept	Controlled Vocabulary	Keywords
	hand prosthesis limb prosthesis shoulder prosthesis **PsycINFO** prostheses	
Prosthetic Concepts/Technologies	**MeSH** *artificial intelligence *bioelectric energy sources *biomechanics *biomedical engineering *bionics *brain mapping *electric stimulation *electromyography *electrophysiological phenomena *feedback, sensory *human engineering *man-machine systems *neural networks, computer *neurofeedback *signal processing, computer-assisted *user computer interface **EMBASE** *computer assisted therapy *computer simulation *electrodes *electromyography *electrotactile stimulation *functional electrical stimulation *grip strength *hand grip *hand strength *innervation *myoelectric control *myoelectricity *nerve stimulation *pinch strength *robotics *sensor *signal processing **PsycINFO** *human information storage *neural development *neural networks *neurorehabilitation *sensory feedback *technology	biomechan* body-powered body powered cosmesis cosmetic* "ease of use" externally-powered externally powered force grasp* grieffer grip* harness* innervat* myoelectric* nerve* neurointegrat* osseointegrat* pinch* reinnervat* rotator sensor* terminal* strength torque weigh*

Concept	Controlled Vocabulary	Keywords
	*virtual reality	
Stages of Treatment	**MeSH** *continuity of care *counseling *patient education as topic *postoperative care *preoperative counseling *preoperative period *patient acceptance of health care *time *time factors **EMBASE** *follow up *long term care *patient counseling *patient education *preoperative care *preoperative education *preoperative evaluation *preoperative period *preoperative treatment **PsycINFO** *aftercare *client education *posttreatment followup	after-care after care follow-up followup frequen* intensity interval* post-operative postoperative post-surgical postsurgical pre-implant preimplant* pre-operative preoperative pre-prosthetic preprosthetic pre-surgical presurgical timing treatment stage* window
Activities of Daily Living/ Recovery/ Reintegration Treatment Outcomes/	**MeSH** *activities of daily living *adaptation psychological *automobile driving *cost of illness *eating *health expenditures *health status *independent living *longterm care *mentors *outcome assessment (health care) *patient acceptance of health care *patient satisfaction *postoperative complications *prognosis *quality of life *recovery of function *“referral and consultation” *self care *self concept	adaptive assistive device* eat eating equipment bathe bathing dressing grooming hygiene instrument* product* self-help self help technolog* toileting peer* wounded warrior*

Concept	Controlled Vocabulary	Keywords
	*self-help devices *social adjustment *social participation *treatment outcome **EMBASE** *assistive technology device *body image *car driving *daily life activity *driving ability *employment *functional assessment *long-term care *outcome *patient satisfaction *postoperative complication *prognosis *"quality of life" *social adaptation *technical aid **PsycINFO** *adaptation *assistive technology *client attitudes *client satisfaction *community care *community reintegration *coping behavior *happiness *hygiene *life satisfaction *medical therapeutic devices *mental health *mentor *occupational guidance *peer relations *peers *quality of care *quality of life *physical health *physical mobility *psychosocial readjustment *psychosocial rehabilitation *resilience (psychological) *self care *well being *social adjustment	

Concept	Controlled Vocabulary	Keywords
	*social integration *social support *vocational guidance *vocational rehabilitation	
Rehabilitation/Restorative Therapies	**MeSH** *biofeedback, psychology *desensitization *drug therapies *electric stimulation *exercise *exercise movement techniques *exercise therapy *hot temperature *massage *occupational therapy *"physical education and training" *physical exertion *physical therapy modalities *range of motion, articular *recreation therapy *rehabilitation *rehabilitation centers *rehabilitation nursing *rehabilitation, vocational *transcutaneous electric nerve stimulation *sensation/physiology **EMBASE** *cryotherapy *desensitization *feedback system *hyperthermic therapy *mirror therapy *kinesiotherapy *occupational therapy *physical activity *physiotherapy *range of motion *recreational therapy *rehabilitation care *rehabilitation center *rehabilitation medicine *rehabilitation patient *relaxation training *skin care *transcutaneous nerve stimulation	trunk flexibility

Concept	Controlled Vocabulary	Keywords
	PsycINFO *biofeedback *electrical stimulation *physical treatment methods *relaxation *relaxation therapy *systematic desensitization therapy *training	
Phantom Limb/Mirror Therapy	**MeSH** mirror therapy phantom limb **EMBASE** phantom pain **PsycINFO** phantom limbs	mirror* phantom*
Pain	**MeSH** pain pain management pain, postoperative **EMBASE** battle injury blast injury intractable pain limb pain missile wound phantom pain **PsycINFO** chronic pain neuropathic pain pain pain perception	
Demographic Variables	**MeSH** *age factors *age groups *confounding factors (epidemiology) *demography *educational status *epidemiology *marital status *sex *sex factors **EMBASE** *epidemiology *gender *"gender and sex" *gender identity	

Concept	Controlled Vocabulary	Keywords
	*groups by age *marriage *race *race difference **PsycINFO** *chronological age *client characteristics *demographic characteristics *educational attainment level *educational background *epidemiology *gender identity	
Prosthesis Abandonment/Selected Variables	**MeSH** comorbidity cumulative trauma disorders depression dermatitis edema functional laterality lost to follow up mood disorders patient compliance posture referral and consultation refusal to treat retention (psychology) transfer (psychology) treatment refusal withholding treatment **EMBASE** body posture cumulative trauma disorder hemispheric dominance mood disorder neuroma treatment refusal	prosthe* abandon* skin care skin integrity
Transplantation/Replantation	**MeSH** replantation transplantation transplantation, autologous **EMBASE** reimplantation	reimplant* re-plant* replant* transplant* free-floating subheading transplantation
Exclusions		**Publication Types** addresses authored book autobiography

Concept	Controlled Vocabulary	Keywords
		bibliography biography book book series case case reports conference abstract conference paper conference proceeding case reports clinical conference collected works comment congresses consensus development conference consensus development conference, nih dictionary directory duplicate publication editorial erratum government publications in vitro interactive tutorial interview lectures letter news periodical index note published erratum reference book retracted publication report retraction of publication short survey video-audio media webcasts

OVID Conventions

* (within or following a term) = truncation character (wildcard)

* (preceding a term) = denotes major category focus/major MeSH

.ab. = limit to abstract

ADJ*n* = search terms within a specified number (*n*) of words from each other in any order

exp/ = "explodes" controlled vocabulary term (e.g., expands search to all more specific related terms in the vocabulary's hierarchy)

.de. = limit controlled vocabulary heading

.fs. = floating subheading
.hw. = limit to heading word
.mp. = combined search fields (default if no fields are specified)
.pt. = publication type
.ti. = limit to title
.tw. = limit to title and abstract fields

Table A-4. Search Strategies Conducted using EMBASE/MEDLINE/PsycINFO OVID Syntax

Set #	Concept	Search Statement
1	**Upper Extremity Sites**	arm/ or "arm (anatomy)"/ or arm injuries/ or arm injury/ or elbow/ or "elbow (anatomy)"/ or elbow injuries/ or elbow injury/ or finger/ or "fingers (anatomy)"/ or finger injuries/ or finger injury/ or fingers/ or forearm/ or forearm injuries/ or hand/ or "hand (anatomy)"/ or hand injuries/ or hand injury/ or shoulder/ or "shoulder (anatomy)"/ or shoulder injuries/ or shoulder injury/ or thumb/ or thumb injury/ or upper extremity/ or wrist/ or wrist injuries/ or wrist injury/
2	**Amputation Categories**	amputation/ or amputation stump/ or amputation stumps/ or amputation, traumatic/ or amputees/ or limb amputation/ or traumatic amputation/ or (amputation level*or bone lengthening or elective amput* or arm shaping or hand shaping or limb shaping).ti,ab.
3	**Amputation Sites**	arm amputation/ or finger amputation/ or hand amputation/ or thumb amputation/
4	**Artificial Limbs/Prosthetics**	arm prosthesis/ or artificial limbs/ or elbow prosthesis/ or electric limb prosthesis/ or hand prosthesis/ or limb prosthesis/ or shoulder prosthesis/
5	**Upper Extremity/ Amputation/Prosthetic Keyword Combinations**	((arm or arms or elbow* or finger* or forearm* or hand or hands or phalang* or phalanx or shoulder* or thumb* or upper extrem* or upper limb* or wrist*) and (amputat* or amputee* or artificial or myoelectric* or prosthetic* or prosthes* or robot*)).ti.
6	**Prosthetic Concepts/ Technologies**	*artificial intelligence/ or *bioelectric energy sources/ or *biomechanics/ or *biomedical engineering/ or *bionics/ or *brain mapping/ or *computer assisted therapy/ or *computer simulation/ or *electric stimulation/ or *electrodes/ or *electromyography/ or *electrophysiological phenomena/ or *electrotactile stimulation/ or *functional electrical stimulation/ or *feedback, sensory/ or *grip strength/ or *hand grip/ or *hand strength/ or *human *engineering/ or *human information storage/ or *innervation/ or *man-machine systems/ or *myoelectric control/ or *myoelectricity/ or *nerve stimulation/ or *neural development/ or *neural networks/ or *neural networks, computer/ or *neurofeedback/ or *neurorehabilitation/ or *pinch strength/ or *robotics/ or *sensor/ or *sensory feedback/ or *signal processing/ or *signal processing, computer-assisted/ or *user-computer interface/ or *virtual reality/ or (biomechan* or body-powered or body powered or cosmesis or cosmetic* or "ease of use" or externally-powered or externally powered or force or grasp* or grieffer or grip* or harness* or innervat* or myoelectric* or nerve* or neurointegrat* or osseointegrat* or pinch* or reinnervat* or rotator or sensor* or strength or terminal* or torque or weigh*).ti,ab.

Set #	Concept	Search Statement
7	**Stages of Treatment**	*aftercare/ or *client education/ or *continuity of care/ or *follow up/ or *long term care/ or *longterm care/ or *patient discharge education/ or *patient education/ or *postoperative care/ or *postoperative period/ or *posttreatment followup/ or *preoperative care/ or *preoperative counseling/ or *preoperative education/ or *preoperative evaluation/ or *preoperative period/ or *preoperative treatment/ or *time/ or *time factors/ or (after-care or after care or follow-up or followup or frequen* or intensity or interval* or post-operative or postoperative or post-surgical or postsurgical or pre-implant or preimplant* or pre-operative or preoperative or pre-prosthetic or preprosthetic or pre-surgical or presurgical or timing or treatment stage* or window).ti,ab.
8	**Activities of Daily Living/ Recovery/Reintegration Treatment Outcomes/**	((*activities of daily living/ or *adaptation/ or adaptation, psychological/ or *assistive technology/ or *assistive technology device/ or *automobile driving/ or *body image/ or *car driving/ or *client attitudes/ or *client satisfaction/ or *community care/ or *community integration/ or *community reintegration/ or *coping behavior/ or *cost of illness/ or *happiness/ or *daily life activity/ or *driving ability/ or *eating/ or *employment/ or *functional assessment/ or *happiness/ or *health status/ or *hygiene/ or *independent living/ or *life satisfaction/ or *long term care/ or *longterm care/ or *medical therapeutic devices/ or *mental health/ or *mentor/ or *mentors/ or *occupational guidance/ or *outcome/ or *"outcome assessment (health care)"/ or *patient acceptance of health care/ or *patient satisfaction/ or *peer relations/ or *peers/ or *physical health/ or *physical mobility/ or *postoperative complications/ or *prognosis/ or *"referral and consultation"/ or *psychosocial readjustment/ or *psychosocial rehabilitation/ or *quality of care/ or *quality of life/ or *recovery of function/ or *"resilience (psychological)"/ or *self care/ or *self concept/ or *self-help devices/ or *social adaptation/ or *social adjustment/ or *social integration/ or *social participation/ or *social support/ or *technical aid/ or *treatment outcome/ or *vocational education/ or *vocational guidance/ or *vocational rehabilitation/ or *well being/ or (eat or eating or bathe or bathing or dressing or grooming or hygiene or toileting or wounded warrior* or ((assistive or adaptive or self-help or self help) adj2 (device* or equipment or instrument* or product* or technolog*))).ti.
9	**Rehabilitation/ Restorative Therapies**	*biofeedback/ or *biofeedback, psychology/ or cryotherapy/ or *desensitization/ or *desensitization, psychologic/ or *drug therapy/ or *electric stimulation/ or *exercise/ or *exercise movement techniques/ or *exercise therapy/ or *feedback system/ or *hot temperature/ or *hyperthermic therapy/ or *kinesiotherapy/ or *massage/ or *occupational therapy/ or *physical activity/ or *"physical education and training"/ or *physical exertion/ or *physical therapy modalities/ or *physical treatment methods/ or

Set #	Concept	Search Statement
		*physiotherapy/ or *range of motion/ or *range of motion, articular/ or *recreation therapy/ or *recreational therapy/ or *rehabilitation/ or *rehabilitation care/ or *rehabilitation center/ or *rehabilitation centers/ or *rehabilitation medicine/ or *rehabilitation nursing/ or *relaxation/ or *relaxation therapy/ or *relaxation training/ or *rehabilitation patient/ or *rehabilitation, vocational/ or *relaxation therapy/ or *skin care/ or *systematic desensitization therapy/ or *training/ or *transcutaneous electric nerve stimulation/ or *transcutaneous nerve stimulation/ or (trunk flexibility).ti,ab.
10	**Phantom Limb/Mirror Therapy**	mirror therapy/ or phantom limb/ or phantom limbs/ or phantom pain/ or (phantom limb or phantom pain).ti.
11	**Pain and Injury**	battle injury/ or blast injury/ or chronic pain/ or intractable pain/ or limb pain/ or missile wound/ or neuropathic pain/ or pain/ or pain management/ or pain perception/ or pain, postoperative/ or phantom pain/
12	**Demographic Variables**	*age factors/ or *age groups/ or *chronological age/ or *client characteristics/ or *"confounding factors (epidemiology)"/ or *demographic characteristics/ or *demography/ or *educational attainment level/ or *educational background/ or *educational status/ or *epidemiology/ or *gender/ or *gender identity/ or *"gender and sex"/ or *gender identity/ or *groups by age/ or *marital status/ or *marriage/ or *race/ or *race difference/ or *sex/ or *sex factors/
13	**Prosthesis Abandonment/ Selected Outcomes**	body posture/ or comorbidity/ or cumulative trauma disorder/ or cumulative trauma disorders/ or depression/ or dermatitis/ or edema/ or functional laterality/ or hemispheric dominance/ or lost to follow up/ or mood disorder/ or mood disorders/ or neuroma/ or patient compliance/ or posture/ or prosthesis failure/ or refusal to treat/ or *"referral and consultation"/ or "retention (psychology)"/ or "transfer (psychology)"/ or treatment refusal/ or withholding treatment/ or (prosthe* abandon* or skin care or skin integrity).mp.
14	**Transplantation/ Replantation**	transplantation/ or transplantation, autologous/ or replantation/ or reimplantation/ or (transplant* or replant* or reimplant* or re-plant* or reimplant*).ti,ab. OR tr.fs
15	**Selected Study Designs/ Publications Types**	randomized controlled trial/ or randomized controlled trial.pt. or (randomized controlled trial* or systematic review*).mp. or (systematic* or random*).ti.
16	**Combine Sets**	(2 or 3 or 4 or 5) and 15
17	**Combine Sets**	(1 and 2) or (3 or 4 or 5)
18	**Combine Sets**	(1 or 2) and (3 or 4 or 5)
19	**Combine Sets**	(3 or 5) and 4
20	**Combine Sets**	(2 or 3 or 4 or 5) and (6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14)
21	**Combine Sets**	10
22	**Combine Sets**	6 and 14
23	**All Combined Sets**	16 or 17 or 18 or 19 or 20 or 21 or 22
24	**Additional Limit**	limit 23 to english language
25	**Additional Limit**	limit 24 to human

Set #	Concept	Search Statement
26	**Additional Limit**	limit 25 to yr="2002 -Current"
27	**Additional Limit**	limit 26 to humans
28	**Additional Limit**	remove duplicates from 27
29	**Exclusion Set**	28 not (addresses or authored book or autobiography or bibliography or biography or book or book series or case or case reports or conference abstract or conference paper or conference proceeding or clinical conference or collected works or comment or congresses or consensus development conference or consensus development conference, nih or dictionary or directory or duplicate publication or editorial or erratum or government publications or in vitro or interactive tutorial or interview or lectures or letter or news periodical index or note or published erratum or reference book or retracted publication or retraction of publication or report or short survey or video-audio media or webcasts).pt.)
30	**Questions 1-20**	Selected results

Results of Literature Searches

The literature search identified 3,140 citations potentially addressing the Key Questions of interest to this evidence review. Of those, 1,190 were excluded upon title review for not meeting inclusion criteria (e.g., not pertinent to the topic, published prior to 2002). Overall, 1,227 abstracts were reviewed and 937 studies were excluded for the following reasons:

- Non-systematic reviews or non-clinical trials
- Studies not addressing a Key Question of interest
- Technical studies that did not enroll patients with an amputation
- Studies published:
    - prior to 2002 for clinical studies
    - prior to 2007 for systematic reviews

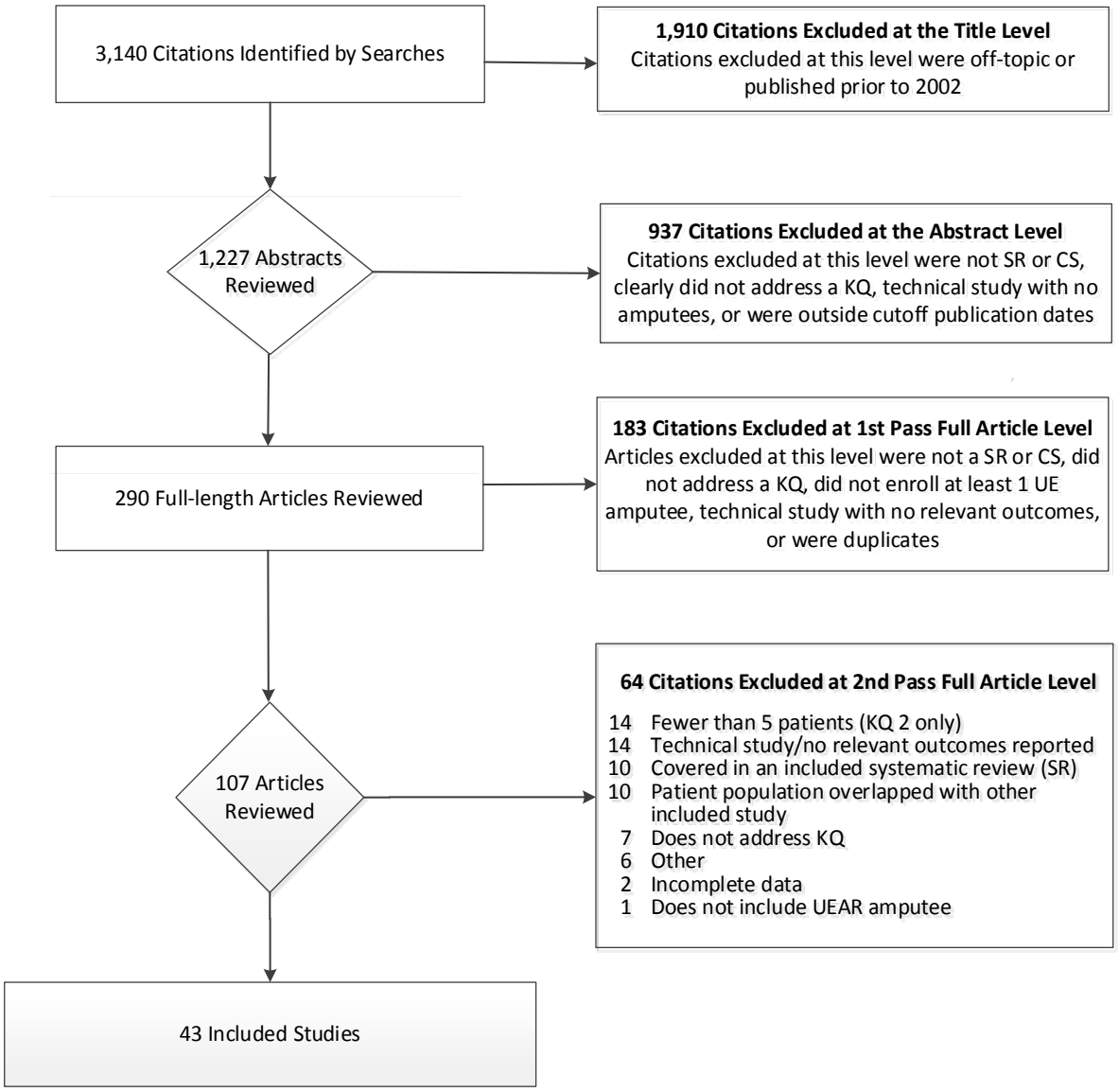
A total of 290 full-length articles were reviewed. Of those, 183 were excluded during review for the following reasons:

- Not a full-length systematic review or clinical study
- Not addressing a Key Question
- Not enrolling at least one patient with an upper extremity amputation
- Being a technical study with no relevant outcomes
- Duplicate studies

A total of 107 full-length articles were thought to address one or more KQs and were further reviewed. Of these, 64 were ultimately excluded. Reasons for their exclusion are presented in Figure A-1 below.

Overall, 43 studies addressed one or more of the Key Questions and were considered as evidence in this review. Table A-5 describes the number of studies that addressed each of the questions.

Figure A-1. Study Flow Diagram



CS: Clinical study
KQ: Key Question
SR: Systematic review
UE: Upper extremity

Table A-5. Evidence Base for Key Questions

Question Number	Question	Number of Studies
Perioperative Phase		
1	What factors used to determine elective amputation level (i.e., limb length consideration, myoplasty vs. myodesis, nerve function, skin integrity etc.) and peri-op exercises are associated with maximal functional outcome, with or without prosthesis?	No studies identified that addressed this KQ.
Postoperative Phase		
2	In adults with UE amputations, what are the most effective strategies to treat postoperative, phantom and residual limb pain?	20 studies
3	In adults with UE amputations, do those who receive immediate post-op peer visits (others with amputations) have better functional outcomes than those who do not?	2 studies
Pre-prosthetic Training Phase		
4	In adults with UE amputations, what pre-prosthetic rehabilitation protocols are most effective to improve patient function with ADL (i.e., dressing, bathing, grooming, toileting, hygiene, and eating) without the use of a prosthesis?	No studies identified that addressed this KQ.
5	In adults with UE amputations, what pre-prosthetic exercise protocols are most effective to prepare a patient to use an upper extremity prosthesis (body-powered, myoelectric, hybrid, or cosmetic)?	No studies identified that addressed this KQ.
6	In adults with UE amputations, what adaptive equipment or assistive devices maximize independence with ADL i.e., dressing, bathing, grooming, toileting, hygiene, and eating) without use of a prosthetic in the short-term (i.e., after amputation but before receiving prosthesis)?	No studies identified that addressed this KQ.
7	In adults with UE amputations, what is the optimal time period in which pre-prosthetic training should be initiated? Is the “golden window” really true?	No studies identified that addressed this KQ.
8	In adults with UE amputations, does the time between amputation and the first prosthesis fit and training have an effect on the acceptance and use of a definitive prosthesis?	No studies identified that addressed this KQ.
Prosthetic Training Phase		
9	In adults with UE amputations, which device (body-powered, myoelectric) should an individual be trained on first and how does this affect training of next device?	No studies identified that addressed this KQ.
10	In adults with UE amputations, what factors of training (e.g., timing, intensity, frequency, etc.) are associated with use or abandonment of prosthesis?	1 study
11	In adults with UE amputations, is type of prosthesis originally trained on associated with use versus abandonment of newer prosthesis?	No studies identified that addressed this KQ.

Question Number	Question	Number of Studies
12	In adults with UE amputations, what prosthetic factors (cosmesis, weight, ease of use of terminal devices, etc.) are associated with use or abandonment of prosthesis?	Our searches did not identify any studies that specifically addressed this question. Information provided in the Evidence Report for KQ 17 may be applicable to this question.
13	In adults with UE amputations, what patient characteristics (age, marital status, education level, dominant hand v. non-dominant hand) are associated with use or abandonment of prosthesis?	Our searches did not identify any studies that specifically addressed this question. Information provided in the Evidence Report for KQ 17 may be applicable to this question.
14	In adults with UE amputations, which myoelectric and body-powered prosthesis components (wrist rotator, harnessing system) and terminal devices (Grieffer, sensor hand, electric terminal device, or ilimb and all are not compatible) are associated with the best functional outcomes (with each type of available prosthesis – body-powered or myoelectric)?	1 study
Long-term Care		
15	In the long-term management of persons following upper extremity amputation, do routine clinical follow-up, education programs, and intervention such as referral to specialty care for comorbid injuries and conditions reduce morbidity and improve functional outcomes.	1 study
16	Following upper extremity amputation, what are the factors associated with successful, long-term prosthetic use (1, 3 and 5 years after discharge)?	10 studies
17	Following upper extremity amputation, what are the best strategies for improving long-term functional outcomes and successful community and vocational reintegration?	2 studies
18	Following upper extremity amputation, does long-term rehabilitation therapy maintain functional abilities and improve independence in ADL compared to no therapy services?	No studies identified that addressed this KQ.
19	What is the impact of advances in technology and treatment advances such as limb transplant, targeted muscle reinnervation, and osseo-integration on the long-term functional outcomes of individuals following upper extremity amputation?	6 studies

Appendix B: Summary of Assessments and Interventions in Rehabilitation Phases

Table B-1. Summary of Assessments and Interventions in Rehabilitation Phases

	Perioperative	Pre-Prosthetic	Prosthetic Training	Lifelong Care
1. Present Health Status *[nutritional, cardiovascular, endocrine, neurologic, bowel & bladder, skin, musculoskeletal including HO, infections]*	• Complete initial assessment of medical comorbidities and consultation as appropriate, especially if not addressed preoperatively • Initiate medical interventions and education as needed	• Continue medical interventions and education as needed	• Assess changes in medical comorbidities, and perform interventions and education as needed	• Assess changes in medical comorbidities and perform interventions and education as needed • Address preventative strategies • Specialty referrals as indicated
2. Discharge Planning	• Complete initial assessment and initiate discharge planning • Contact family and/or caregiver • Develop discharge plan	• Determine new needs and update discharge plan as appropriate	• Determine new needs and update discharge plan as appropriate • Arrange appropriate follow-up plans	• Implement appropriate follow-up plans • Assist with care transitions with relocation or major life changes
3. Level of Function 3.1- Range of Motion	• Preoperatively, treat identified contractures except in urgent cases • Assess current ROM in proximal joints of residual limb and on contralateral side • Initiate passive ROM of residual and contralateral limb in all available planes of	• Maximize ROM of scapula, shoulder girdle, elbow, wrist and hand as applicable • Advance to active ROM of residual and contralateral limbs	• Continue contracture prevention with stretching program • Maximize ROM for prosthetic fit and training	• Reassess ROM and review home stretching program if needed

	Perioperative	Pre-Prosthetic	Prosthetic Training	Lifelong Care
	motion • Educate on importance of proper positioning to prevent contracture • Progress to active-assistive ROM in all planes of motion for residual and contralateral limb			
3.2- Gross Motor Strength and Skills	• Assess for strength deficits of upper and lower limbs and treat as appropriate • Initiate strengthening program for major muscle groups in the arms and legs •	• Continue therapeutic exercise program for strengthening UE to include periscapular muscles •	• Progress therapeutic exercise program for all extremities	• Reassess general strength and educate on maintenance of strength for long-term activity
3.3- Core Stabilization and Balance	• Initiate trunk and core stabilization exercises Assess and initiate a balance progression: o Static sitting balance o Sitting weight shifts • Assess and initiate core stabilization: o Pelvic tilts o Bridges	• Advance trunk and core stabilization exercises Progress dynamic balance	• Advance balance activities and challenge upper limb functional reach	• Reassess core strength and balance as it relates functional activities using the prosthesis
3.4- Home Exercise	• Determine or obtain HEP	• Give patient supplies and	• Advance HEP to focus on	• Address new physical

	Perioperative	Pre-Prosthetic	Prosthetic Training	Lifelong Care
Program (HEP)	addressing deficiencies and maximize above ROM strength, balance, etc.	instruction in exercise program for home	full ROM, strength and endurance	requirements as patient goals change
3.5- Cardiovascular (CV)	• Assess current CV fitness for increased energy requirement for prosthetic use and incorporate a CV component into the therapy program • Educate regarding increased energy demand with active prosthesis use • Establish cardiac precautions to rehabilitation (heart rate, blood pressure, perceived exertion scales)	• Advance CV aspect of program to meet needs of patient • Maintain cardiac precautions • Encourage reducing risk factors	• Establish maintenance program for endurance and fitness • Maintain cardiac precautions • Encourage reduction of cardiovascular risk factors	• Establish maintenance program for endurance and fitness • Maintain cardiac precautions if indicated • Encourage reduction of cardiovascular risk factors
3.6- ADL and IADL	• Assess activity level and independence in ADL and IADL to help establish goals and expectations • Initiate ADL training such as eating, dressing, grooming, bathing, toileting • Provide training for any	• Teach adaptive techniques for dressing, bathing, grooming, and toileting without a prosthesis • Continue change of dominance training as appropriate • Begin IADL training • Progress independence	• Instruct in proper care and maintenance of prosthesis • Instruct and train in prosthetic donning and doffing strategies • Practice ADL and IADL with prosthesis as appropriate	• Reassess functional needs and provide any necessary training to maximize independence • Teach energy conservation principles • Teach injury prevention techniques

	Perioperative	Pre-Prosthetic	Prosthetic Training	Lifelong Care
	strategies to perform basic ADL with one hand • Ensure patient safety • Initiate change of dominance training as appropriate • Initiate transfer training as necessary: o Sit to stand o Floor to chair o Chair to bed o Chair to toilet, as appropriate o Chair to car, as appropriate	with more complex IADL training		
3.7 Community Integration	• Obtain recreational interests • Offer and promote trained peer visitation	• Initiate outings into the community without a prosthesis • Complete recreational training activities without the prosthesis(es)	• Initiate recreational training activities with a prosthesis • Practice use of a prosthesis during recreational training activities	• Reassess community integration needs and refer to recreation therapy as necessary • Provide education on opportunities and precautions for long-term sport specific, recreation skills or resources, and prosthesis or assistive devices available • Provide counseling and contact information regarding opportunities

	Perioperative	Pre-Prosthetic	Prosthetic Training	Lifelong Care
				in sports and recreation (Paralympics, golfing, fishing, hunting, etc.)
3.8- Home Evaluation	• Assess patient's home for accessibility and safety and provide information on home modifications	• Assess patient's home for accessibility and safety if not already completed	–	• Reassess home modification needs with any significant changes to medical condition
3.9- Equipment	• Provide education about available assistive devices or adaptive equipment Educate regarding available home modifications, ramps, etc.	• Assess for personal equipment and assistive devices to perform ADL • Provide training for personal equipment and assistive devices to perform ADL • Assess for home adaptation needs and equipment	• Assess for personal equipment and any necessary accommodations to perform IADL (i.e., voice recognition, one handed keyboard, Bluetooth devices, etc.) and provide training	• Reassess for any personal equipment or necessary accommodations to perform ADL, vocation and avocational IADL as needs and goals evolve • Provide necessary training for identified personal equipment and assistive device needs
3.10- Driving Evaluation and Training	–	• Assess for driving evaluation needs (e.g., cognitive, visual, or need for vehicle modifications patient with UE amputation for adaptive driving equipment such	• Consult Certified Driving Specialist to complete driving evaluation • Complete driver's training with recommended adaptive equipment as needed (e.g., spinner knob or hand controls) • Educate patient, family	• Reassess driving modification needs with any significant changes to medical condition

	Perioperative	Pre-Prosthetic	Prosthetic Training	Lifelong Care
			and/or caregiver to comply with local state driving laws and individual insurance company policies	
4. Pain Management	• Assess for existing pain prior to surgery and treat aggressively • Assess and aggressively treat RLP and PLP (liberal narcotic use, regional anesthesia, and non-narcotic medications especially for neuropathic pain)	• Assess and treat RLP and PLP (transition to non-narcotic modalities including pharmacological, physical, psychological, and mechanical)	• Assess and treat RLP and PLP (transition to non-narcotic modalities including pharmacological, physical, psychological, and mechanical)	• Reassess and adjust treatment for RLP and PLP (transition to non-narcotic modalities including pharmacological, physical, psychological, and mechanical) • Assess and treat associated musculoskeletal pain and overuse syndromes
5. Behavioral and Cognitive Health *[psychological & cognitive function]*	• Complete psychological assessment if not done preoperatively • Evaluate and address psychosocial symptoms/issues • Complete cognitive assessment if not done pre-operatively	• Evaluate and address psychosocial symptoms/issues • Evaluate and address cognitive issues	• Evaluate and address psychosocial symptoms/issues • Evaluate and address cognitive issues	• Evaluate and address psychosocial symptoms/issues • Assess changes in psychosocial support • Assess changes in cognitive issues
6. Patient Education	• Pain Control • Patient Safety • Prevention of	• Positioning • Rehabilitation progress • Pain control	• Positioning • Rehabilitation process • Pain control	• Positioning • Rehabilitation process • Pain control

	Perioperative	Pre-Prosthetic	Prosthetic Training	Lifelong Care
	Complications • Procedural/Recovery issues: o Level of amputation o Prosthetic options o Postoperative dressing o Sequence of amputation care o Equipment • Role of the care team members • Psychosocial anticipatory guidance • Expected functional outcomes • Positioning • Rehabilitation process • Pain control • Residual limb care • Edema control • Compression wrapping • Wound care • Prosthetic timeline • Coping methods • Contracture prevention	• Residual limb care • Edema control • Application of shrinker • Prosthetic timeline • Equipment needs • Coping methods • Prevention of complications • Contracture prevention • Safety	• Residual limb care • Energy expenditure • Prosthetic education o Donning & doffing o Care of prosthesis o Skin integrity o Sock management • Equipment needs • Coping methods • Prevention of complications • Weight management • Contracture prevention • Injury prevention techniques • Safety	• Residual limb care • Equipment needs • Coping methods • Prevention of complications • Weight management • Contracture prevention • Injury prevention techniques • Safety • Technological advances in the field that may benefit patient to achieve individual needs and desired goals
7. Residual Limb Management	• Manage postoperative dressings • Monitor the surgical wound for signs and	• Continue to monitor wound healing • Continue shaping and shrinkage of residual	• Optimize limb shaping and shrinkage prior to prosthetic fitting • Teach donning/doffing	• Reinforce education regarding skin care • Educate regarding signs and symptoms of ill-

	Perioperative	Pre-Prosthetic	Prosthetic Training	Lifelong Care
	symptoms of ischemia or infection • Control edema and shape residual limb with the use of postoperative dressing and figure of eight compression wrap; progress to shrinker once cleared by surgeon • Teach figure of eight compression wrap application or shrinker application • Promote skin and tissue integrity with the use of a residual limb dressing • Promote ROM and strengthening of proximal joints and muscles	limb • Teach compression wrap application or shrinker application • Teach patient care of residual limb • Promote ROM and strengthening of proximal joints and muscles • Instruct in desensitization exercises	of prosthetic system • Instruct in use of shrinker or compression wrap when out of prosthesis • Teach skin checks and skin hygiene • Teach management of sock ply (if appropriate) • Progress wear schedule • Optimize pain management in order to promote ROM and restoration of function • Instruct patient to observe pressure points • Monitor skin and tissue integrity with limits on wearing time and frequent skin checks in the newly fitted socket	fitting socket • Monitor effectiveness of pain management • Continue limb volume management
8. Prosthetic Management	• Determine optimal residual limb length in accordance with patient goals • Peer visit / education • Limb care • Postoperative dressing if appropriate	• Initial prosthetic prescription generation	• Prosthetic fabrication, fitting, alignment, and modification as applicable • Test various prosthesis components	• Prosthetic fabrication, fitting, alignment, and modification as applicable • Prosthetic device repairs as indicated • Schedule routine maintenance (components, upgrades, socket changes and

	Perioperative	Pre-Prosthetic	Prosthetic Training	Lifelong Care
				specialty use devices) • Consider activity-specific prosthesis, such as a kayaking arm, to meet newly established goals
9. Vocational Rehabilitation	• Obtain vocation interests	• Complete vocational rehabilitation evaluation	• Conduct worksite evaluation • Identify worksite modifications to enhance function • Initiate vocational training activities with a prosthesis • Practice use of a prosthesis during vocational training activities	• Reassess vocational needs and refer as needed to achieve new or ongoing vocational goals • With any significant changes to medical condition, reassess for any additional work place modification needs

Appendix C: Outcome Measures

The International Classification of Functioning, Disability and Health (ICF) was endorsed by the World Health Organization (WHO) in 2001 with the aim of creating a common language to describe health and health-related status. It classifies human functioning into four multi-dimensional domains: body functions and structures, activities and participation, environmental factors, and personal factors, and includes elaborate classification taxonomy. [98] The ICF frames "health" and "disability" as universal human experiences and shifts the focus to the impact of a health condition rather than its cause. [98] The ICF model is increasingly utilized in clinical settings to assess functional status, set goals, plan and monitor treatment, and as a framework for outcome measurement. Use of the ICF allows clinicians and researchers from different fields and locations to use a common language and share a common purpose. Appropriate selection and administration of outcome measures, linked to the ICF taxonomy, [99,100] can clearly identify the impact of a health or health related condition, evaluate needs, and track health and function over time. Many authors have attempted to link specific outcome measures to ICF taxonomy. [101] Generally speaking, most outcome measures were not developed based upon the ICF conceptual model, and as such, may not cover all the aspects of human functioning that are pertinent to specific clinical conditions. Therefore, clinicians may need to employ more than one outcome measure when seeking a comprehensive view of the patient's status and progress. [102-105] Thus, a "toolkit" of outcome measure instruments is required.

To insure that we had the most current information, we performed our own systematic review to: search scientific literature to identify outcome measures that have been used to assess function in persons with upper limb amputation; evaluate each measure's focus, content, clinimetric and psychometric properties. This systematic review was an update of one that was performed by members of the Measurement Group for the VA Amputation System of Care Registry/Repository in 2012. For the purposes of this literature review, two distinct search strategies were utilized to conduct literature searches in PubMed and CINAHL. Additional publications were obtained from other sources (including citation searching, personal libraries etc.). The systematic review is current as of 8-22-14. One hundred and eighty-one articles were identified as a result. Abstracts of all identified articles were independently reviewed by two Reviewers to determine if they met the following inclusion/exclusion criteria:

Inclusion Criteria

- The manuscript employed a standardized outcome measure that was developed or used with ADULT amputee patients/subjects to measure the specified domain for evaluating or predicting outcome
- The research used the measure with a sample of at least ten persons with upper limb amputation
- The paper was written in English (or translated)
- An abstract was available for review

Exclusion Criteria

- Dissertation, thesis, book chapter or conference proceedings
- The full text publication was unavailable for review
- Exclude if used only with a pediatric population

- Exclude if sample was only non-disabled persons using a prosthetic simulator

Thirty manuscripts met the inclusion criteria and these publications yielded a total of 24 pertinent outcome measures (including modified versions of original measures). [105-134]

The original review included only those outcome measures that assessed the domain of physical function, and had been utilized in published literature with a minimum of ten persons with upper limb amputation. Thus, the review is of measures that had been reported in the scientific literature and does not include an exhaustive list of all outcome measures available for use with the upper limb amputee population or those that have been used in small studies or studies of prosthetic simulators. That said, our tables below include one additional measure, the Southampton Hand Assessment Procedure, because of its popularity, evidence of content validity [135], and use in multiple small studies of transradial amputees (1-6 subjects), as well several studies of prosthetic simulation [135-144].

All measures and their subscales are summarized in Table E-1. Some of the listed measures also include the minimal detectable change (MDC). These numbers can be very useful in interpreting MDC scores, however scores vary by population, and may or may not be clinically significant. This table provides a rating of the evidence supporting important measurement properties of the identified outcome measures, as documented in the literature. Table E-2 lists the same outcome measures categorized according to broad ICF categories, utility, and functional element assessed. This review should facilitate, not replace clinical judgment. The review focuses on physical function and does not include measures designed to assess important domains such as social participation or satisfaction with the prosthesis. The intent is to supply the clinician with information to help him or her choose the best measures of physical function for their own “toolkit” that are appropriate for their patients and their facility.

Table C-1. Review of Evidence in Support of Measurement Properties of Functional Status Measures for Upper Extremity Amputation

Measure	Reliability evidence				Validity			Overall Rating
	Inter-rater	Test-retest	IRT/Rasch	Internal consistency	Construct Validity	No Floor/Ceiling	Sensitivity to change/Responsiveness (MDC)	
ABILHAND	UK	UK	0	UK	UK	UK	UK	UK
ABILHAND-ULA	UK	UK	+	N/A	+	?	UK	UK
Activities Measure for Upper Limb Amputees (AM-ULA)	+	+	N/A	+	+	UK	+ (MDC 90 3.7)	+
Actual Use Index	N/A	UK	N/A	UK	+	UK	UK	UK
Assessment of Capacity for Myoelectric Control (ACMC)	+	UK	+	N/A	+	+	UK	+
Assessment of Capacity for Myoelectric Control (ACMC) V2	+	+	+	N/A	+	+	+ MDC 95 0.55-0.69 logits	++
Box and Block Test of Manual Dexterity	+	+	N/A	N/A	+	+	+ (MDC 90 6.5)	++
Carroll test (Upper Extremity Function Test)	UK	UK	N/A	UK	UK	UK	UK	UK
Carroll test (modified)	UK	UK	N/A	UK	UK	UK	UK	UK
DASH	N/A	UK	N/A	UK	+	UK	?	UK
Jebsen-Taylor Hand Function Test - modified	+	+	N/A	N/A	+	0	? (MDC 90 0.09-0.18 items/second)	?
OPUS UEFS	UK	UK	0	UK	UK	UK	UK	0
OPUS UEFS modified (Burger)	UK	UK	+	UK	+	UK	UK	UK
OPUS UEFS modified rating scale (Jarl)	N/A	+	UK	N/A	UK	UK	+ (MDC 95 14.8)	UK
OPUS UEFS modified 27 item scale (Jarl)	N/A	UK	+	N/A	+	0	UK	UK
OPUS UEFS modified 22 item scale (Resnik)	N/A	+	UK	N/A	0	+	0 (MDC 90 12)	0

Measure	Reliability evidence				Validity			Overall Rating
	Inter-rater	Test-retest	IRT/Rasch	Internal consistency	Construct Validity	No Floor/Ceiling	Sensitivity to change/Responsiveness (MDC)	
OPUS UEFS Use	N/A	?	N/A	UK	0	+	0 (MDC 900.39)	0
Patient-Specific Function Scale (PSFS)	N/A	UK	N/A	UK	+	+	+	UK
Purdue Pegboard	N/A	UK	N/A	UK	?	UK	UK	UK
Southampton Hand Assessment Procedure (SHAP)	UK	UK	N/A	UK	UK	UK	UK	UK
Total Skill Score	UK	UK	N/A	UK	+	UK	UK	UK
University of New Brunswick Skill	+	+	N/A	UK	+	UK	+ (MDC 90 0.8)	+
University of New Brunswick Spontaneity	+	+	N/A	UK	+	UK	+ (MDC 90 0.7)	+
QuickDASH	N/A	UK	N/A	UK	UK	UK	UK	UK

Measurement property rating scheme

(++) Excellent = evidence from 2 or more separate studies with strong methodology supporting the property

(+) Good = evidence from 1 study with strong methodology supporting the property

(?) Fair = evidence from 1 or more studies with fair methodology supporting the property, more research needed

(0) Poor = evidence from poor quality study/studies, and/or results from well-constructed studies did not strongly support the property or indicated serious issues

(UK) Unknown = to date no research has been conducted on the measurement property. MDC 90 = Minimal Detectable Change at 90% confidence interval

Overall rating scheme

(++) Excellent =evidence from 2 or more separate studies with strong methodology supporting both reliability and validity

(+) Good =evidence from 1 study with strong methodology supporting both reliability and validity

(?) Fair=evidence from 1 or more studies with fair methodology supporting both reliability and or validity, more research needed

(0) Poor =evidence from poor quality study/studies, and/or results from well-constructed studies did not strongly support both reliability and validity or indicated serious issues

(UK) Unknown=to date insufficient research has been conducted on measurement properties

Table C-2. Utility, Elements Assessed, Content, and Evidence Rating of Upper Extremity Functional Outcome Measures

	Utility				Elements Assessed								ICF Content Areas													Rating
													Body Functions				Activities and Participation									
	Phase of rehabilitation	Easy to score	Easy to interpret score	Burden (minutes to complete)	Speed	Difficulty/skill	Special equipment (prosthesis use)	Task completion	Spontaneity of prosthetic use	Movement quality	Assistance	Skillfulness of prosthetic device use	Pain/tingling/stiffness	Sleep	Hand grips/grasping	Use of visual feedback	Carry and handle objects	Household activities	Eating/drinking	Food preparation	Bathing/grooming	Dressing	Other daily activities	Sexual activities	Recreation	Social activities	
Self-Report Measures																										
ABILHAND	All	Y	N	15		Y											Y	Y	Y	Y	Y	Y	Y				UK
ABILHAND-ULA	All	Y	N	10		Y											Y	Y	Y	Y	Y	Y	Y				UK
Actual Use Index (AUI)	Pros	Y	Y	?			Y										Y	Y	Y	Y	Y	Y	Y				UK
DASH	All	Y	Y	10-15		Y							Y	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	UK
OPUS UEFS	All	Y	N	5-10		Y		Y									Y	Y	Y	Y	Y	Y	Y				0
OPUS UEFS (Burger)	All	Y	N	5-10		Y		Y									Y	Y	Y	Y	Y	Y	Y				UK
OPUS UEFS modified rating scale (Jarl)	All	Y	N	5-10		Y		Y									Y	Y	Y	Y	Y	Y	Y				UK
OPUS UEFS modified 27 item scale (Jarl)	All	Y	N	5-10		Y		Y									Y	Y	Y	Y	Y	Y	Y				UK
OPUS UEFS modified 22 item scale (Resnik)	All	Y	N	5-10				Y									Y	Y	Y	Y	Y	Y	Y				0
OPUS UEFS Use	All	Y	Y	5-10			Y										Y	Y	Y	Y	Y	Y	Y				0
PSFS	All	Y	Y	5-10		Y											Patient lists tasks of importance										UK
QuickDASH	All	Y	Y	5		Y							Y	Y			Y	Y		Y					Y	Y	UK

	Utility				Elements Assessed								ICF Content Areas														Rating
													Body Functions				Activities and Participation										
	Phase of rehabilitation	Easy to score	Easy to interpret score	Burden (minutes to complete)	Speed	Difficulty/skill	Special equipment (prosthesis use)	Task completion	Spontaneity of prosthetic use	Movement quality	Assistance	Skillfulness of prosthetic device use	Pain/tingling/stiffness	Sleep	Hand grips/grasping	Use of visual feedback	Carry and handle objects	Household activities	Eating/drinking	Food preparation	Bathing/grooming	Dressing	Other daily activities	Sexual activities	Recreation	Social activities	
Performance Measures																											
ACMC	Pros	N	Y	10-15		Y			Y	Y		Y			Y	Y	Y										+
ACMC v 2	Pros	N	Y	10-15		Y			Y	Y		Y			Y	Y	Y										++
AM-ULA	Pros	Y	Y	30	Y	Y		Y		Y	Y							Y	Y	Y		Y	Y	Y			+
Box and Block Test of Manual Dexterity	Pros	Y	Y	2	Y												Y										++
Carroll test	Pros	N	Y	25 ?	Y	Y		Y									Y	Y									UK
Carroll test (modified)	Pros	N	Y	20 ?	Y	Y											Y	Y									UK
JTHF - modified	Pros	Y	Y	15+	Y													Y		Y				Y			?
Purdue Pegboard	Pros	Y	Y	5	Y												Y										UK
SHAP	Pros	N	N	?	Y										Y		Y	Y		Y			Y				UK
Total Skill Score	Pros	Y	Y	?	Y					Y							Y	Y	Y	Y	Y	Y	Y	Y			UK
UNB Skill (1 subtest)	Pros	Y	Y	20-40								Y			Y												+
UNB Spontaneity (1 subtest)	Pros	Y	Y	20-40					Y						Y												+

Rating scheme

(++) Excellent =evidence from 2 or more separate studies with strong methodology supporting both reliability and validity

(+) Good =evidence from 1 study with strong methodology supporting both reliability and validity

(?) Fair=evidence from 1 or more studies with fair methodology supporting both reliability and or validity, more research needed

(0) Poor =evidence from poor quality study/studies, and/or results from well-constructed studies did not strongly support both reliability and validity or indicated serious issues

(UK) Unknown=to date insufficient research has been conducted on measurement properties

Appendix D: Essential Elements of the Annual Contact

1. Level of functional independence and physical activity level
2. Daily time utilization with functional and leisure activities
3. Fit and function of the prosthesis
4. Amount of prosthesis use and barriers to greater use
5. Residual limb skin condition
6. Pain issues (residual limb, phantom limb, musculoskeletal pain issues, i.e., neck, shoulder, back)
7. Environmental modification or assistive technology needs
8. Family or caregiver support
9. Emotional and adjustment issues including attitude toward wearing prosthesis
10. Vocational, recreational, community resources and support
11. Social work and case management support
12. Nutritional status
13. Changes in medical comorbidities/status
14. Changes in functional goals
15. Changes in the home environment and required adaptations
16. Driver's training if not previously addressed
17. Risk factors for secondary amputation

Appendix E: Activities of Daily Living

Table E-1. Bilateral Upper Limb Activity of Daily Living Task Sample Technique Options and Considerations

ADL Task	Sample Technique Options	Considerations
Toileting	▪ Use of a bidet ▪ Squatting down and using one's heel covered with toilet paper or hygienic wipes ▪ Toilet paper folded back on itself repeatedly placed on the toilet seat with the tail of the toilet paper dropped into the water to secure it.	▪ The prosthesis should have wrist flexion and rotation if the user is to perform toilet hygiene without other aids. This is patient dependent ▪ Develop a regular bowel program to facilitate a routine to use the restroom in a location where the environment is ideal for modified independent toileting ▪ Use of hygienic wipes when out in public
Feeding	▪ Use of a rocker knife or Knork (Phantom Enterprises Inc, North Newton, Kan) for cutting Request for dense foods to be pre-cut before serving when dining out ▪ Universal cuff to hold silverware to residual limb ▪ Use of a straw for liquids ▪ Use of Dycem (Dycem Limited, Warwick Central Industrial Park, RI) or other available nonskid material to secure plates or bowls on tabletop ▪ Use of food guards on plates or broad bowls to allow for ease in loading the utensil ▪ Some patients are comfortable bringing their mouth to the tabletop ▪ Use of commercially available self-feeding systems	▪ A prosthesis that supports maximal elbow flexion, wrist rotation, and wrist flexion will allow a patient to feed themselves with unmodified utensils ▪ Smaller foods are often the most difficult due to the significant amount of ROM required to get to the mouth without the added length of the utensil ▪ The shorter the residual limb the more challenging to self-feed, particular for patients with elbow or shoulder disarticulation, transhumeral or forequarter amputation
Dressing	**Upper body dressing** ▪ Pull over clothing should be placed at a higher height to allow patients easier donning with use of residual limbs in concert with the mouth and gross body motions to get shirt over the torso ▪ Donned open front shirts hung from a hook or hanger ▪ Lie on bed to maneuver clothing onto body ▪ Use button hooks or hook terminal device to fasten and unfasten buttons ▪ Modify button down shirt with Velcro (Velcro USA Inc, Manchester, NH) for closure ▪ Use zippers with stable catches and a large pull tab; use string or	▪ Loose-fitting clothing with limited fasteners is easier to manage ▪ Leave cuffs loose on jackets and shirts.

ADL Task	Sample Technique Options	Considerations
	zipper pull ▪ Wear clip-on ties **Lower body dressing** ▪ Garments with elastic waists will ease lower body dressing. ▪ Use of non-skid material like Dycem (Dycem Limited, Warwick Central Industrial Park, RI) mounted on the wall slightly below waist height can be used to assist in raising or lowering lower body garments ▪ Socks with loose cuffs that have been rolled down facilitate donning ▪ Sock aids are useful to some patients ▪ Place loops at top of sock for easier donning while wearing prostheses ▪ Wear slip-on shoes or loose athletic shoes ▪ Use elastic laces, lace locks, or Velcro (Velcro USA Inc, Manchester, NH) closures on shoes ▪ Preplace belt in pant loops before donning pants ▪ Mount hooks at various heights on a donning stand or wall to assist with dressing	
Bathing	▪ Use elastic shower mitts over the end of the residual limb ▪ Use of suction wall- mounted sponges or loofas ▪ Wall-mounted soap dispensers ▪ Pump dispense bottles ▪ Hang a terry cloth type robe to don for drying self ▪ Use of a wall or countertop-mounted hairdryer ▪ Use of commercially available body washing and drying systems ▪ Use of custom shower prostheses	▪ Ensure safety while bathing and implement strategies to prevent falls ▪ Place a nonskid mat in the tub ▪ Use of a tub bench ▪ Patients with transradial amputations can use a floor to ceiling pole to assist with getting in or out of a tub
Hygiene	▪ Use an electric razor for shaving ▪ Mount modified gooseneck clamps to the wall to hold devices such as razors, electric toothbrushes, hairdryers or brushes ▪ While sitting use universal cuff to hold razor with residual limb and shave legs and underarms or consider laser hair removal, waxing, or electrolysis as an option for hair removal. ▪ Use an electric toothbrush for oral hygiene	▪ Performing hygiene activities independently can be done with use of prosthetic devices, adaptive equipment, modifications to the environment, and use of many products made for the general public

ADL Task	Sample Technique Options	Considerations
	▪ Use commercially available disposable dental floss holders for flossing ▪ Use clamps at end of toothpaste for ease of application ▪ Large suction mounted nail clips for trimming nails ▪ Use commercially available hairdryer stands	

Table E-2. Prosthetic Training: ADL and IADL Task List

Feed self with utensils	Clean prosthesis
Cut food with knife	Don/doff prosthesis
Open variety of food packages	Re-charge batteries
Eat finger foods	Change terminal devices
Drink from cup or bottle	Remove/apply harness
Don/doff bra	Turn prosthesis on/off
Don/doff pull-over shirt	Apply compression garment or sleeve
Dress button-down shirt: cuffs and front	Skin care management – visual inspection
Manage zippers and snaps	Perform laundry
Don/doff pants	Hang clothes
Don/doff belt	Fold clothes
Don/doff socks	Set up ironing board
Don/doff shoes, boots	Iron clothes
Lace and tie shoes	Hand wash dishes
Screw/unscrew cap of toothpaste tube	Dry dishes with a towel
Squeeze toothpaste	Load and unload dishwasher
Use toothbrush to brush teeth	Use broom and dustpan
Floss teeth	Operate vacuum cleaner
Open/close bottle of pills or pillbox	Use wet and dry mop
Manipulate pills	Sweep/mop the floor
Shave	Dust the furniture
Perform residual limb care	Clean countertops
Wash your back	Clean the toilet/sink/tub
Apply deodorant	Make bed/change sheets

Wash/dry hand	Change garbage/trash bag
Bathe/dry upper body	Open/close jar – tight or new
Bathe/dry lower body	Open lid of can
Wash/blow dry hair	Cut vegetables
Blow nose	Peel vegetables
Toilet paper management	Peel banana
Feminine hygiene	Crack an egg
Flushing toilet	Stir food in bowl
Wipe self	Manipulate hot pots
Apply lotion	Turn and egg or pancake with spatula
Apply make-up	Use measuring cups
Clean fingernails	Use measuring spoons
Cut and file fingernails	Scoop ice cream
Polish finger nails	Use toaster
Use/remove contacts	Open pop-top
Place and remove glasses	Wrap/unwrap food in foil and or plastic wrap
Patient specific tasks	Put dishes in overhead cabinet
Open/close safety pin	Pour milk from carton
Change diapers	Use mixer
Brush/arrange child's hair	Use lock-type plastic bags
Use phone and take notes simultaneously	Light a match
Operate door knob	Sew a button
Place chain on chain lock	Turn key in lock
Plug/unplug cord into wall outlet	Carry a suitcase
Set time on watch	Operate window blinds
Receive change/ count coins	Open pet food container
Remove keys or wallet from pocket	Attach and hold dog leash
Take dollar bill from wallet	Change litter box
Write signature	Fill water dish
Answer phone	Play cards or board game
Text message on cell phone	Operate TV remote control
Open mail	Manipulate radio

Hold/turn pages of paperback, magazine, newspaper	Use computer: typing, mouse
Operate lamp	Use CD/DVD player
Use an umbrella	Grocery shopping – push a cart, load, unload
Change a light bulb	Carry grocery bags
Hang a picture	Use vending machine
Use scissors	Make change/receive change
Use ruler	Use ATM
Remove and replace ink pen cap	Use public transportation
Sharpen pencil	Open and close car doors, trunk and hood
Fold and seal letter	Perform steps required to operate vehicle
Use paper clip	Open/close gas cap and door
Use stapler	Operate gas pump
Thread a needle	Fill windshield wiper fluid
Wrap package	Test level and add oil
Carry a tray	Wash windows
Don/doff pantyhose	Scrape ice/snow from car
Tie a tie or scarf	Fasten/unfasten seat belt
Don/doff glove	Start ignition
	Operate controls

Appendix F: Advantages and Disadvantages of Prostheses

Table F-1. Advantages and Disadvantages of Prostheses by Type

	Advantages	Disadvantages
No Prosthesis	+ No maintenance + Tactile sensation or proprioceptive feedback	– Lack of active prehension or mechanical grasp – Limited ability to do tasks that require both hands – Limb is unprotected from environmental hazards – Increased potential for overuse injuries due to awkward body mechanics or using sound hand for all tasks
Electrically Powered Prosthesis	+ Proportional grip force + Ease of electric TD / wrist operation + Can be fit early in rehabilitation + Natural appearance + Can be applied to high amputation levels + Simultaneous control of elbow and TD or wrist + Larger functional work envelope than body-powered prosthesis + Decreased shear forces and distal end bearing to operate terminal devices.	– Battery maintenance – Overall weight consideration – Repairs may be more complex – Susceptible to damage from moisture or excessive vibration
Body-Powered Prosthesis	+ Durable and can be used in tasks or environments that could damage an electric prosthesis (i.e., conditions involving excessive water, dust, or vibrations caused by some motorized vehicles and power tools) + Secondary proprioceptive feedback + Lower maintenance costs than electric options	– Restrictive harness – Decreased grip force compared with electric options – Forces exerted on residual limb – Difficult to control for high amputation levels – Limited function of typical body-powered hands – Appearance of hook and cables
Hybrid Prosthesis	+ Simultaneous control of elbow and TD or wrist + Lighter than fully electric elbow prosthesis + Increased grip force compared with body-powered options + Ease of electric TD/wrist operation	– Requires a harness for elbow – The force needed to fully flex the elbow may be difficult to generate for short transhumeral and higher amputation levels
Passive Prosthesis	+ Lightweight + Minimal harnessing + Low maintenance + No control cables + Cosmesis, positive body image + Silicone products resist staining	– Difficult to perform activities that require mechanical grasp – Latex and PVC products stain easily
Task-Specific Prosthesis	+ Enhanced function in particular activity + Minimal harnessing + Limited or no control cables + Durable, low maintenance + Protects primary prosthesis from damage	– Not appropriate for a broad range of functions

Appendix G: Surgical Considerations

Partial Hand Amputation

The mangled hand is a common traumatic injury in young individuals, most commonly occurring from agricultural, industrial, household, and motor vehicle accidents, as well as combat-related injuries. [145] Because of its functional importance, special consideration should be taken to preserve the thumb even if only partial function can be preserved. [146] The ring and small finger are also considered critical for grip strength and power grasp that would be critical in young laborers and Service Members. [147] More proximal amputation levels should be discouraged if preservation of basic prehensile function with two sensate digits able to oppose one another may be accomplished. However, a more stable terminal pinch can be expected with preservation of the thumb and at least two additional digits. [148] While outside the scope of this guideline, the decision to perform digital salvage vs. amputation can be difficult, and there is currently no specific algorithm or extremity scoring system to guide the surgeon. Consultation with an upper limb specialist is highly recommended, if available. Surgeon experience, a patient-centered approach to treatment, and multi-specialty consultation all help guide decision making.

Amputations through the carpal bones require special consideration. Reconstruction to allow pinching and grasping are not possible at this level. Consideration can be made to revise the amputation to a wrist disarticulation or transradial level. However, if the radiocarpal joint is preserved, consideration can be made to salvage a transcarpal level when soft tissue coverage is available. The advantage of this level is the long limb that may allow functional use for rudimentary tasks, or to assist a contralateral normal extremity, without need for a prosthesis. The perceived disadvantage is the same as that for wrist disarticulation; historically, this level has been difficult to fit with a highly functional prosthesis when compared to the transradial level. However, this may be changing with advanced prosthesis technology and the emergence of hand transplantation procedures.

Wrist Disarticulation Amputation

The advantages of the wrist disarticulation level amputation are the following:

- Full forearm rotation is preserved when the distal radioulnar joint (DRUJ) is preserved
- There is no risk of impingement of the distal radius and ulna as seen in transradial amputations
- The large surface of the distal radius can allow weight-bearing through the terminal end
- The long sensate residual limb increases functional length
- It is a better platform for the self-suspension of the prosthesis

The main disadvantage, historically, has been limited prosthesis options due to the very short working length between the end of the residual limb and the terminal device, while attempting to achieve an acceptable limb length and cosmetic result. A survey of United States surgeons conducted by Tooms in 1972, prior to the introduction of modern wrist components, indicated a preference for distal transradial amputations over wrist disarticulations. [149] However, more recent advances in prosthesis design and materials have greatly improved function for the wrist disarticulation patient. [150]

Transradial Amputation

The transradial level amputation is the most common upper extremity amputation. [59] This level of amputation also has the highest prosthesis acceptance rates in the upper limb. In distal transradial amputations, the long lever arm, available forearm rotation, and preserved shoulder and elbow function allow the patient to easily position the terminal device and prosthesis in space. The transradial amputation level is also cosmetically appealing due to the ability to fit body-powered or myoelectric prostheses with quick-disconnecting components, while still maintaining equal limb lengths. When practical, at least two thirds of the forearm should be maintained. Removal of 6cm to 8cm of bone is recommended in order to offer a robust soft-tissue envelope and permit a wide variety of prosthetic options. At least 5cm of residual ulna is required to allow for prosthetic fitting and elbow motion. [48,93] At this level, consideration should be made to transfer the distal biceps tendon to the proximal ulna. [85] The obvious prosthesis and mechanical advantages of the transradial level coupled with the superior prosthetic acceptance rates should prompt the surgeon to consider all reconstruction options, including free tissue transfer, to preserve an amputation at this level.

Elbow Disarticulation Amputation

Elbow disarticulation and distal transhumeral amputations are functionally quite similar, with both maintaining a flare to the distal humerus allowing improved suspension and improved rotational control of a prosthesis when compared to more proximal amputation levels. The major disadvantage of this level is the cosmetic appearance of length inequality with the prosthetic elbow joint distal compared to the contralateral normal elbow, or with the center of rotation placed lateral to the axis of the humerus to minimize the length inequality. [48] However, the improved suspension and rotational control will usually outweigh any cosmetic considerations for most patients. Consideration can be made to a shortening osteotomy of the humerus to improve the cosmetic result, but this is rarely indicated or performed.

Transhumeral Amputation

If the condyles of the distal humerus are not preserved, the ideal level for transhumeral amputation is approximately 3cm to 5cm proximal to the elbow joint. Adequately suspended and standard prosthetic components are expected at this level, but rotational control is decreased compared to the elbow disarticulation. Anterior angulation osteotomy, described by Neusel et al., can be performed to the distal humerus to allow a rotation-stable prosthesis and a free-moving shoulder. [151] The osteotomy is generally angulated 70 degrees anterior, and fixation with either inter-fragmentary screw fixation, or a compression plate and screw construct is performed.

In the proximal transhumeral amputation level, maintenance of length is critical, with most sources recommending preservation of at least 5cm to 7cm of length from the glenohumeral joint to preserve maximum function. As in the transradial amputation level, use of dermal substitutes, skin grafting, and local and free flaps are strongly considered to preserve adequate length. [152] Preservation of the deltoid, pectoralis major, and latissimus dorsi insertions to the humerus will allow for body-powered or myoelectric prosthesis control.

Shoulder Disarticulation Amputation

Amputation proximal to these named tendon insertions will functionally result in a shoulder disarticulation level amputation. In such instances, preservation of the humeral head will improve body contour and the cosmetic result, and may aid in force transmission. Unless stabilizing myodesis can be performed with available muscles, the unopposed pull of the rotator cuff muscles may result in painful or disfiguring abduction contracture or subluxation. As a result, glenohumeral arthrodesis, often as a planned, staged procedure, is strongly recommended. [48,93,150]

Surgical Muscle Balancing Strategies and Wound Closure Techniques

Myodesis, the process of attaching muscle tendon units directly to bone, is the surgical technique that provides the most stable construct over the distal bone end. This is typically achieved by suturing the muscle and/or tendon to the bone end, usually through drill tunnels, or less commonly, to periosteum. Myoplasty, attaching agonist muscles to antagonist muscles over the bone end to create physiologic tension, and myofascial closure, or suturing of muscle and fascia together, are less stable constructs that may be indicated when myodesis cannot be achieved for secondary muscles once primary myodesis is performed, or to contour remaining muscles prior to closure. While there is no data in the literature to support the superiority of myodesis over myoplasty, the expert consensus is to recommend myodesis in upper limb amputations to provide the most stable residual extremity, and to best isolate muscle signals and myoelectric prosthetic control.

Stabilizing the muscle tendon units of the residual extremity near physiologic tension at the time of amputation closure serves two main purposes. First, it serves to provide robust coverage over the distal bone end, providing comfortable padding for the prosthetic socket while preventing formation of painful bursa from mobile muscle units. Second, optimal contractility characteristics of the muscle are preserved, improving muscle signal quality, and maximizing myoelectric prosthetic control.

Consider local tissue flaps or free tissue transfer in the following cases:

- Preserve a functional shoulder joint and a transhumeral amputation level
- Preserve a functional elbow joint and a transradial amputation level
- Preserve a partial carpal or hand amputation level for future reconstructive efforts

When residual tissue flaps are inadequate to provide distal amputation coverage, and shortening will diminish prosthetic fitting and functional outcomes, additional soft tissue coverage options, including skin grafts and flaps, should be strongly considered. This is perhaps most important in shoulder and elbow joint preservation, as well as when optimizing length of the transhumeral and transradial amputation.

Studies have demonstrated that residual extremities can still have excellent function with a terminal skin graft, provided otherwise robust soft tissue coverage is present. Use of dermal substitutes as an adjunct to skin grafting have proven successful in the upper extremity, providing a more durable skin graft prosthetic interface, and allow direct surgical approaches for future reconstructive procedures. [153,154]

Use of microvascular free tissue transfer in well-selected patients to maximize length and provide durable soft tissue coverage has been successful in upper limb amputations. [152,155,156] An indication for free tissue transfer includes:

- Shoulder joint preservation by preserving a transhumeral amputation level
- Elbow joint preservation
- Preservation of bone greater than 7cm below the shoulder or elbow
- Preservation of a partial hand or carpal level amputation to allow for future reconstructive surgery

Relative indications include wrist joint preservation and skeletal preservation between 5cm and 7cm below the shoulder or elbow. While upper limb amputations requiring skin grafts or flaps will take longer to heal, the functional benefits of joint and/or length preservation will usually outweigh any delays in rehabilitation and prosthetic fitting.

Appendix H: Emerging Technology

At this time there are some new and emerging technologies in several areas including mechanical properties, control and attachment of the upper limb prosthesis. Improvements in mechanical properties have led to the development of myoelectric limbs. These limbs provide greater functionality, greater degrees of freedom and individually powered digits. They are excellent options for more distal amputations; however, the loss of an elbow or shoulder adds an extra challenge due to the need for more functional segments. As the technology continues to advance, the function, weight and durability of the upper extremity prosthesis will also improve.

Targeted Muscle Reinnervation (TMR)

Targeted Muscle Reinnervation (TMR) involves "transferring distally innervating peripheral nerves from muscles that are no longer present or functional to more proximal available or functional musculature." [157] This technique allows the creation of up to six sites for myoelectric control of prosthesis. Kuiken et al. reported three out of five patients were able to control an advanced myoelectric prosthesis following TMR; however, no long-term functional outcomes were addressed. [158] Some of the risks involved in TMR include neuromas of the dissected nerve, local wound problems and compromised limb/socket interface due to scarring or hypersensitivity. [157]

Osseo-integration

For the attachment of the prosthesis to the residual limb, osseo-integration holds some promise. It has been used in Europe for more than 20 years for both lower and upper extremities. [157] It involves inserting a titanium bolt to the distal bone of the residual limb. This allows the prosthesis to attach directly to the skeleton without the use of a socket. As a result the residual limb is free of skin complication and is available for tactile feedback. The inclusion criteria for this procedure as reported by Zlotolow & Kozin include difficulty with traditional prosthetic fitting, adequate bone stock to support the fixture and an uncompromised immune system. [157]

Lundberg et al. evaluated three patients with upper extremity amputation that underwent osseo-integration for prosthesis attachment. All three reported radical improvements in terms of functional restoration and prosthetic use following the procedure. The change went beyond functional improvement and represented improved quality of life. [159] Sierakowski et al. also looked at functional outcomes of three patients who had worn an osseo-integrated prosthesis for up to 13 years. All three patients reported some degree of pain at the bone-implant interface. Two of the three patients had good results with their prosthetic hand function in ADL as measured by the Jebsen Hand Function Test and the Moberg Pick-up Test. [160] Jonsson et al. evaluated 37 patients with osseo-integration. They did not report long-term functional outcomes but did report adverse outcomes that led to prosthesis abandonment. These included infection, loosening of the fixture, implant fracture, incomplete integration and removal of the implant. These adverse outcomes, along with concerns about superficial and deep infections, have limited broad acceptance of this procedure. [161]

Upper Limb Transplant

A non-prosthetic option for the person with upper limb amputation includes limb transplantation. As with osseo-integration this procedure is still experimental and has not gained wide acceptance. Petruzzo

et al. published the largest case series of upper limb transplantation (mostly hand transplants) based on an international registry. A total of 33 patients were followed-up at one to ten years. The Hand Transplant Score System (HTSS) and DASH were used to assess function. [162] Both Petruzzo et al. and Cavadas et al. reported improvements in function in people with both bilateral and unilateral transplants. [162,163] Petruzzo et al. also stated that quality of life improved in more than 75 percent of patients; however, they did not report how that was measured. [162]

Petruzzo et al. also reported negative outcomes and adverse effects among the patients with hand transplants. [162] Loss of the graft occurred in ten of 33 patients; seven of ten lost the graft due to non-compliance with immunosuppressive regimens. Non-compliance was mostly due to inability to afford the cost. At least one rejection episode occurred in 28 patients (85 percent) in the first year following transplant; these were reversible in all compliant patients when promptly reported and treated. Risks associated with transplantation include immunosuppression issues, metabolic derangements, neoplasms and death. In addition, the restoration of pre-amputation levels of function is not likely. [157]

It is important to have a systematic way to deal with current and emerging technologies. It is recommended that the VA/DoD amputation care leadership develop and disseminate to all levels of the patient amputation care system uniform (if not formal) evaluations or technology assessments for current and emerging technologies. These assessments would address the technical specifications and limitations of the technology being reviewed. The characteristics of a patient for whom the technology may or may not be appropriate include physical features (e.g., stump length required for deployment of the technology), patient's goals which are consistent with the functional capabilities of the technology (e.g., the patient desires an appropriate level of manual dexterity for a robotic device capable of delivering it), and ability and willingness to train for the new device (e.g., dedication to a long period of retraining for a complicated device) and should be addressed in a uniform way.

The patient with an upper limb amputation should be provided with a medium to receive up to date information on all available treatment options, the risks involved with each and the ability to ask questions about each of these. The care team should then work with the patient in the shared decision making process to determine an appropriate plan of care based on personal and clinical goals. An educated patient, and one who is involved in the selection process, is more likely to be successful in their short and long term goals and continue as a productive member of society.

Appendix I: Control Strategies for Body-Powered and Externally Powered Prostheses

Control of a Body-Powered Prosthesis

A body-powered or cable driven prosthesis is controlled by one's own body motions. Depending on the level of amputation, gross muscle movements are captured by a cable traversing from a harness to the terminal device. [67,68] Specific combinations of proximal motions produce tension through the cable that results in prosthetic function.

For a transradial amputation patient, glenohumeral flexion and scapular protraction will produce terminal device function. It is important to train the patient to minimize motions of the contralateral shoulder and scapula to allow for optimal control of a unilateral prosthesis. [67]

For a transhumeral amputation patient, the cable from the harness to terminal device will pass through an anchor(s) near the elbow joint. Glenohumeral flexion and scapular protraction will produce elbow flexion when the elbow is unlocked and terminal device open or closed, depending on the type of terminal device used (voluntary open or voluntary close). [67,68] Locking and unlocking of the elbow unit is captured through a strap attached to the harness and routed to the anterior aspect of the shoulder into the elbow unit. The application of tension through the locking strap locks the elbow and unlocks the elbow. Locking the elbow unit in various positions is achieved with oblique glenohumeral extension of the residual limb and scapular depression. [67] To unlock the elbow, the locking strap must recoil first and then the same motion for locking is used to unlock. [67] The elbow will not lock if tension has not been removed from the locking strap which is achieved through scapular elevation with the shoulder in neutral or slightly flexed. For new users, glenohumeral abduction may be exaggerated during glenohumeral extension and scapular depression to lock or unlock the elbow however as proficiency improves abduction will be used less frequently. [67]

Control of an Externally Powered Prosthesis

An externally powered prosthesis is one characterized by at least one motorized joint, powered through a battery, and actuated by the user by means of one or more control inputs. The most common control inputs for externally powered prostheses are EMG (electromyography) surface electrodes embedded into the socket. Externally powered prostheses that utilize EMG electrodes are commonly referred to as "myoelectric" prostheses. The EMG electrodes can be thought of as antennae that pick up the electrical signal given off by muscle tissue as it contracts. These signals are then amplified and converted into commands used to control the movement of a given motorized joint. Adjustments and programming are possible using various software packages, specific to the prosthesis product being used. It is important to understand that EMG sites are not required in order to consider externally powered components. Other control inputs, such as force sensitive resistors (FSRs), linear transducers and toggle switches, to name a few, are available to increase the potential for using externally powered joints. These other input devices can also be used in conjunction with EMG inputs, or each other, to allow the simultaneous control of two joints or functions. Depending on the level of amputation, types of components and number of available "joints" that make up the myoelectric prosthesis, various control strategies may be utilized. The control strategy is the method used to translate the user's intent, with regards to operating the prosthesis, by converting that intention into an electric signal and using that electric signal to actuate a particular motion of a powered joint. There are various control configurations that can be programmed into the prosthesis by the prosthetist with input from the patient and therapist. They include sequential, and/or simultaneous, control strategies.

Sequential control refers to a system where each joint is controlled by the same input signals and the user must cycle through each "mode" (for example, "hand mode," "wrist mode," or "elbow mode"), to get to the joint motion they wish to control. To switch from one mode to another, the control

configuration may involve co-contraction of two myosites, use of a hard/fast versus a soft/slow contraction, or may be set to automatically switch to a specific mode after a predetermined time delay.

Simultaneous control refers to the use of additional control inputs that can be designated for specific movements. The most common example is that of a powered transhumeral prosthesis that uses a linear transducer to control a powered elbow and two antagonistic myosites that are programmed to control the powered terminal device and/or wrist. This set-up allows the user to simultaneously activate the elbow with the terminal device or wrist, since the elbow is always active. Control of the wrist and terminal device would be navigated using a sequential strategy as described above.

New advancements, such as EMG pattern recognition software, are available and can improve the ability of a patient with upper limb amputation to obtain more intuitive control of externally powered prostheses. Pattern recognition systems utilize an array of numerous surface EMG electrodes and are capable of discerning more diverse muscle contraction patterns, as compared to the traditional single-site or dual-site set ups. The patterns can be differentiated and assigned to specific motor commands of the externally powered prosthesis using computer software.

Other advancements in control strategies will increase proportionally with advancements in electronic and bioengineering technologies. It is important for the care team to stay current with what is commercially available to select the control option that is functionally and financially best suited for the patient to have successful outcomes.

Appendix J: Preparatory Prosthesis Recommendations

The preparatory prosthesis concept has been utilized in upper extremity fittings for over 30 years and improves the chances for a positive outcome. [88] The preparatory prosthesis can be used while the residual limb is still healing/maturing to decrease edema, allow the patient to improve wear tolerance, commence the prosthetic training program, and experiment with different component options to help determine the most appropriate final prosthetic prescription, prior to definitive socket fabrication. Use of a preparatory prosthesis often results in a better fit with the definitive prosthesis. [84,164]

In order to trial various parts, it is necessary to have access to the various components for each patient to trial. The term "limb bank" has been described by Brenner et al. as "a collection of electronic components representing a cross section of commercially available electronic hardware." [164] The "limb/components bank" can be expanded to include various body-powered components as well, such as various mechanical hooks, hands and wrists. In many cases, a limb bank may not be available however; most manufacturers of upper limb prosthetic components offer the option of ordering a component for period of trial use.

Table J-1. Prosthesis Recommendations for the Wrist Disarticulation Level

Wrist Disarticulation Level
Electric* • Flexible thermoplastic inner socket, one-way mini-expulsion valve, rigid thermoplastic frame • Anatomically contoured, self-suspending suction/evaporative moisture donning technique • Myoelectric control, dual-site with two viable EMG outputs (other control options are used for patients who do not have two myosites) • Preparatory prosthesis used until the residual limb can sustain greater pressures from the tighter fitting prosthesis • Due to the lack of quick disconnect capability, terminal devices must be associated with separate sockets and frames, i.e., microprocessor-controlled hand prosthesis, microprocessor-controlled powered prehensor prosthesis, microprocessor-controlled work hook prosthesis **Body-Powered** • Fit concurrent with definitive fabrication of electric prosthesis • Flexible thermoplastic inner socket, one-way mini-expulsion valve, rigid thermoplastic frame • Anatomically contoured, self-suspending suction/evaporative moisture donning technique • Titanium VO hook, VO hand, titanium VC hook, stainless-steel disconnect locking wrist, limited friction cable • Preparatory prosthesis used until the residual limb can sustain greater pressures from the tighter fitting prosthesis
EMG: electromyographic VC: voluntary closing VO: voluntary opening *Multiple socket/frames required because of a lack of quick disconnect capability: microprocessor-controlled hand prosthesis; microprocessor-controlled powered prehensor prosthesis; and microprocessor-controlled work hook prosthesis.

Table J-2. Prosthesis Recommendations for the Transradial Level

Transradial Level
Electric* • Flexible thermoplastic inner socket, rigid thermoplastic frame • Anatomically contoured, self-suspending with reduced friction donning sock technique, dynamic muscle-contoured interface with ¾ modification for transradial level • Myoelectric control, dual-site, TD/electric wrist rotator switching (other control options are used for patients who do not have two myosites) • Multiple interchangeable TDs through quick disconnect collar: microprocessor-controlled hand; microprocessor-

Transradial Level
controlled prehensor; microprocessor-controlled work hook with locking wrist flexion • Preparatory used until the residual limb can sustain greater pressures from the tighter fitting prosthesis **Body-Powered** • Flexible thermoplastic inner socket, one-way removable expulsion valve, rigid thermoplastic frame, outside locking hinges • Anatomically contoured self-suspension (if epicondyles are present) with reduced friction donning sock technique or evaporative moisture technique • Shoulder saddle/chest strap harness • Titanium VO hook, VO hand, stainless-steel quick disconnect locking wrist, limited friction cable, wrist flexion unit • Preparatory prosthesis used until the residual limb can sustain greater pressures from the tighter fitting prosthesis
TD: terminal device VO: voluntary opening

Table J-3. Prosthesis Recommendations for the Elbow Disarticulation Level [85]

Elbow Disarticulation Level
Hybrid • Flexible thermoplastic inner socket, one-way removable expulsion valve, rigid thermoplastic frame, outside locking hinges • Anatomically contoured, self-suspension (if epicondyles are present) with reduced friction donning sock technique or evaporative moisture technique • Shoulder saddle / chest strap harness • Myoelectric control, dual-site, TD/electric wrist rotator switching (other control options are used for patients who do not have two myosites) • Multiple interchangeable TDs through quick disconnect collar: microprocessor-controlled hand; microprocessor-controlled prehensor; microprocessor-controlled work hook with locking wrist flexion • Preparatory prosthesis used until the residual limb can sustain greater pressures from the tighter fitting prosthesis **Body-Powered** • Flexible thermoplastic inner socket, rigid thermoplastic frame • Anatomically contoured self-suspension with reduced friction donning sock technique, dynamic muscle-contoured interface with ¾ modification for trans-radial level • Preparatory prosthesis used until the residual limb can sustain greater pressures from the tighter fitting prosthesis
TD: terminal device VC: voluntary closing VO: voluntary opening

Table J-4. Prosthesis Recommendations for the Transhumeral Level

Transhumeral Level
Electric* • Flexible thermoplastic inner socket, one-way removable expulsion valve, rigid thermoplastic frame • Anatomically contoured interface with reduced friction donning sock technique • Shoulder saddle/chest strap harness • Microprocessor-controlled electric elbow unit; linear transducer control of elbow allows simultaneous control with myoelectric TDs or wrist rotator • Myoelectric control, dual-site, TD/electric wrist rotator switching (other control options are used for patients who do not have two myosites) • Multiple interchangeable TDs through quick disconnect collar: microprocessor-controlled hand; microprocessor-controlled prehensor; microprocessor-controlled work hook with locking wrist flexion • Preparatory used until the residual limb can sustain greater pressures from the tighter fitting prosthesis **Body-Powered** • Flexible thermoplastic inner socket, one-way removable expulsion valve, rigid thermoplastic frame

Transhumeral Level
• Anatomically contoured interface with reduced friction donning sock technique • Shoulder saddle/chest strap harness • Lift-assist enhanced elbow unit • Titanium VO hook, VO hand, stainless-steel quick disconnect locking wrist, limited friction cable, wrist flexion unit. • Preparatory prosthesis used until the residual limb can sustain greater pressures from the tighter fitting prosthesis
TD: terminal device VO: voluntary opening

Appendix K: Control Training for Body-Powered and Externally Powered Prostheses

Figure K-1. Controls Training for Body-Powered Prosthesis by Level of Amputation

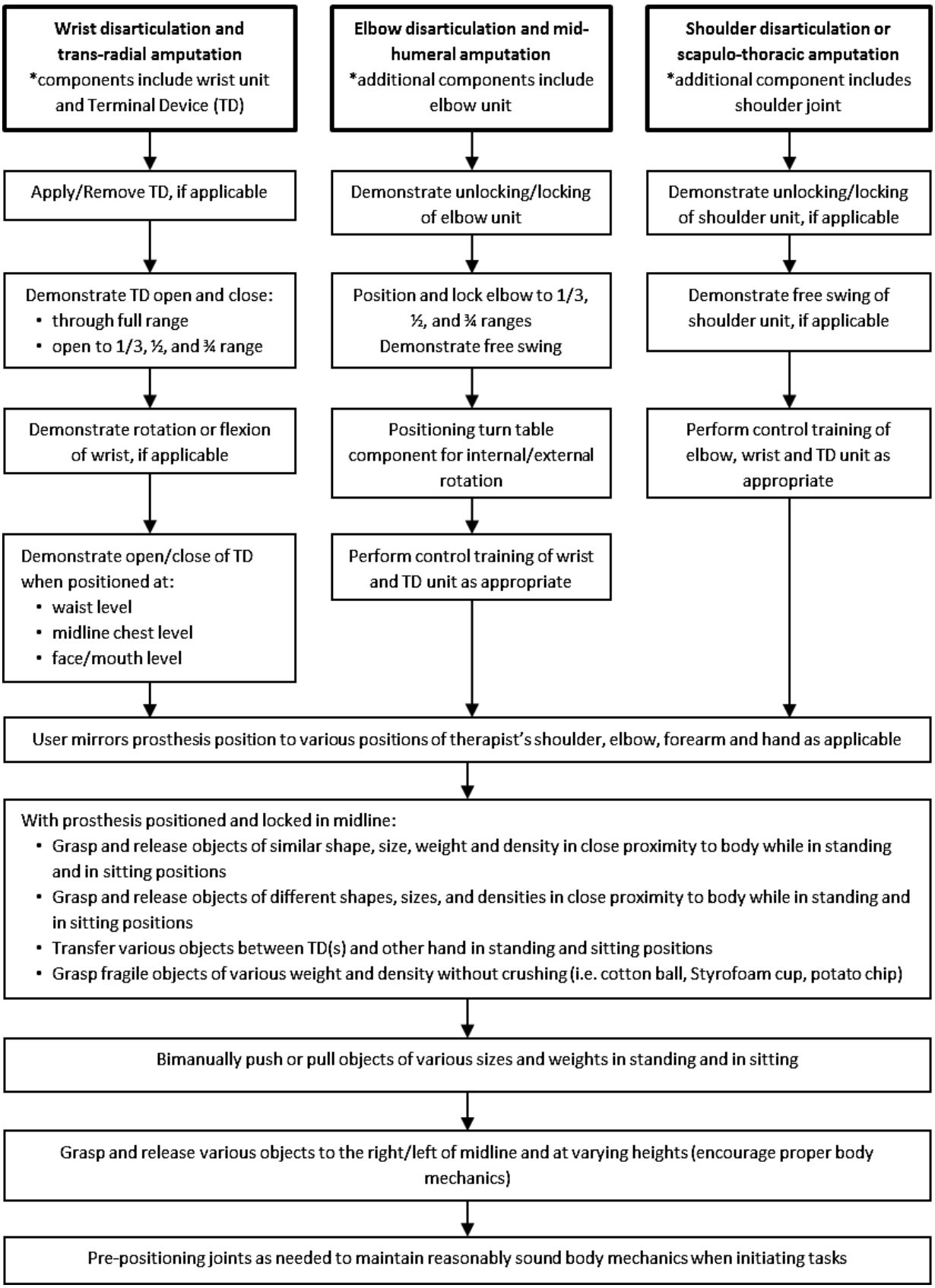
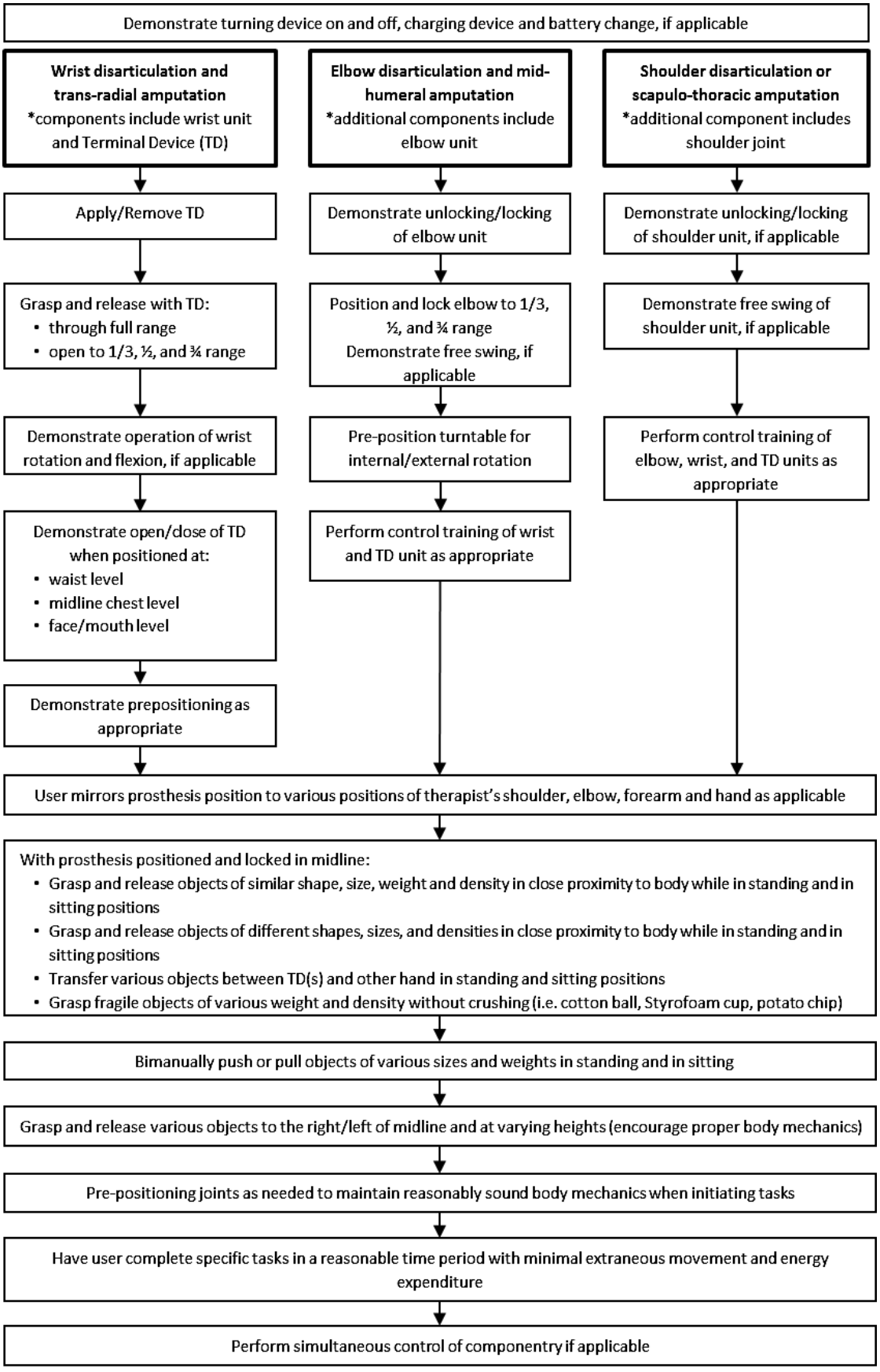


Figure K-2. Controls Training for Externally Powered Prosthesis by Level of Disarticulation



Appendix L: Evidence Tables

Table L-1. Guideline Recommendations, Supporting Evidence and Grade

Recommendations	Sources of Evidence	Certainty of Net Benefit	Magnitude of Net Benefit	GRADE
Core 1: The Care Team Approach				
1. An interdisciplinary amputation care team (care team) approach, including the patient, family and/or caregiver(s), is recommended in the management of all patients with upper extremity amputation.	Expert Opinion	Low	Substantial	EO
2. Care teams should communicate on a regular basis to facilitate integration of a comprehensive treatment plan.	Expert Opinion	Low	Substantial	EO
Core 2: Comprehensive Interdisciplinary Assessments				
3. Comprehensive interdisciplinary assessments and reassessments should be completed during each of the first three phases of care (perioperative, pre-prosthetic and prosthetic training).	Expert Opinion	Low	Substantial	EO
4. Annual comprehensive interdisciplinary screening should be conducted for all patients with an upper extremity amputation throughout lifelong care.	Expert Opinion	Low	Substantial	EO
5. Functional status measures should be utilized during assessments and reassessments throughout all phases of care to document outcomes and monitor the efficacy of rehabilitation.	Expert Opinion Huckabay, 1980 [47] Resnik & Borgia, 2012 [60] Heinemann et al. 2014 [61]	Fair	Substantial	C
Core 3: Patient-Centered Care				
6. A shared decision making model, driven by patient goals, should be used throughout the phases of care to ensure patient autonomy.	Expert Opinion	Low	Substantial	EO
7. A comprehensive, interdisciplinary, patient-centered rehabilitation plan should be developed as early as possible and updated throughout all phases of care based on patient's progress, changes in functional status, emerging needs, and goals.	Expert Opinion	Low	Substantial	EO
8. Patient-centered physical and functional rehabilitation interventions should be initiated based on the rehabilitation plan and the patient's physical and psychological status.	Expert Opinion	Low	Substantial	EO
9. Various types of pain following upper limb loss should be managed appropriately and individually throughout all phases using pharmacological	Expert Opinion	Low	Substantial	EO

Recommendations	Sources of Evidence	Certainty of Net Benefit	Magnitude of Net Benefit	GRADE
and non-pharmacological treatment options.				
10. The care team should provide appropriate education and informational resources to patients, family and caregiver(s) throughout all phases of care.	Expert Opinion	Low	Substantial	EO
11. The care team should facilitate early involvement of a trained peer visitor.	Wegener et al 2009 [81]	Fair	Substantial	C
Perioperative Phase				
12. The decision for amputation should be made based upon accepted surgical and medical standards of care.	Expert Opinion	Low	Substantial	EO
13. Communication must occur between the surgical and non-surgical members of the care team in order to optimize surgical and functional outcomes.	Expert Opinion	Low	Substantial	EO
14. The care team should ensure that the patient is optimized for rehabilitation to enhance functional outcomes.	Expert Opinion	Low	Substantial	EO
15. Following amputation, the care team should ensure that the patient has achieved his or her highest level of functional independence without a prosthesis.	Expert Opinion	Low	Substantial	EO
Pre-Prosthetic Phase				
16. The care team should ensure that patients undergo pre-prosthetic training to help determine the most appropriate type of device to achieve functional goals.	Expert Opinion	Low	Substantial	EO
17. Once the appropriate type of prosthesis is identified, the care team should write a prosthetic prescription including all necessary components.	Expert Opinion	Low	Substantial	EO
18. Initiate upper extremity prosthetic fitting as soon as the patient can tolerate mild pressure on the residual limb.	Expert Opinion	Low	Substantial	EO
Prosthetic Training Phase				
19. Upon delivery of the prescribed prosthesis, or change in the control scheme or componentry, the care team must engage the patient in prosthetic training and education.	Expert Opinion	Low	Substantial	EO
20. The care team should frequently reassess the patient's prosthetic fit and function throughout the prosthetic training phase and modify as appropriate.	Expert Opinion	Low	Substantial	EO
21. The final check out of the prosthesis should take place with appropriate members of the care team to verify that the prosthesis is acceptable.	Expert Opinion	Low	Substantial	EO

Recommendations	Sources of Evidence	Certainty of Net Benefit	Magnitude of Net Benefit	GRADE
22. The care team should offer active prosthesis users at least one back up device to ensure consistency with function.	Expert Opinion	Low	Substantial	EO
23. Prescription of activity specific or alternate design prostheses may be considered, dependent upon the patient's demonstration of commitment, motivation, and goals.	Expert Opinion	Low	Substantial	EO
Lifelong Care				
24. Upon completion of functional training, and to ensure continuity, the care team should coordinate patient transition into the lifelong care phase.	Expert Opinion	Low	Substantial	EO
25. The care team should provide routine, scheduled follow-up contact for patients with upper extremity amputation at a minimum of every 12 months, regardless of prosthetic use or non-use.	Expert Opinion	Low	Substantial	EO
26. Upon notification of patient relocation to a new catchment area, the care team should communicate with the receiving care team and coordinate transition of patient care.	Powell & Tahan, 2008 [94]	Low	Fair	EO
27. The care team should provide education to the patient, family, and caregiver(s) regarding advancements in technology, surgical, and rehabilitation procedures related to the management of upper extremity amputation.	Biddiss & Chau, 2007 [42]	Low	Substantial	EO

Appendix M: Participant List

Laurel Adams-Koss, OT Occupational Therapist James A. Haley Veterans' Hospital Tampa, FL	**Dave Bleacher, CP** Prosthetist Walter Reed National Military Medical Center Bethesda, MD
MAJ Jocelyn Blackwell, MD Primary Care Physician Carl R. Darnall Army Medical Center Fort Hood, TX	**Erin Butler, MSW** Social Worker San Francisco VA Medical Center San Francisco, CA
Carla Cassidy, CRNP, MSN, M.Ed Director VA/DoD Evidence-Based CPG Program Office of Quality, Safety and Value Department of Veterans Affairs Washington, DC	**MAJ Jay Clasing, PhD, OTR, CPE (Co-Chair)** Occupational Therapist U.S. Army Public Health Command Aberdeen Proving Grounds, MD
Ernest Degenhardt, COL USA (Ret.) MSN, RN, ANP, FNP Chief, Office of Evidence Based Practice Clinical Performance Directorate US Army Medical Command Ft. Sam Houston, TX	**Corinne K.B. Devlin MSN, RN, FNP-BC** Family Nurse Practitioner Chronic Disease Clinical Practice Guideline Coordinator US Army Medical Command Quality Management Division, Office of Evidence Based Practice Ft. Sam Houston, TX
David F. Drake, MD Director, Interventional Pain Clinic Hunter Holmes McGuire VA Medical Center Richmond, VA	**Christopher Fantini, MSPT, CP, BOCO** Prosthetist/Orthotist Network 3 Prosthetics Services NY VA Medical Center New York, NY
Louise Hassinger, CP Prosthetist Walter Reed National Military Medical Center Bethesda, MD	**Jeffrey T. Heckman, DO** Medical Director, Regional Amputation Center VA Puget Sound Health Care System Seattle, WA
Patty Jackson, RN, CRRN RN/CRRN Polytrauma Lexington VA Medical Center Lexington, KY	**Gail Latlief, DO** Physiatrist James A. Haley Veterans' Hospital Tampa, FL
Peggy Merchak, MA, OTR, CHT Occupational Therapist Minneapolis VA Health Care System Minneapolis, MN	**Heather Miller, MEd., C.T.R.S.** Recreation Therapist Center for the Intrepid Brooke Army Medical Center Ft. Sam Houston, TX
MAJ Sarah Mitsch, OTR/L Occupational Therapist Womack Army Medical Center Fort Bragg, NC	**Elise Moore, LICSW** Poly-trauma Case Manager Veteran's Health Administration Washington, DC

CDR George Nanos, MD Orthopedic Surgeon (hand) Walter Reed National Military Medical Center Bethesda, MD	**Stacey Pollack, PhD** Clinical Psychologist Department of Veterans Affairs Central Office Washington, DC
Cindy Poorman, MSPT (Co-Chair) Physical Therapist Rehabilitation National Program Office VA Central Office Field Based in Denver, CO	**Jay Pyo, DO** Medical Director, Polytrauma Amputation Network Site Physical Medicine and Rehabilitation VA San Diego Healthcare System San Diego, CA
Billie J. Randolph, PT, PhD (Co-Chair) Deputy Director, Extremity Trauma and Amputation Center of Excellence Department of Veterans Affairs Washington, DC	**Linda Resnik, PT, PhD** Research Health Scientist Providence VA Medical Center Providence, RI
M. Eric Rodgers, PhD, FNP, BC Acting Director VA/DoD Evidence-Based CPG Program Office of Quality, Safety and Value Department of Veterans Affairs Washington, DC	**LCDR Robert Selvester, MD** Family Practice Naval Air Station Corpus Christi Corpus Christi, TX
Lisa Smurr Walters, MS, OTR, CHT (Co-Chair) Occupational Therapist Center For the Intrepid Brooke Army Medical Center San Antonio, TX	**René M. Sutton, BS, HCA** Educational Program Specialist Evidence-Based Clinical Practice Guidelines Office of Quality, Safety and Value Department of Veterans Affairs Washington, DC
Jorge Torres, APN Behavioral Specialist Brooke Army Medical Center Ft. Sam Houston, TX	**Joseph Webster, MD (Co-Chair)** Medical Director Hunter Holmes McGuire VA Medical Center Richmond, VA
Alicia White, PT, DPT Physical Therapist/Researcher Center For the Intrepid Brooke Army Medical Center Ft. Sam Houston, TX	

References

1. Ziegler-Graham K, MacKenzie EJ, Ephraim PL, Travison TG, Brookmeyer R. Estimating the prevalence of limb loss in the United States: 2005 to 2050. *Arch Phys Med Rehabil.* Mar 2008;89(3):422-429.

2. National Limb Loss Information Center. *Limb loss in the United States: Amputation statistics by cause.* Knoxville, TN: Amputee Coalition of America; 2008. http://www.amputee-coalition.org/fact_sheets/amp_stats_cause.pdf.

3. Extremity Trauma and Amputation Center of Excellence. Patient care statistics. *HQ US Army Medical Command, JBSA*. Ft. Sam Houston, TX: 2014.

4. Yancosek KE. Management of dominant upper extremity injuries: A survey of practice patterns. *J Hand Ther.* Jan-Mar 2012;25(1):79-87; quiz 88.

5. U.S. Department of Veteran Affairs, Department of Defense. Guideline for guidelines. Veterans Health Administration, Office of Quality & Performance, Evidence Review Subgroup; Revised April 10, 2013.

6. Society for Medical Decision Making Committee on Standardization of Clinical Algorithms. Proposal for clinical algorithm standards. *Med Decis Making.* Apr-Jun 1992;12(2):149-154.

7. VATAP. *A systematic review of clinical predictors of outcomes in adults with recent major lower limb amputation.* VA Technology Assessment Program; 2005. http://www.va.gov/VATAP/amputation_topic.htm.

8. Potter BK, Burns TC, Lacap AP, Granville RR, Gajewski DA. Heterotopic ossification following traumatic and combat-related amputations. Prevalence, risk factors, and preliminary results of excision. *J Bone Joint Surg Am.* Mar 2007;89(3):476-486.

9. Radomski MV, Latham CAT. *Occupational therapy for physical dysfunction.* Lippincott Williams & Wilkins; 2008.

10. Fasoli S. Assessing roles and competence. In: MV Radomski, CAT Latham, eds. *Occupational therapy for physical dysfunction*. Philadelphia, PA: Lippincott Williams & Wilkins; 2014.

11. Pierce S. Restoring functional and community mobility. In: MV Radomski, CAT Latham, eds. *Occupational therapy for physical dysfunction*. Philadelphia, PA: Lippincott Williams & Wilkins; 2014.

12. Hanley MA, Ehde DM, Jensen M, Czerniecki J, Smith DG, Robinson LR. Chronic pain associated with upper-limb loss. *Am J Phys Med Rehabil.* Sep 2009;88(9):742-751; quiz 752, 779.

13. Jensen MP, Smith DG, Ehde DM, Robinsin LR. Pain site and the effects of amputation pain: Further clarification of the meaning of mild, moderate, and severe pain. *Pain.* Apr 2001;91(3):317-322.

14. Marshall HM, Jensen MP, Ehde DM, Campbell KM. Pain site and impairment in individuals with amputation pain. *Arch Phys Med Rehabil.* Aug 2002;83(8):1116-1119.

15. Ostlie K, Franklin RJ, Skjeldal OH, Skrondal A, Magnus P. Musculoskeletal pain and overuse syndromes in adult acquired major upper-limb amputees. *Arch Phys Med Rehabil.* Dec 2011;92(12):1967-1973.e1961.

16. Jensen TS, Krebs B, Nielsen J, Rasmussen P. Immediate and long-term phantom limb pain in amputees: Incidence, clinical characteristics and relationship to pre-amputation limb pain. *Pain.* Mar 1985;21(3):267-278.

17. Boothby J, Thorn B, Stroud M, Jensen M. *Psychosocial factors in pain: Critical perspectives; coping with pain.* New York, NY: The Guilford Press; 1999.

18. Jensen MP, Karoly P, Harris P. Assessing the affective component of chronic pain: Development of the pain discomfort scale. *J Psychosom Res.* 1991;35(2-3):149-154.

19. Sullivan MJ, Rodgers WM, Kirsch I. Catastrophizing, depression and expectancies for pain and emotional distress. *Pain.* Mar 2001;91(1-2):147-154.

20. Cansever A, Uzun O, Yildiz C, Ates A, Atesalp AS. Depression in men with traumatic lower part amputation: A comparison to men with surgical lower part amputation. *Mil Med.* Feb 2003;168(2):106-109.

21. Fukunishi I, Sasaki K, Chishima Y, Anze M, Saijo M. Emotional disturbances in trauma patients during the rehabilitation phase: Studies of posttraumatic stress disorder and alexithymia. *Gen Hosp Psychiatry.* Mar 1996;18(2):121-127.

22. Horgan O, MacLachlan M. Psychosocial adjustment to lower-limb amputation: A review. *Disabil Rehabil.* Jul 22-Aug 5 2004;26(14-15):837-850.

23. Koren D, Norman D, Cohen A, Berman J, Klein EM. Increased PTSD risk with combat-related injury: A matched comparison study of injured and uninjured soldiers experiencing the same combat events. *Am J Psychiatry.* Feb 2005;162(2):276-282.

24. Desmond DM, MacLachlan M. Psychosocial perspectives on postamputation rehabilitation: A review of disease, trauma, and war related literature. *Critical Reviews™ in Physical and Rehabilitation Medicine.* 2004;16(2).

25. Epstein RA, Heinemann AW, McFarland LV. Quality of life for veterans and service members with major traumatic limb loss from Vietnam and OIF/OEF conflicts. *J Rehabil Res Dev.* 2010;47(4):373-385.

26. Livneh H, Antonak RF, Gerhardt J. Psychosocial adaptation to amputation: The role of sociodemographic variables, disability-related factors and coping strategies. *Int J Rehabil Res.* Mar 1999;22(1):21-31.

27. Hanley MA, Jensen MP, Ehde DM, Hoffman AJ, Patterson DR, Robinson LR. Psychosocial predictors of long-term adjustment to lower-limb amputation and phantom limb pain. *Disabil Rehabil.* Jul 22-Aug 5 2004;26(14-15):882-893.

28. Jensen MP, Ehde DM, Hoffman AJ, Patterson DR, Czerniecki JM, Robinson LR. Cognitions, coping and social environment predict adjustment to phantom limb pain. *Pain.* Jan 2002;95(1-2):133-142.

29. Williams RM, Ehde DM, Smith DG, Czerniecki JM, Hoffman AJ, Robinson LR. A two-year longitudinal study of social support following amputation. *Disabil Rehabil.* Jul 22-Aug 5 2004;26(14-15):862-874.

30. Beck A, Steer R, Brown G. *Manual for the beck depression inventory-II.* San Antonio, TX: The Psychological Corporation; 1996.

31. Steer RA, Cavalieri TA, Leonard DM, Beck AT. Use of the beck depression inventory for primary care to screen for major depression disorders. *Gen Hosp Psychiatry.* Mar-Apr 1999;21(2):106-111.

32. Beck A, Steer R. *Beck anxiety inventory manual.* San Antonio,TX: The Psychological Corporation, Harcourt Brace & Company; 1993.

33. Beck AT, Epstein N, Brown G, Steer RA. An inventory for measuring clinical anxiety: Psychometric properties. *J Consult Clin Psychol.* Dec 1988;56(6):893-897.

34. Blanchard EB, Jones-Alexander J, Buckley TC, Forneris CA. Psychometric properties of the PTSD checklist (pcl). *Behav Res Ther.* Aug 1996;34(8):669-673.

35. Ware JE, Kosinski M, Dewey JE, Gandek B. *SF-36 health survey: Manual and interpretation guide.* Quality Metric Inc.; 2000.

36. Ware Jr JE, Sherbourne CD. The mos 36-item short-form health survey (SF-36): I. Conceptual framework and item selection. *Medical care.* 1992:473-483.

37. Millon T, Green CJ, Meagher RB. *Millon behavioral health inventory manual.* Interpretive Scoring Systems Minneapolis, MN; 1982.

38. Jensen MP, Nielson WR, Turner JA, Romano JM, Hill ML. Readiness to self-manage pain is associated with coping and with psychological and physical functioning among patients with chronic pain. *Pain.* Aug 2003;104(3):529-537.

39. Miller WR, Rollnick S. *Motivational interviewing: Preparing people for change.* Guilford press; 2002.

40. Rybarczyk BD, Nyenhuis DL, Nicholas JJ, Schulz R, Alioto RJ, Blair C. Social discomfort and depression in a sample of adults with leg amputations. *Arch Phys Med Rehabil.* Dec 1992;73(12):1169-1173.

41. Donovan-Hall MK, Yardley L, Watts RJ. Engagement in activities revealing the body and psychosocial adjustment in adults with a trans-tibial prosthesis. *Prosthet Orthot Int.* Apr 2002;26(1):15-22.

42. Biddiss EA, Chau TT. Upper limb prosthesis use and abandonment: A survey of the last 25 years. *Prosthet Orthot Int.* Sep 2007;31(3):236-257.

43. American Academy of Neurology. Assessment: Neuropsychological testing of adults. Considerations for neurologists. Report of the therapeutics and technology assessment subcommittee of the American Academy of Neurology. *Neurology.* Aug 1996;47(2):592-599.

44. Radomski M, Roberts P. Assessing context: Personal, social, cultural and payer-reimbursement factors. In: MV Radomski, CAT Latham, eds. *Occupational therapy for physical dysfunction*. Philadelphia, PA: Lippincott Williams & Wilkins; 2014.

45. Davis TC, Long SW, Jackson RH, et al. Rapid estimate of adult literacy in medicine: A shortened screening instrument. *Fam Med.* Jun 1993;25(6):391-395.

46. Gagné R, Driscoll M. *Essentials of learning for instruction.* 2nd ed. Englewood Cliffs, NJ: Prentice Hall College Div; 1988.

47. Huckabay LM. A strategy for patient teaching. *Nursing Admin Quart.* 1980;4(2):47-54.

48. Smith D, Michael J, Bowker J, editors. *Atlas of amputations and limb deficiencies: Surgical, prosthetic, and rehabilitation principles.* 3rd ed. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2004.

49. Department of Veterans Affairs, Department of Defense. VA/DoD clinical practice guideline for rehabilitation of lower limb amputation. Washington, DC; 2007.

50. Ritchie S, Wiggins S, Sanford A. Perceptions of cosmesis and function in adults with upper limb prostheses: A systematic literature review. *Prosthet Orthot Int.* Dec 2011;35(4):332-341.

51. Bhaskaranand K, Bhat AK, Acharya KN. Prosthetic rehabilitation in traumatic upper limb amputees (an Indian perspective). *Arch Orthop Trauma Surg.* Sep 2003;123(7):363-366.

52. McFarland LV, Hubbard Winkler SL, Heinemann AW, Jones M, Esquenazi A. Unilateral upper-limb loss: Satisfaction and prosthetic-device use in veterans and servicemembers from Vietnam and OIF/OEF conflicts. *J Rehabil Res Dev.* 2010;47(4):299-316.

53. Ostlie K, Lesjo IM, Franklin RJ, Garfelt B, Skjeldal OH, Magnus P. Prosthesis rejection in acquired major upper-limb amputees: A population-based survey. *Disabil Rehabil Assist Technol.* Jul 2012;7(4):294-303.

54. Fisher K, Hanspal RS, Marks L. Return to work after lower limb amputation. *Int J Rehabil Res.* Mar 2003;26(1):51-56.

55. Dajpratham P, Tantiniramai S, Lukkapichonchut P, Kaewnaree S. Factors associated with vocational reintegration among the thai lower limb amputees. *J Med Assoc Thai.* Feb 2008;91(2):234-239.

56. Schoppen T, Boonstra A, Groothoff JW, van Sonderen E, Goeken LN, Eisma WH. Factors related to successful job reintegration of people with a lower limb amputation. *Arch Phys Med Rehabil.* Oct 2001;82(10):1425-1431.

57. Millstein S, Bain D, Hunter GA. A review of employment patterns of industrial amputees--factors influencing rehabilitation. *Prosthet Orthot Int.* Aug 1985;9(2):69-78.

58. Hill W, Kyberd P, Hermansson L, Hubbard S, Stavdahl O, Swanson S. Upper limb prosthetic outcome measures (ULPOM): A working group and their findings. 2009; Conference of the American Academy of Orthotists and Prosthetists.

59. Wright TW, Hagen AD, Wood MB. Prosthetic usage in major upper extremity amputations. *J Hand Surg Am.* Jul 1995;20(4):619-622.

60. Resnik L, Borgia M. Reliability and validity of outcome measures for upper limb amputation. *JPO: Journal of Prosthetics and Orthotics.* 2012;24(4):192-201.

61. Heinemann AW, Connelly L, Ehrlich-Jones L, Fatone S. Outcome instruments for prosthetics: Clinical applications. *Phys Med Rehabil Clin N Am.* Feb 2014;25(1):179-198.

62. Edwards A, Elwyn G. Inside the black box of shared decision making: Distinguishing between the process of involvement and who makes the decision. *Health Expect.* Dec 2006;9(4):307-320.

63. Esquenazi A, Meier RH, 3rd. Rehabilitation in limb deficiency. 4. Limb amputation. *Arch Phys Med Rehabil.* Mar 1996;77(3 Suppl):S18-28.

64. Pezzin LE, Dillingham TR, MacKenzie EJ. Rehabilitation and the long-term outcomes of persons with trauma-related amputations. *Arch Phys Med Rehabil.* Mar 2000;81(3):292-300.

65. Jelic. M, Eldar R. Rehabilitation following major traumatic amputation of lower limbs--a review. *Critical Reviews™ in Physical and Rehabilitation Medicine.* Dec 1 2003;15(3&4):18.

66. Royal College of Physicians. *Amputee rehabilitation: Recommended standards and guidelines.* London, United Kingdom: A report by the Working Party of the Amputee Medical Rehabilitation Society; September 1992.

67. Atkins DJ. Prosthetic training. In: DG Smith, JW Michael, JH Bowker, eds. *Atlas of amputations and limb deficiencies: Surgical, prosthetic, and rehabilitation principles*. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2004:275-284.

68. Smurr L, Yancosek K, Gulick K, et al. Occupational therapy for polytrauma casualty with limb loss. In: DG Smith, JW Michael, JH Bowker, eds. *Atlas of amputations and limb deficiencies: Surgical, prosthetic, and rehabilitation principles*. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2009:275-284.

69. Ayhan C, Unal E, Yakut Y. Core stabilisation reduces compensatory movement patterns in patients with injury to the arm: A randomized controlled trial. *Clin Rehabil.* Jan 2014;28(1):36-47.

70. Gerhards F, Florin I, Knapp T. The impact of medical, reeducational, and psychological variables on rehabilitation outcome in amputees. *Int J Rehabil Res.* 1984;7(4):379-388.

71. Ostojic L, Ostojic Z, Rupcic E, Punda-Basic M. Intermediate rehabilitation outcome in below-knee amputations: Descriptive study comparing war-related with other causes of amputation. *Croat Med J.* Oct 2001;42(5):535-538.

72. Alviar MJ, Hale T, Dungca M. Pharmacologic interventions for treating phantom limb pain. *Cochrane Database Syst Rev.* 2011(12):Cd006380.

73. Abbass K. Efficacy of gabapentin for treatment of adults with phantom limb pain. *Ann Pharmacother.* Dec 2012;46(12):1707-1711.

74. Turk DC, Okifuji A. Psychological factors in chronic pain: Evolution and revolution. *J Consult Clin Psychol.* Jun 2002;70(3):678-690.

75. Sherman RA, Sherman CJ, Parker L. Chronic phantom and stump pain among American veterans: Results of a survey. *Pain.* Jan 1984;18(1):83-95.

76. O'Halloran CM, Altmaier EM. The efficacy of preparation for surgery and invasive medical procedures. *Patient Educ Couns.* Feb 1995;25(1):9-16.

77. Butler DJ, Turkal NW, Seidl JJ. Amputation: Preoperative psychological preparation. *J Am Board Fam Pract.* Jan-Feb 1992;5(1):69-73.

78. Pandian G, Kowalske K. Daily functioning of patients with an amputated lower extremity. *Clin Orthop Relat Res.* Apr 1999(361):91-97.

79. Purk JK. Support groups: Why do people attend? *Rehabil Nurs.* Mar-Apr 2004;29(2):62-67.

80. Healio Orthotics/Prosthetics. *Support groups provide many benefits for amputees*. 2005; http://www.healio.com/orthotics-prosthetics/prosthetics/news/online/%7B997eb430-b141-427a-bc5b-b93567bae7d3%7D/support-groups-provide-many-benefits-for-amputees.

81. Wegener ST, Mackenzie EJ, Ephraim P, Ehde D, Williams R. Self-management improves outcomes in persons with limb loss. *Arch Phys Med Rehabil.* Mar 2009;90(3):373-380.

82. Bosse MJ, MacKenzie EJ, Kellam JF, et al. A prospective evaluation of the clinical utility of the lower-extremity injury-severity scores. *J Bone Joint Surg Am.* Jan 2001;83-a(1):3-14.

83. Bosse MJ, McCarthy ML, Jones AL, et al. The insensate foot following severe lower extremity trauma: An indication for amputation? *J Bone Joint Surg Am.* Dec 2005;87(12):2601-2608.

84. Fantini C. Prosthetic prescriptions for long transradial amputations. In: Douglas P Murphy, ed. *Fundamentals of amputation care and prosthetics*. New York, NY: Demos Medical Publishing; 2013.

85. Shawen S, Doukas W, Shrout J, et al. *Care of the combat amputee.* Washington, DC: Dept. of the Army, Borden Institute; 2009.

86. Dromerick AW, Schabowsky CN, Holley RJ, Monroe B, Markotic A, Lum PS. Effect of training on upper-extremity prosthetic performance and motor learning: A single-case study. *Arch Phys Med Rehabil.* Jun 2008;89(6):1199-1204.

87. Resnik L, Meucci MR, Lieberman-Klinger S, et al. Advanced upper limb prosthetic devices: Implications for upper limb prosthetic rehabilitation. *Arch Phys Med Rehabil.* Apr 2012;93(4):710-717.

88. Dakpa R, Heger H. Prosthetic management and training of adult upper limb amputees. *Current Orthopaedics.* 1997;11(3):193-202.

89. Silcox DH, 3rd, Rooks MD, Vogel RR, Fleming LL. Myoelectric prostheses. A long-term follow-up and a study of the use of alternate prostheses. *J Bone Joint Surg Am.* Dec 1993;75(12):1781-1789.

90. Atkins DJ. Adult upper limb prosthetic training. In: DG Smith, JW Michael, JH Bowker, eds. *Atlas of amputations and limb deficiencies: Surgical, prosthetic, and rehabilitation principles*. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2002.

91. Gaine WJ, Smart C, Bransby-Zachary M. Upper limb traumatic amputees. Review of prosthetic use. *J Hand Surg Br.* Feb 1997;22(1):73-76.

92. Mitsch S, Smurr L, Yancosek Y. Amputations and prosthetics. In: K Trombly, M Radomski, eds. *Occupational therapy for physical dysfunction*. 6th Ed. 2014:Manuscript in process.

93. Pasquina PF, Bryant PR, Huang ME, Roberts TL, Nelson VS, Flood KM. Advances in amputee care. *Arch Phys Med Rehabil.* Mar 2006;87(3 Suppl 1):S34-43; quiz S44-35.

94. Powell S, Tahan H. *CMSA core curriculum for case management.* 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2008.

95. Powell SK. Safe transitions are a team sport! *Prof Case Manag.* Sep-Oct 2008;13(5):247-249.

96. Agency for Health Research and Quality. The Effective Health Care Program stakeholder guide appendix d: Research questions & PICO(TS) 2011. http://www.ahrq.gov/clinic/epcpartner/stakeholderguide/.

97. Agency for Health Research and Quality. *Methods guide for effectiveness and comparative effectiveness reviews.* Rockville, MD: Agency for Health Research and Quality;2008. http://effectivehealthcare.ahrq.gov/index.cfm/search-for-guides-reviews-and-reports/?productid=318&pageaction=displayproduct.

98. *International classification of functioning, disability, and health* Geneva: World Health Organization;2001.

99. Cieza A, Brockow T, Ewert T, et al. Linking health-status measurements to the international classification of functioning, disability and health. *J Rehabil Med.* Sep 2002;34(5):205-210.

100. Cieza A, Geyh S, Chatterji S, Kostanjsek N, Ustun B, Stucki G. ICF linking rules: An update based on lessons learned. *J Rehabil Med.* Jul 2005;37(4):212-218.

101. Fayed N, Cieza A, Edmond Bickenbach J. Linking health and health-related information to the ICF: A systematic review of the literature from 2001 to 2008. *Disabil Rehabil.*33(21-22):1941-1951.

102. Hill W, Kyberd P, Hermansson L, et al. Upper limb prosthetic outcome measures (uplom): A working group and their findings. *Journal of Prosthetics & Orthotics.* 2009;Vol. 21(4S):69-P82

103. Lindner HY, Natterlund BS, Hermansson LM. Upper limb prosthetic outcome measures: Review and content comparison based on International Classification of Functioning, Disability and Health. *Prosthetics and Orthotics International.* Jun 2010;34(2):109-128.

104. Wright V. Prosthetic outcome measures for use with upper limb amputees: A systematic review of the peer-reviewed literature, 1970 to 2009. *Journal of prosthetics & orthotics.* 2009;21(4S).

105. Resnik L, Borgia M. Reliability and validity of outcome measures for upper limb amputation. *JPO: Journal of Prosthetics and Orthotics.* 2012;24(4):192-212

106. Resnik L, Borgia M. Responsiveness of outcome measures for upper limb prosthetic rehabilitation. *Prosthet Orthot Int.* In-Press.

107. Resnik L, Borgia M, Latlief G, Sasson N, Smurr-Walters L. Self-reported and performance-based outcomes using deka arm. *Journal of rehabilitation research and development.* Jun 2014;51(3):351-362.

108. Lindner HY, Langius-Eklof A, Hermansson LM. Test-retest reliability and rater agreements of assessment of capacity for myoelectric control version 2.0. *Journal of rehabilitation research and development.* Jul 2014;51(4):635-644.

109. Jarl G, Holmefur M, Hermansson LM. Test-retest reliability of the Swedish version of the orthotics and prosthetics users' survey. *Prosthetics and orthotics international.* Feb 2014;38(1):21-26.

110. Resnik L, Baxter K, Borgia M, Mathewson K. Is the unb test reliable and valid for use with adults with upper limb amputation? *J Hand Ther.* Oct-Dec 2013;26(4):353-359; quiz 359.

111. Resnik L, Adams L, Borgia M, et al. Development and evaluation of the activities measure for upper limb amputees. *Archives of physical medicine and rehabilitation.* Mar 2013;94(3):488-494 e484.

112. Lindner HY, Eliasson AC, Hermansson LM. Influence of standardized activities on validity of assessment of capacity for myoelectric control. *Journal of rehabilitation research and development.* 2013;50(10):1391-1400.

113. Ostlie K, Lesjo IM, Franklin RJ, Garfelt B, Skjeldal OH, Magnus P. Prosthesis use in adult acquired major upper-limb amputees: Patterns of wear, prosthetic skills and the actual use of prostheses in activities of daily life. *Disabil Rehabil Assist Technol.* Nov 2012;7(6):479-493.

114. Office of Inspector General Department of Veterans Affairs. Prosthetic limb care in VA facilities. 2012.

115. Jarl GM, Heinemann AW, Norling Hermansson LM. Validity evidence for a modified version of the orthotics and prosthetics users' survey. *Disability and rehabilitation. Assistive technology.* Nov 2012;7(6):469-478.

116. Ostlie K, Franklin RJ, Skjeldal OH, Skrondal A, Magnus P. Assessing physical function in adult acquired major upper-limb amputees by combining the disabilities of the arm, shoulder and hand (DASH) outcome questionnaire and clinical examination. *Arch Phys Med Rehabil.* Oct 2011;92(10):1636-1645.

117. Gallagher P, O'Donovan MA, Doyle A, Desmond D. Environmental barriers, activity limitations and participation restrictions experienced by people with major limb amputation. *Prosthet Orthot Int.* Sep 2011;35(3):278-284.

118. Huizing K, Reinders-Messelink H, Maathuis C, Hadders-Algra M, van der Sluis CK. Age at first prosthetic fitting and later functional outcome in children and young adults with unilateral congenital below-elbow deficiency: A cross-sectional study. *Prosthet Orthot Int.* Jun 2010;34(2):166-174.

119. Davidson JH, Khor KE, Jones LE. A cross-sectional study of post-amputation pain in upper and lower limb amputees, experience of a tertiary referral amputee clinic. *Disabil Rehabil.* 2010;32(22):1855-1862.

120. Lindner HY, Linacre JM, Norling Hermansson LM. Assessment of capacity for myoelectric control: Evaluation of construct and rating scale. *J Rehabil Med.* May 2009;41(6):467-474.

121. Jarl GM, Hermansson LM. Translation and linguistic validation of the Swedish version of orthotics and prosthetics users' survey. *Prosthetics and orthotics international.* Dec 2009;33(4):329-338.

122. Daigeler A, Lehnhardt M, Khadra A, et al. Proximal major limb amputations--a retrospective analysis of 45 oncological cases. *World J Surg Oncol.* 2009;7:15.

123. Burger H, Franchignoni F, Kotnik S, Giordano A. A rasch-based validation of a short version of abilhand as a measure of manual ability in adults with unilateral upper limb amputation. *Disabil Rehabil.* 2009;31(24):2023-2030.

124. Burger H, Franchignoni F, Heinemann AW, Kotnik S, Giordano A. Validation of the orthotics and prosthetics user survey upper extremity functional status module in people with unilateral upper limb amputation. *J Rehabil Med.* May 2008;40(5):393-399.

125. Hermansson LM, Bodin L, Eliasson AC. Intra- and inter-rater reliability of the assessment of capacity for myoelectric control. *J Rehabil Med.* Mar 2006;38(2):118-123.

126. Lifchez SD, Marchant-Hanson J, Matloub HS, Sanger JR, Dzwierzynski WW, Nguyen HH. Functional improvement with digital prosthesis use after multiple digit amputations. *J Hand Surg Am.* Jul 2005;30(4):790-794.

127. Hermansson LM, Fisher AG, Bernspang B, Eliasson AC. Assessment of capacity for myoelectric control: A new rasch-built measure of prosthetic hand control. *J Rehabil Med.* May 2005;37(3):166-171.

128. Desmond DM, MacLachlan M. Factor structure of the trinity amputation and prosthesis experience scales (tapes) with individuals with acquired upper limb amputations. *Am J Phys Med Rehabil.* Jul 2005;84(7):506-513.

129. Dudkiewicz I, Gabrielov R, Seiv-Ner I, Zelig G, Heim M. Evaluation of prosthetic usage in upper limb amputees. *Disabil Rehabil.* Jan 7 2004;26(1):60-63.

130. Davidson J. A comparison of upper limb amputees and patients with upper limb injuries using the disability of the arm, shoulder and hand (DASH). *Disabil Rehabil.* Jul 22-Aug 5 2004;26(14-15):917-923.

131. Datta D, Selvarajah K, Davey N. Functional outcome of patients with proximal upper limb deficiency--acquired and congenital. *Clin Rehabil.* Mar 2004;18(2):172-177.

132. Melikyan EY, Beg MS, Woodbridge S, Burke FD. The functional results of ray amputation. *Hand surgery : an international journal devoted to hand and upper limb surgery and related research : journal of the Asia-Pacific Federation of Societies for Surgery of the Hand.* Jul 2003;8(1):47-51.

133. Heinemann AW, Bode RK, O'Reilly C. Development and measurement properties of the orthotics and prosthetics users' survey (opus): A comprehensive set of clinical outcome instruments. *Prosthet Orthot Int.* Dec 2003;27(3):191-206.

134. Graham B, Adkins P, Tsai TM, Firrell J, Breidenbach WC. Major replantation versus revision amputation and prosthetic fitting in the upper extremity: A late functional outcomes study. *J Hand Surg Am.* Sep 1998;23(5):783-791.

135. Light CM, Chappell PH, Kyberd PJ. Establishing a standardized clinical assessment tool of pathologic and prosthetic hand function: Normative data, reliability, and validity. *Arch Phys Med Rehabil.* Jun 2002;83(6):776-783.

136. Vasluian E, Bongers RM, Reinders-Messelink HA, Burgerhof JG, Dijkstra PU, van der Sluis CK. Learning effects of repetitive administration of the southampton hand assessment procedure in novice prosthetic users. *Journal of rehabilitation medicine : official journal of the UEMS European Board of Physical and Rehabilitation Medicine.* May 21 2014.

137. Head JS, Howard D, Hutchins SW, Kenney L, Heath GH, Aksenov AY. The use of an adjustable electrode housing unit to compare electrode alignment and contact variation with myoelectric prosthesis functionality: A pilot study. *Prosthetics and orthotics international.* Aug 18 2014.

138. Fougner AL, Stavdahl O, Kyberd PJ. System training and assessment in simultaneous proportional myoelectric prosthesis control. *Journal of neuroengineering and rehabilitation.* 2014;11:75.

139. Bouwsema H, van der Sluis CK, Bongers RM. Changes in performance over time while learning to use a myoelectric prosthesis. *Journal of neuroengineering and rehabilitation.* 2014;11:16.

140. van der Niet O, Bongers RM, van der Sluis CK. Functionality of i-limb and i-limb pulse hands: Case report. *Journal of rehabilitation research and development.* 2013;50(8):1123-1128.

141. Dalley SA, Bennett DA, Goldfarb M. Preliminary functional assessment of a multigrasp myoelectric prosthesis. *Conference proceedings : ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual Conference.* 2012;2012:4172-4175.

142. Bouwsema H, Kyberd PJ, Hill W, van der Sluis CK, Bongers RM. Determining skill level in myoelectric prosthesis use with multiple outcome measures. *J Rehabil Res Dev.* 2012;49(9):1331-1348.

143. Kyberd PJ. The influence of control format and hand design in single axis myoelectric hands: Assessment of functionality of prosthetic hands using the southampton hand assessment procedure. *Prosthetics and orthotics international.* Sep 2011;35(3):285-293.

144. Ramirez IA, Lusk CP, Dubey R, Highsmith MJ, Maitland ME. Crossed four-bar mechanism for improved prosthetic grasp. *Journal of rehabilitation research and development.* 2009;46(8):1011-1020.

145. Gupta A, Wolff TW. Management of the mangled hand and forearm. *J Am Acad Orthop Surg.* Jul 1995;3(4):226-236.

146. Andersson G, Cocchiarella L. *Guides to the evaluation of permanent impairment.* 5th ed: American Medical Association; 2000.

147. Neumeister MW, Brown RE. Mutilating hand injuries: Principles and management. *Hand Clin.* Feb 2003;19(1):1-15, v.

148. Moran SL, Berger RA. Biomechanics and hand trauma: What you need. *Hand Clin.* Feb 2003;19(1):17-31.

149. Tooms RE. Amputation surgery in the upper extremity. *Orthop Clin North Am.* Jul 1972;3(2):383-395.

150. Tintle SM, Baechler MF, Nanos GP, 3rd, Forsberg JA, Potter BK. Traumatic and trauma-related amputations: Part II: Upper extremity and future directions. *J Bone Joint Surg Am.* Dec 15 2010;92(18):2934-2945.

151. Neusel E, Traub M, Blasius K, Marquardt E. Results of humeral stump angulation osteotomy. *Arch Orthop Trauma Surg.* 1997;116(5):263-265.

152. Baccarani A, Follmar KE, De Santis G, et al. Free vascularized tissue transfer to preserve upper extremity amputation levels. *Plast Reconstr Surg.* Sep 15 2007;120(4):971-981.

153. Foong DP, Evriviades D, Jeffery SL. Integra permits early durable coverage of improvised explosive device (IED) amputation stumps. *J Plast Reconstr Aesthet Surg.* Dec 2013;66(12):1717-1724.

154. Helgeson MD, Potter BK, Evans KN, Shawen SB. Bioartificial dermal substitute: A preliminary report on its use for the management of complex combat-related soft tissue wounds. *J Orthop Trauma.* Jul 2007;21(6):394-399.

155. Rohrich RJ, Ehrlichman RJ, May JW, Jr. Sensate palm of hand free flap for forearm length preservation in nonreplantable forearm amputation: Long-term follow-up. *Ann Plast Surg.* May 1991;26(5):469-473.

156. Wood MR, Hunter GA, Millstein SG. The value of stump split skin grafting following amputation for trauma in adult upper and lower limb amputees. *Prosthet Orthot Int.* Aug 1987;11(2):71-74.

157. Zlotolow DA, Kozin SH. Advances in upper extremity prosthetics. *Hand Clin.* Nov 2012;28(4):587-593.

158. Kuiken TA, Li G, Lock BA, et al. Targeted muscle reinnervation for real-time myoelectric control of multifunction artificial arms. *JAMA.* 2009;301(6):619-628.

159. Lundberg M, Hagberg K, Bullington J. My prosthesis as a part of me: A qualitative analysis of living with an osseointegrated prosthetic limb. *Prosthet Orthot Int.* Jun 2011;35(2):207-214.

160. Sierakowski A, Watts C, Thomas K, Elliot D. Long-term outcomes of osseointegrated digital prostheses for proximal amputations. *J Hand Surg Eur Vol.* Feb 2011;36(2):116-125.

161. Jonsson S, Caine-Winterberger K, Branemark R. Osseointegration amputation prostheses on the upper limbs: Methods, prosthetics and rehabilitation. *Prosthet Orthot Int.* Jun 2011;35(2):190-200.

162. Petruzzo P, Lanzetta M, Dubernard JM, et al. The international registry on hand and composite tissue transplantation. *Transplantation.* Dec 27 2010;90(12):1590-1594.

163. Cavadas PC, Landin L, Thione A, et al. The Spanish experience with hand, forearm, and arm transplantation. *Hand Clin.* Nov 2011;27(4):443-453, viii.

164. Brenner CD, Brenner JK. The use of preparatory/evaluation/training prostheses in developing evidenced-based practice in upper limb prosthetics. *JPO: Journal of Prosthetics and Orthotics.* 2008;20(3):70-82