VA/DoD Clinical Practice Guidelines

Management of Upper Limb Amputation Rehabilitation

Provider Summary

Version 2.0 | 2022

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

Department of Veterans Affairs

Department of Defense

Provider Summary

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 recommendation.

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 with a patient-centered approach.

These guidelines are not intended to represent Department of Veterans Affairs or 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 by contacting your regional TRICARE Managed Care Support Contractor.

Version 2.0 – 2022

Table of Contents

Introduction

The Department of Veterans Affairs (VA) and Department of Defense (DoD) Evidence-Based Practice Work Group (EBPWG) was established and first chartered in 2004, with a mission to advise the Health Executive Committee (HEC) "… on the use of clinical and epidemiological evidence to improve the health of the population …" across the Veterans Health Administration (1) and Military Health System (MHS), by facilitating the development of clinical practice guidelines (CPGs) for the VA and DoD populations.(2) Development and update of VA/DoD CPGs is funded by VA Evidence Based Practice, Office of Quality and Patient Safety. The system-wide goal of evidence-based CPGs is to improve patient health and well-being.

In 2014, the VA and DoD published a CPG for the Management of Upper Extremity Amputation Rehabilitation (2014 VA/DoD UEAR CPG), which was based on evidence reviewed through June 2013. Since the release of that CPG, a growing body of research has expanded the evidence base and understanding of upper limb amputation (ULA) rehabilitation. Consequently, the VA/DoD EBPWG initiated the update of the 2014 VA/DoD UEAR CPG in 2020. This updated CPG's use of GRADE reflects a more rigorous application of the methodology than previous iterations. Consequently, the strength of some recommendations may have been modified due to the confidence in the quality of the supporting evidence (see Evidence Quality and Recommendation Strength in the full CPG).

The updated CPG includes recent objective, evidence-based information on the care and rehabilitation of persons with ULA. It is intended to provide guidance to assist healthcare providers in perioperative, pre-prosthetic training, prosthetic training, and life-long phases of patient care. The system-wide goal of this evidence-based guideline is to improve the patient's health and well-being. It guides healthcare providers along evidence supported management pathways to assist patients in rehabilitation following ULA. The expected outcome of successful implementation of this guideline is to:

- Assess the patient's condition and collaborate with the patient, family, and caregivers to determine optimal management of patient care
- Emphasize the use of patient-centered care and shared decision making
- Minimize preventable complications and morbidity
- Optimize individual health outcomes and quality of life

The full VA/DoD ULA CPG, as well as additional toolkit materials including a pocket card and patient summary, can be found at: https://www.healthquality.va.gov/index.asp.

Recommendations

The following evidence-based clinical practice recommendations were made using a systematic approach considering four domains as per the GRADE approach (see Methods). These domains include: confidence in the quality of the evidence, balance of desirable and undesirable outcomes (i.e., benefits and harms), patient values and preferences, and other implications (e.g., resource use, equity, acceptability).

Table 1. Recommendations

Topic	#	Recommendation	Strength[a]	Category[b]
Surgery/Pre-prosthetic	1.	There is insufficient evidence to assess the impact of the level of amputation or amputation surgical procedure type on functional status and prosthesis-related outcomes.	Neither for nor against	Reviewed, New-added
	2.	For patients undergoing upper limb amputation surgery, there is insufficient evidence to recommend the use of any particular factors to predict the speed and quality of wound healing, successful prosthesis fitting, or need for revision surgery.	Neither for nor against	Reviewed, New-added
	3.	There is insufficient evidence to recommend for or against the use of any particular recent treatment advances including hardware, software, surgical, technology, or supplemental surgical interventions, such as: • targeted muscle reinnervation (TMR) • regenerative peripheral nerve interfaces (RPNI) • vascularized composite allotransplantation (VCA) • agonist-antagonist myoneural interface (AMI) • implantable myoelectric sensor system (IMES) • osseointegration (OI)	Neither for nor against	Reviewed, New-added
Rehabilitation	4.	There is insufficient evidence to recommend for or against any particular training protocol to improve function and outcomes.	Neither for nor against	Reviewed, New-added
	5.	We suggest the use of mirror therapy for the short-term reduction of phantom limb pain.	Weak for	Reviewed, New-replaced
	6.	There is insufficient evidence to recommend for or against any particular treatment setting, intensity, or service delivery model.	Neither for nor against	Reviewed, New-replaced
Prosthetic Restoration	7.	For patients with major unilateral upper limb amputation (i.e., through or proximal to the wrist), we suggest use of a body-powered or externally powered prosthesis to improve independence and reduce disability.	Weak for	Reviewed, New-added
	8.	There is insufficient evidence to recommend for or against any specific control strategy, socket design, suspension method, or component.	Neither for nor against	Reviewed, New-added
Medical	9.	There is insufficient evidence to recommend for or against a particular intervention for the *prevention* of phantom and/or residual limb pain.	Neither for nor against	Reviewed, New-replaced
	10.	There is insufficient evidence to recommend for or against any particular pharmacologic intervention for the *management* of phantom and/or residual limb pain.	Neither for nor against	Reviewed, New-replaced
	11.	There is insufficient evidence to recommend for or against the use of non-invasive brain stimulation for the management of phantom limb pain.	Neither for nor against	Reviewed, New-added

Topic	#	Recommendation	Strength[a]	Category[b]
Outcomes	12.	There is insufficient evidence to recommend for or against the use of any specific assessment tool to guide the determination of prosthetic candidacy, the need for therapy, or for identifying improvement or worsening of function and quality of life.	Neither for nor against	Reviewed, New-added
Psychosocial Considerations	13.	We suggest screening patients for cognition, mental health conditions such as posttraumatic stress disorder and depression, and pain during the initial evaluation and across the continuum of care.	Weak for	Reviewed, New-added
	14.	We suggest offering peer support services.	Weak for	Reviewed, New-replaced

[a] For additional information, see Determining Recommendation Strength and Direction in the full VA/DoD ULA CPG.

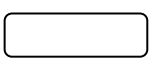
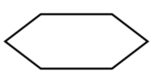
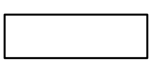
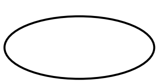
[b] For additional information, see Recommendation Categorization and Appendix K in the full VA/DoD ULA CPG.

Algorithm

This CPG's algorithm is designed to facilitate understanding of the clinical pathway and decision making process used in managing patients with ULA. This algorithm format represents a simplified flow of the management of patients with ULA and helps foster efficient decision making by providers. It includes:

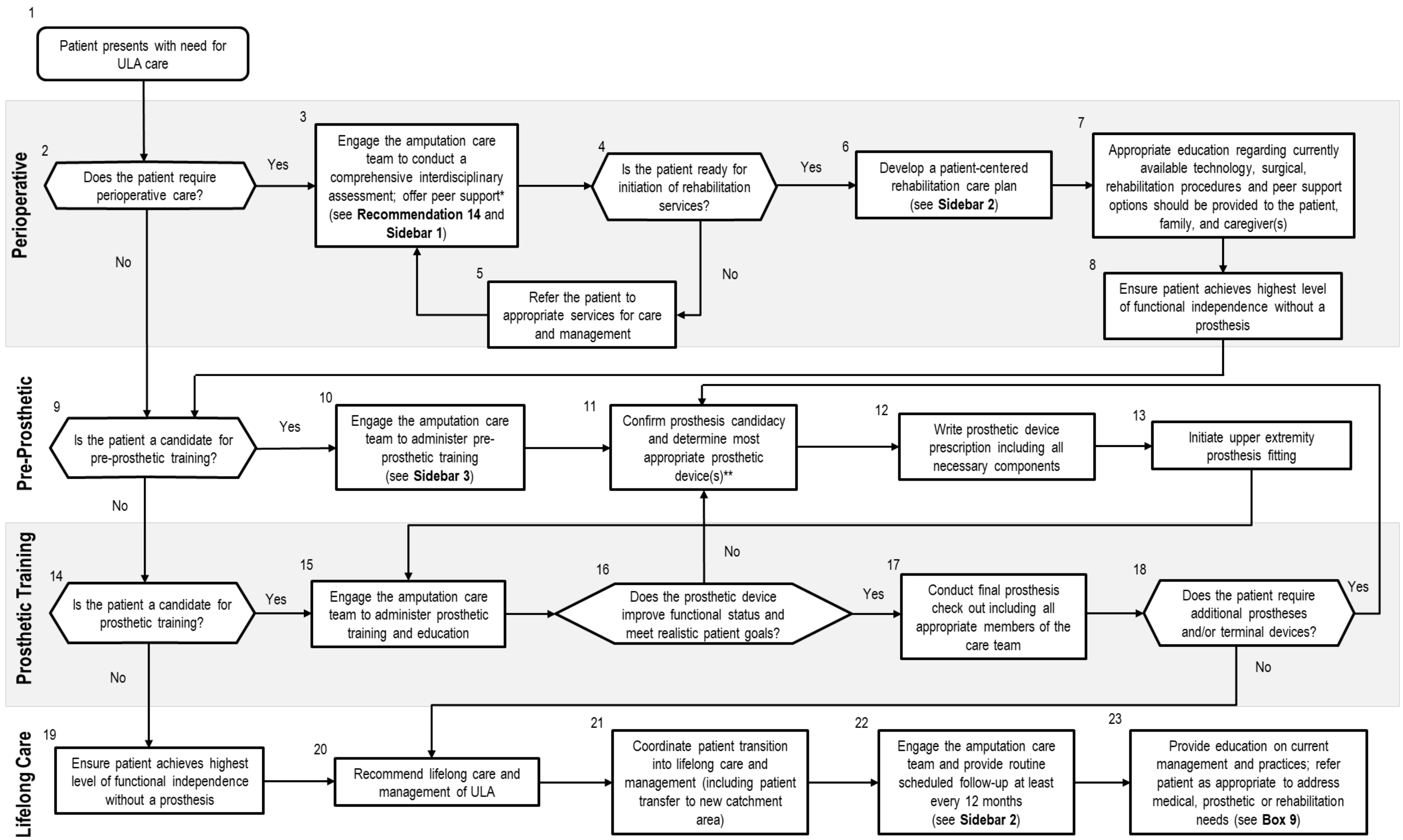
- An ordered sequence of steps of care
- Decisions to be considered
- Recommended decision criteria
- Actions to be taken

The algorithm is a step-by-step decision tree. Standardized symbols are used to display each step, and arrows connect the numbered boxes indicating the order in which the steps should be followed.(3) Sidebars provide more detailed information to assist in defining and interpreting elements in the boxes.

Shape	Description
	Rounded rectangles represent a clinical state or condition
	Hexagons represent a decision point in the process of care, formulated as a question that can be answered "Yes" or "No"
	Rectangles represent an action in the process of care
	Ovals represent a link to another section within the algorithm

For alternative text descriptions of the algorithm, see Appendix N in the full VA/DoD ULA CPG.

Module A: Upper Limb Amputation Management



*Peer support includes both peer visitors right after surgery and peer support in an outpatient setting

**May involve trials of various device components as appropriate and feasible

Abbreviations: ULA: upper limb amputation

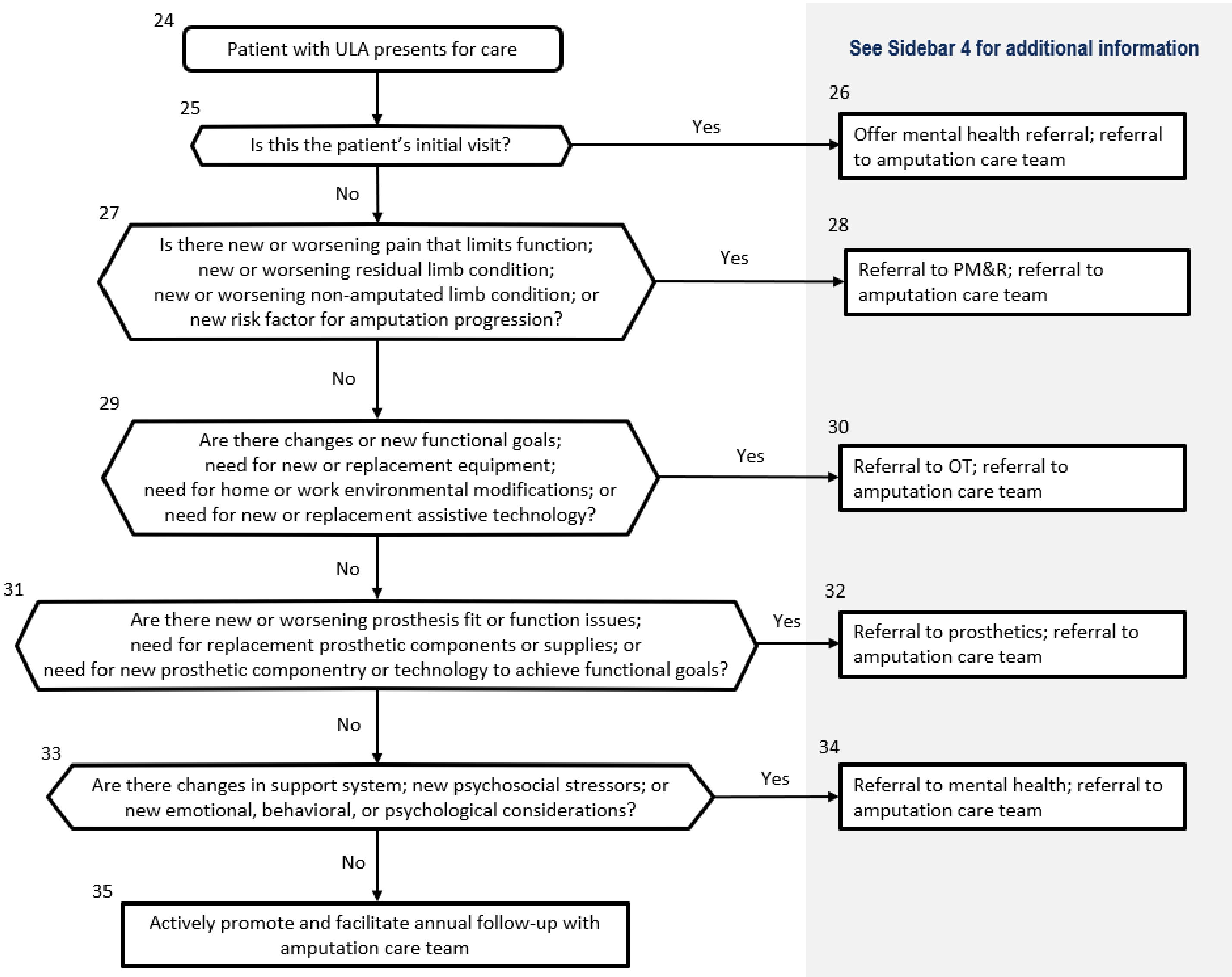
Sidebar 1: Components of the Comprehensive Assessment
• Present health status • Level of function • Modifiable/controllable health risk factors • Pain assessment • Cognition and behavioral health • Personal, family, social, and cultural context • Learning assessment • Residual limb assessment • Non-amputated limb and trunk assessment • Prosthetic assessment (if applicable) • Vocational assessment

Sidebar 2: The Patient-centered Rehabilitation Plan
• 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

Sidebar 3: Physical and Functional Rehabilitation Interventions
• 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 ROM exercises • Postural exercises and progressive strengthening • Cardiovascular endurance • IADL interventions, home and driving modifications, assistive technologies, and community integration • Adaptive sports or leisure activities

Abbreviations: ADL: activities of daily living; IADL: instrumental activities of daily living; ROM: range of motion

Module B: Upper Limb Amputation Management for Primary Care



Abbreviations: OT: occupational therapy; PM&R: physical medicine and rehabilitation; ULA: upper limb amputation

Sidebar 4: Amputation Care Team
The amputation care team is an interdisciplinary team consisting of, at a minimum, a physiatrist (or prescribing clinician), occupational and physical therapists, and prosthetist, that provides assessment and treatment for amputation-related needs. Other providers who may be included are mental health, rehabilitation psychology (if available), social work, nursing, wound care, surgery, vocational planning, etc. Members of the team may participate face to face or via telehealth as appropriate.

Scope of the CPG

This CPG is based on published clinical evidence and related information available through April 30, 2021. It is intended to provide general guidance on best evidence-based practices (see Appendix A in the full VA/DoD ULA CPG for additional information on the evidence review methodology). This CPG is not intended to serve as a standard of care.

This CPG is intended for use by all healthcare providers caring for patients with ULA. This version of the CPG was specifically tailored to be of greatest value to rehabilitation care providers, including physicians, therapists, and prosthetists, involved in the management of persons with ULA.

The patient population of interest for this CPG is adults (≥18 years) with ULA, including Veterans as well as Service Members, military retirees, and beneficiaries.

Methods

The methodology used in developing this CPG follows the *Guideline for Guidelines*, an internal document of the VA/DoD EBPWG updated in January 2019 that outlines procedures for developing and submitting VA/DoD CPGs.(4) The *Guideline for Guidelines* is available at https://www.healthquality.va.gov/policy/index.asp. This CPG also aligns with the National Academy of Medicine's (NAM) principles of trustworthy CPGs (e.g., explanation of evidence quality and strength, the management of potential conflicts of interest [COI], interdisciplinary stakeholder involvement, use of systematic review (SR), and external review).(5) Appendix A in the full VA/DoD ULA CPG provides a detailed description of the CPG development methodology.

The Work Group used the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach to craft each recommendation and determine its strength. Per GRADE approach, recommendations must be evidence-based and cannot be made based on expert opinion alone. The GRADE approach uses the following four domains to inform the strength of each recommendation: confidence in the quality of the evidence, balance of desirable and undesirable outcomes, patient values and preferences, other considerations as appropriate (e.g., resource use, equity) (see Determining Recommendation Strength and Direction in the full VA/DoD ULA CPG).(6)

Using these four domains, the Work Group determined the relative strength of each recommendation (*Strong* or *Weak*). The strength of a recommendation is defined as the extent to which one can be confident that the desirable effects of an intervention outweigh its undesirable effects and is based on the framework above, which incorporates the four domains.(7) A *Strong* recommendation generally indicates *High* or *Moderate* confidence in the quality of the available evidence, a clear difference in magnitude between the benefits and harms of an intervention, similar patient values and preferences, and understood influence of other implications (e.g., resource use, feasibility).

In some instances, there is insufficient evidence on which to base a recommendation for or against a particular therapy, preventive measure, or other intervention. For example, the systematic evidence review may have found little or no relevant evidence, inconclusive evidence, or conflicting evidence for the intervention. The manner in which this is expressed in the CPG may vary. In such instances, the Work Group may include among its set of recommendations a statement of insufficient evidence for an intervention that may be in common practice even though it is not supported by clinical evidence, and particularly if there may be other risks of continuing its use (e.g., high opportunity cost, misallocation of resources). In other cases, the Work Group may decide to not include this type of statement about an intervention. For example, the Work Group may remain silent where there is an absence of evidence for a rarely used intervention. In other cases, an intervention may have a favorable balance of benefits and harms but may be a standard of care for which no recent evidence has been generated.

Using these elements, the Work Group determines the strength and direction of each recommendation and formulates the recommendation with the general corresponding text (see Table 2).

Table 2. Strength and Direction of Recommendations and General Corresponding Text

Recommendation Strength and Direction	General Corresponding Text
Strong for	We recommend …
Weak for	We suggest …
Neither for nor against	There is insufficient evidence to recommend for or against …
Weak against	We suggest against …
Strong against	We recommend against …

It is important to note that a recommendation's strength (i.e., *Strong* versus *Weak*) is distinct from its clinical importance (e.g., a *Weak* recommendation is evidence-based and still important to clinical care). The strength of each recommendation is shown in the Recommendations section.

The GRADE of each recommendation made in the 2022 CPG can be found in the section on Recommendations. Additional information regarding the use of the GRADE system can be found in Appendix A in the full VA/DoD ULA CPG.

The Work Group developed both new and updated recommendations based on the evidence review conducted for the priority areas addressed by the KQs. A set of recommendation categories was adapted from those used by the National Institute for Health and Care Excellence (NICE).(8, 9) The categories and definitions can be found in Table 3. For more information, see Evidence Quality and Recommendation Strength in the full VA/DoD ULA CPG.

Table 3. Recommendation Categories and Definitions[a]

Evidence Reviewed	Recommendation Category	Definition
Reviewed[b]	New-added	New recommendation
	New-replaced	Recommendation from previous CPG was carried forward and revised
	Not changed	Recommendation from previous CPG was carried forward but not changed
	Amended	Recommendation from previous CPG was carried forward with a nominal change
	Deleted	Recommendation from previous CPG was deleted
Not reviewed[c]	Not changed	Recommendation from previous CPG was carried forward but not changed
	Amended	Recommendation from previous CPG was carried forward with a nominal change
	Deleted	Recommendation from previous CPG was deleted

[a] Adapted from the NICE guideline manual (2012) (9) and Garcia et al. (2014) (8)

[b] The topic of this recommendation was covered in the evidence review carried out as part of the development of the current CPG.

[c] The topic of this recommendation was not covered in the evidence review carried out as part of the development of the current CPG.

Abbreviation: CPG: clinical practice guideline

Guideline Work Group

Table 4. Guideline Work Group and Guideline Development Team

Organization	Names*
Department of Veterans Affairs	**Billie Randolph, PT, PhD (Champion)**
	Joseph Webster, MD (Champion)
	Irina Agranova-Breyter, MPT
	Erin Andrews, PsyD, ABPP
	Roxanne Disla, OTD, OTR/L
	Selina Doncevic, MSN, RN, CRRN
	Christopher Fantini, MSPT, CP, BOCO
	M. Jason Highsmith, PhD, DPT, CP, FAAOP
	Denise Lester, MD
	William C. Mayes, MSPO, CPO
	Linda Resnik, PT, PhD, FAPTA
	Bradley Tucker, MD
Department of Defense	**Andrea Crunkhorn, PT, DPT (Champion)**
	MAJ Megan Loftsgaarden, DO (Champion)
	Shannon Barnicott, MOT, OTR/L
	Josef Butkus, MS, OTR/L
	Rachael Coller, PharmD, BCPS, BCPP
	LCDR Joseph Happel, MD
	Louise Hassinger, CP
	Michelle Nordstrom, MS, OTR/L
	Annemarie Orr, OTD, OTR/L
	Maj Casey Sabbag, MD
Office of Quality and Patient Safety *Veterans Health Administration*	M. Eric Rodgers, PhD, FNP-BC
	James Sall, PhD, FNP-BC
	Rene Sutton, BS, HCA
Clinical Quality Improvement Program *Defense Health Agency*	Lisa D. Jones, BSN, RN, MHA, CPHQ
	Elaine Stuffel, MHA, BSN, RN
The Lewin Group	Clifford Goodman, PhD
	Erika Beam, MS
	Ben Agatston, JD, MPH
	Shaina Haque, MPH
	Amanda Huben, BA
	Ryan Wilson, BA

Organization	Names*
ECRI	Kris D'Anci, PhD
	Stacey Uhl, MS
	Aaron Bloschichak, MPH
	Amber Moran, MA
	Emilio Berdiel, MPH
	Jessica T. Gontarek, MSLIS
	Michele Datko, MLS
Sigma Health Consulting	Frances Murphy, MD, MPH
	James Smirniotopoulos, MD
Duty First Consulting	Rachel Piccolino, BA
	Mary Kate Curley, BA
	Richa Ruwala, BS
	Anita Ramanathan, BA

*Additional contributor contact information is available in Appendix L in the full VA/DoD ULA CPG.

Patient-Centered Care

Guideline recommendations are intended to consider patient needs and preferences. Guideline recommendations represent a whole/holistic health approach to care that is patient-centered, culturally appropriate, and available to people with limited literacy skills and physical, sensory, or learning disabilities. VA/DoD CPGs encourage providers to use a patient-centered, whole/holistic health approach (i.e., individualized treatment based on patient needs, characteristics, and preferences). This approach aims to treat the particular condition while also optimizing the individual's overall health and well-being.

Regardless of the care setting, all patients should have access to individualized evidence-based care. Patient-centered care can decrease patient anxiety, increase trust in clinicians, and improve treatment adherence.(10, 11) A whole/holistic health approach (https://www.va.gov/wholehealth/) empowers and equips individuals to meet their personal health and well-being goals. Good communication is essential and should be supported by evidence-based information tailored to each patient's needs. An empathetic and non-judgmental approach facilitates discussions sensitive to sex, culture, ethnicity, and other differences.

Shared Decision Making

This CPG encourages providers to practice shared decision making, which is a process in which providers and patients consider clinical evidence of benefits and risks as well as patient values and preferences to make decisions regarding the patient's treatment.(12) Shared decision making was emphasized in *Crossing the Quality Chasm,* an Institute of Medicine (IOM) (now NAM) report, in 2001 (13) and is inherent within the whole/holistic health approach. Providers must be adept at presenting information to their patients regarding individual treatments, expected risks, expected outcomes, and levels and/or settings of care, especially where there may be patient heterogeneity in risks and benefits. The VHA and MHS have embraced shared decision making. Providers are encouraged to use shared decision making to individualize treatment goals and plans based on patient capabilities, needs, and preferences.

Phases of Rehabilitation Care

The VA and DoD have previously described four phases of care which create a framework for rehabilitation and long-term management of patients with an ULA. 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 the 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 ULA or the decision has been made that amputation is necessary. In most cases, the underlying cause resulting in the need for an ULA involves a traumatic injury. Complete interdisciplinary assessments of the patient's medical, functional, and psychological status should be performed as soon as it is clinically appropriate to establish a baseline level of function and prepare the patient for the ensuing rehabilitation plan and, ultimately, lifelong 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 incisions are closed and free of infection, sutures are removed, self-care activities of daily living (ADL) using one-handed strategies and adaptive or durable medical equipment are progressing, and the patient has been medically cleared for further rehabilitation.

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 a prosthesis and aids the patient in determining which type of prosthesis(es) 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 initial prosthesis prescription should be developed with input from all members of the care team and individualized for the patient based on the patient's specific needs and goals related to prosthesis use. Table 5 provides the care team with the essential elements that should be included in an upper limb prosthesis prescription. The pre-prosthetic phase ends with the fitting of the initial prosthesis. This phase typically occurs in an outpatient or rehabilitation setting.

Table 5. Components of the Upper Limb Prosthesis Prescription

Comprehensive prescription for an upper limb 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)

The prosthetic training phase marks a turning point in the rehabilitation of the patient who is determined to be an appropriate candidate to proceed to prosthesis fitting. 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 desired functional outcomes 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. Patients may ebb and flow through this phase after receiving each new or different type of prosthesis. During this phase of care, the members of the care team must monitor the patient for potential complications that can occur during prosthesis use. Table 6 provides the care team with some common signs and symptoms that the prosthesis may need to be modified. This phase may also begin because a patient receives a new prosthetic component or a novel control scheme.

Table 6. Signs and Symptoms the Prosthesis May Need to Be Modified

Patients who use a prosthesis should be advised to report any of the following symptoms:
• 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 last phase of ULA 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 should return for annual routine follow-up assessments and review of the patient’s functional goals with the amputation care team. A comprehensive, interdisciplinary approach is used at each follow-up regardless of prosthetic use. Each routine follow-up assessment should focus on maximizing the patient’s functional independence using available rehabilitation services and emerging technologies in ULA rehabilitation.

The Algorithm summarizes the activities and milestones achieved in each phase of care.

Summary of Assessments and Interventions in Rehabilitation Phases

Table 7. Summary of Assessments and Interventions in Rehabilitation Phases

	Perioperative	Pre-prosthetic	Prosthetic Training	Lifelong Care
1. Physical Health Status (nutritional, CV, endocrine, neurologic, bowel & bladder, skin, MSK)	• Complete initial assessment of medical comorbidities and provide consultation as appropriate, especially if not addressed preoperatively • Initiate medical interventions and education as needed	• Continue medical interventions and provide referrals 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 strategies for prevention of secondary complications • Specialty referrals as indicated
2. Discharge Planning	• Initiate discharge planning during the initial assessment • Develop discharge plan • Communicate discharge plan with family and/or caregiver	• 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 including relocation or major life changes
3. Level of Function **3.1 Range of Motion**	• Assess current ROM in proximal joints of residual limb and on contralateral side • Preoperatively, treat identified contractures • Initiate passive ROM of residual and contralateral limb in all available planes of 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	• 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 use	• Reassess ROM and review home stretching program if needed • Initiate therapy services if needed

	Perioperative	Pre-prosthetic	Prosthetic Training	Lifelong Care
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 upper extremity 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: • Static sitting balance • Sitting weight shifts • Assess and initiate core stabilization: • Pelvic tilts • 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 to functional activities using the prosthesis
3.4 Home Exercise Program (HEP)	• Determine and provide HEP addressing deficiencies and maximize above ROM strength, balance, etc.	• Give patient supplies and instruction in exercise program for home	• Advance HEP to focus on full ROM, strength, and endurance	• Address new physical requirements as patient goals change
3.5 Cardiovascular (CV)	• Assess current CV fitness and incorporate a CV component into the therapy program • Educate regarding energy demand with active prosthesis use • Establish cardiac precautions for rehabilitation (heart rate, blood pressure, perceived exertion scales) as indicated	• Advance CV aspect of rehabilitation program to meet needs of patient • Maintain cardiac precautions as indicated • Encourage reducing risk factors	• Establish maintenance program for endurance and fitness • Maintain cardiac precautions as indicated • Encourage reduction of CV risk factors	• Establish maintenance program for endurance and fitness • Maintain cardiac precautions if indicated • Encourage reduction of CV risk factors

	Perioperative	Pre-prosthetic	Prosthetic Training	Lifelong Care
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 strategies to perform basic ADL with one hand • Ensure patient safety • Initiate change of dominance training as appropriate	• Teach adaptive techniques for dressing, bathing, grooming, and toileting without a prosthesis • Continue change of dominance training as appropriate • Begin IADL training • Progress independence with more complex IADL training	• 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
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) • Offer and maintain individual and group peer support	• Initiate recreational training activities with a prosthesis • Practice use of a prosthesis during recreational training activities • Offer and maintain individual and group peer support	• 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 in sports and recreation
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

	Perioperative	Pre-prosthetic	Prosthetic Training	Lifelong Care
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, environmental modifications, and equipment	• Assess for personal equipment and any necessary accommodations to perform IADL (i.e., voice recognition, one handed keyboard, Bluetooth devices) 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 or need for vehicle modifications or adaptive driving equipment	• Consult Certified Driving Specialist to complete driving evaluation • Complete driver's training with recommended adaptive equipment as needed • Educate patient, family, and/or caregiver to comply with local state driving laws and individual insurance company policies	• Reassess driving modification needs with any significant changes to medical condition or amputation status
4. Pain Management	• Assess for existing pain before surgery and treat aggressively • Following amputation, assess and aggressively treat residual limb pain and PLP (liberal narcotic use, regional anesthesia, and non-narcotic medications especially for neuropathic pain)	• Assess and treat residual limb pain and PLP (transition to non-narcotic modalities including pharmacologic, physical, psychological, and mechanical)	• Assess and treat residual limb pain and PLP (transition to non-narcotic modalities including pharmacologic, physical, psychological, and mechanical)	• Reassess and adjust treatment for residual limb pain and PLP (transition to non-narcotic modalities including pharmacologic, physical, psychological, and mechanical) • Assess and treat associated MSK pain and overuse syndromes

	Perioperative	Pre-prosthetic	Prosthetic Training	Lifelong Care
5. Behavioral and Cognitive Health	• Complete psychological assessment • Evaluate and address psychosocial symptoms/issues • Complete cognitive assessment	• Evaluate and address psychosocial symptoms/issues • Evaluate and address cognitive issues • Offer or maintain individual and group peer support activities	• Evaluate and address psychosocial symptoms/issues • Evaluate and address cognitive issues • Offer or maintain individual and group peer support activities	• 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 complications • Procedural/recovery issues: • Level of amputation • Prosthetic options • Postoperative dressing • Sequence of amputation care • 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	• Positioning • Rehabilitation progress • Pain control • Residual limb care • Edema control • Application of shrinker • Prosthetic timeline • Equipment needs • Coping methods • Prevention of complications • Contracture prevention • Safety	• Positioning • Rehabilitation process • Pain control • Residual limb care • Energy expenditure • Prosthetic education • Donning & doffing • Care of prosthesis • Skin integrity • Sock management • Equipment needs • Coping methods • Prevention of complications • Weight management • Contracture prevention • Injury prevention techniques • Safety	• Positioning • Rehabilitation process • Pain control • 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

	Perioperative	Pre-prosthetic	Prosthetic Training	Lifelong Care
7. Residual Limb Management	• Manage postoperative dressings • Monitor the surgical wound for signs and symptoms of ischemia or infection • Control edema and shape residual limb with the use of postoperative dressing and compression wrap; progress to shrinker once cleared by surgeon • Teach 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	• Continue to monitor wound healing • Continue shaping and shrinkage of residual 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	• Optimize limb shaping and shrinkage before prosthetic fitting • Teach donning/doffing 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 to promote ROM and restoration of function • Instruct patient to observe pressure points • Monitor skin and tissue integrity with progressive wearing time and frequent skin checks in the newly fitted socket	• Reinforce education regarding skin care • Educate regarding signs and symptoms of ill-fitting socket • Monitor effectiveness of pain management • Continue limb volume management
8. Prosthetic Management	• Determine optimal residual limb length per patient goals • Residual limb care • Postoperative dressing if appropriate	• Initial prosthetic prescription generation	• Prosthetic fabrication, fitting, alignment, and modification as applicable • Test various prosthesis components • Consider activity-specific prosthesis to meet goals	• Prosthetic fabrication, fitting, alignment, and modification as applicable • Prosthetic device repairs as indicated • Schedule routine maintenance (components, upgrades, socket changes, and specialty use devices) • Consider activity-specific prosthesis to meet newly established goals

	Perioperative	Pre-prosthetic	Prosthetic Training	Lifelong Care
9. Vocational Rehabilitation	• Obtain vocation interests	• Complete vocational rehabilitation evaluation if indicated	• Conduct worksite evaluation if indicated • 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 workplace modification needs

Abbreviations: ADL: activities of daily living; CV: cardiovascular; HEP: Home Exercise Program; IADL: instrumental activities of daily living; MSK: musculoskeletal; PLP: phantom limb pain; ROM: range of motion

Outcome Measures

The International Classification of Functioning, Disability, and Health (ICF) model was endorsed by the World Health Organization (WHO) in 2001 to create 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.(14) The ICF model is increasingly utilized in clinical settings as a way to conceptualize functional status, identify goals, plan and monitor treatment, and as a framework for outcome measurement. The use of the ICF allows clinicians and researchers from different fields and locations to use a common language to understand health and disability.

Appropriate selection and administration of outcome measures, linked to the ICF taxonomy, can be used to identify the impact of a health or health-related condition, evaluate needs, and track health and function over time.(15, 16) Many authors have attempted to link specific outcome measures to ICF taxonomy across a variety of disciplines, including ULA rehabilitation.(17-19) 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 a "toolkit" of outcome measures when seeking a comprehensive view of the patient's status and progress.(18-21)

In 2014, the UEAR CPG Work Group performed a systematic review to ensure that the most current information was included for recommendation development. The 2014 CPG systematic review intended to identify outcome measures to assess function in persons with ULA and evaluate each measure's focus, content, clinimetric, and psychometric properties. This 2014 CPG systematic review was, in part, an update of one completed in 2012 by the Measurement Group for the VA Amputation System of Care Repository. In 2022, the tables from the 2014 CPG evidence review were updated using the same inclusion and exclusion criteria.

A. Inclusion Criteria

- The manuscript employed a standardized outcome measure 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 10 persons with ULA
- The paper was written in English (or translated)
- An abstract was available for review

B. 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

Based on findings from the literature search, data on outcome measure psychometric properties were updated where indicated. The new literature search update also yielded five additional pertinent outcome measures: The Brief Activity Measure for Upper Limb Amputation (BAM-ULA), the Timed Measure of Activities Performance (T-MAP), the PROMIS-9 UE, the Capacity Assessment of Prosthetic Performance for the Upper Limb (CAPPFUL) and the Nine Hold Peg Test.(18, 19, 22-27) This review is not an exhaustive list of all outcome measures available for use with the upper limb amputation population or those that have been used in small studies or studies of prosthetic simulators. The 2014 VA/DoD UEAR CPG tables included the SHAP because of its popularity, evidence of content validity, and use in multiple small studies of TR amputees (1 – 6 subjects), plus several studies of prosthetic simulation.(28-37) Data on the psychometric properties of the SHAP was updated given a recent publication and led to inclusion of the performance measure Prosthesis Index of Functionality (P-IOF).(27)

All measures and their subscales are summarized in Table 8. 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 9 lists the same outcome measures categorized according to broad ICF categories, utility, and functional element assessed to facilitate 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 clinicians with information to help them choose the best measures of physical function appropriate for their patients and their facility.

Both the VA and the DoD have developed systems for collecting amputation-related outcome measures. The VA is using embedded outcome measures available within the EMR; the DoD is using a SharePoint based system to collect outcome measures. The VA and DoD Champions for this CPG update can assist anyone with questions about the respective agency systems. This updated literature also highlights that additional research is needed to evaluate the psychometric properties of outcome measures in persons with upper limb amputation to evaluate those measures that are most responsive to change and would be most suited for tracking patient outcomes over time.

Table 8. 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-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 (AUI)	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 (BBT)	+	+	N/A	N/A	+	+	+ (MDC 90 6.5)	++
Brief Activity Measure Upper Limb (BAM-ULA)	*	*	UK	*	+	UK	UK	+
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
Capacity Assessment of Prosthetic Performance for the Upper Limb (CAPPFUL)	*	?	UK	*	UK	UK	UK	UK
Disability of the Arm, Shoulder and Hand (DASH)	N/A	UK	N/A	UK	+	UK	?	UK
Jebsen-Taylor Hand Function Test – modified (mJTHFT)	+	+	N/A	N/A	+	0	(MDC 90 0.09-0.18 items/second)	?
PROMIS-9 UE	UK	+	+	+	+	UK	UK	UK
Orthotics and Prosthetics Users Survey (OPUS) Upper Extremity Functional Scale (UEFS)	UK	UK	0	UK	UK	UK	UK	0
OPUS UEFS modified (Burger)	UK	UK	+	UK	+	UK	UK	UK

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 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
OPUS UEFS Use	N/A	?	N/A	UK	0	+	0 (MDC 90.39)	0
Patient-Specific Function Scale (PSFS)	N/A	UK	N/A	UK	+	+	+	UK
Prosthesis Index of Functionality (P-IOF)	N/A	UK	UK	+	+	+	UK	+
Purdue Pegboard	N/A	UK	N/A	UK	?	UK	UK	
Southampton Hand Assessment Procedure (SHAP)	UK	UK	N/A	*	*	Floor effects +	UK	0
Timed Based Measure of Activity Performance (T-MAP)	UK	+	N/A	+	+	UK	UK	+
Total Skill Score	UK	UK	N/A	UK	+	UK	UK	UK
University of New Brunswick (UNB) 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	+	N/A	+	+	UK	(MDC 90 13.9) (MDC 95 17.4)(38)	+

Abbreviations: UE: upper extremity

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 9. Utility, Elements Assessed, Content, and Evidence Rating of Upper Extremity Functional Outcome Measures

		Utility				Elements Assessed								ICF Content Areas													
														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		15		Y											Y	Y	Y	Y	Y	Y	Y			
	ABILHAND-ULA	All	Y	N	10		Y											Y	Y	Y	Y	Y	Y	Y			
	AUI	Pros	Y	Y	?			Y										Y	Y	Y	Y	Y	Y	Y			
	DASH	All	Y	Y	10-15		Y							Y	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	QuickDASH	All	Y	Y	5		Y								Y	Y		Y	Y	Y		Y				Y	Y
	OPUS UEFS	All	Y	N	5-10		Y		Y									Y	Y	Y	Y	Y	Y	Y			
	OPUS UEFS (Burger)	All	Y	N	5-10		Y		Y									Y	Y	Y	Y	Y	Y	Y			
	OPUS UEFS modified rating scale (Jarl)	All	Y	N	5-10		Y		Y									Y	Y	Y	Y	Y	Y	Y			
	OPUS UEFS modified 27 item scale (Jarl)	All	Y	N	5-10		Y		Y									Y	Y	Y	Y	Y	Y	Y			
	OPUS UEFS modified 22 item scale (Resnik)	All	Y	N	5-10				Y									Y	Y	Y	Y	Y	Y	Y			
	OPUS UEFS Use	All	Y	Y	5-10			Y										Y	Y	Y	Y	Y	Y	Y			
	PROMIS-9 UE																										
	PSFS	All	Y	Y	5-10		Y											Patient lists tasks of importance									
	QuickDASH	All	Y	Y	5		Y							Y	Y			Y	Y		Y					Y	Y

		Utility				Elements Assessed								ICF Content Areas: Body Functions				ICF Content Areas: 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			
	BAM-ULA	Pros	Y	Y	10-20				Y									Y	Y		Y		Y				
	BBT	Pros	Y	Y	2	Y												Y									
	CAPPFUL	Pros	Y	Y	25-35	Y	Y	Y	Y	Y	Y	Y	Y			Y		Y	Y		Y		Y	Y		Y	Y
	Carroll test	Pros	N	Y	25 ?	Y	Y		Y									Y	Y								
	Carroll test (modified)	Pros	N	Y	20 ?	Y	Y											Y	Y								
	JTHF - modified	Pros	Y	Y	15+	Y													Y		Y						
	P-IOF	Pros	N	N	?	Y			Y							Y		Y	Y		Y			Y			
	Purdue Pegboard	Pros	Y	Y	5	Y												Y									
	SHAP	Pros	N	N	?	Y			Y							Y		Y	Y		Y			Y			
	T-Map	All	Y	Y	10-20	Y			Y											Y	Y	Y	Y				
	Total Skill Score	Pros	Y	Y	?	Y					Y							Y	Y	Y	Y	Y	Y	Y	Y		
	UNB Skill (1 subtest)	Pros	Y	Y	20-40								Y			Y											
	UNB Spontaneity (1 subtest)	Pros	Y	Y	20-40					Y						Y											

Essential Elements of the Annual Contact

Persons with ULA should be contacted annually at a minimum. Contact can occur via telephone, telehealth visits, in-person visits, or secure messaging as clinically appropriate. Assessment of the following elements should be completed at the time of the annual contact.

A. Medical Considerations

- Changes in medical status and new medical conditions
- Medication changes including use of non-prescription supplements
- Tobacco, alcohol, or illegal substance use
- Physical activity level and exercise program
- Nutritional status and changes in weight (increase or decrease)

B. Functional Status

- Current level of functional independence and changes in functional status (mobility, ADL function)
- Changes or new functional goals
- Need for new or replacement durable medical equipment
- Need for home or work environmental modifications
- Need for assistive technology for ADL and/or vocational support
- Need for therapy (PT/OT) services to address a change in functional status, new functional goals, or address equipment needs

C. Prosthesis-related Considerations

- Fit and function of the prosthesis
- Prosthesis utilization and barriers to greater use
- Need for replacement prosthetic components or supplies
- Need for new prosthetic componentry or technology to achieve functional goals
- Need for activity-specific prosthesis to better perform recreational or vocational activity

D. Pain and Residual Limb Considerations

- Residual limb skin condition and complications
- Pain issues (residual limb, phantom limb pain [PLP], musculoskeletal pain issues [i.e., neck, shoulder, back])
- Overuse symptoms in the proximal amputated limb or contralateral limb

E. Psychosocial Considerations

- Family and caregiver support or changes in support system
- New psychosocial stressors
- New emotional, behavioral, or psychological considerations
- Recreational or community resources and support
- Vocational issues or concerns
- Leisure activity participation
- Engagement in peer support activities

F. Secondary Amputation Prevention

- Risk factors for more proximal or additional amputation

Advantages and Disadvantages of Prostheses

Table 10. Advantages and Disadvantages of Prostheses by Type

	Advantages	Disadvantages
No Prosthesis	+ Comfort (no device/harness/suspension) + Tactile sensation through the residual limb + Proprioceptive feedback available through the residual limb	– No active prehension or mechanical grasp – Limited ability to do bimanual tasks – Increased potential for overuse injuries in the sound limb – Increased risk of asymmetry and back pain
Passive Prosthesis	+ Lightweight + Good cosmetic appearance + Minimal harnessing + Low maintenance + No control cables + Silicone products resist staining	– No functional grasp – Can be very expensive – Latex and PVC glove or prosthetic skin products stain easily
Body-powered Prosthesis	+ Durable and can be used in tasks or environments that could damage externally powered prosthesis (i.e., conditions involving excessive water, dust, or vibration) + Secondary proprioceptive feedback + Lower maintenance costs than electric options + Preferred for heavy duty jobs or activities + Less training required + Can be used with an activity specific TD	– Harnessing over shoulder is required – Less grip force with VO TD compared with electric options – Appearance of hook and cables

	Advantages	Disadvantages
Hybrid Prosthesis	+ Simultaneous control of elbow and TD or wrist + Lighter than fully electric elbow prosthesis + Increased grip force compared with VO body-powered options + Advantage of electric TD and wrist operation	– Requires a harness for elbow – Susceptible to damage from moisture or excessive vibration – Requires battery maintenance
Externally Powered Prosthesis	+ Proportional or variable speed grip/rotation + Advantage of electric TD and wrist operation + Potential for a more natural/ cosmetic appearance + Potential for pattern recognition and simultaneous control + Less shoulder motion required for TD operation	– Increased training time – More complicated to control; inadvertent motions are common – Harness is required for TH level amputations – Requires battery maintenance – Typically heavier than body-powered – Repairs are more complex – Susceptible to damage from moisture or excessive vibration – More expensive
Task-specific Prosthesis	+ TD and arm allow the capability to perform specific activities + May have minimal harnessing + Often has limited or no control cables + Durable, low maintenance + Protects primary prosthesis from damage	– No functional grip – Not appropriate for a broad range of functions – May need multiple TDs to perform different activities

Abbreviations: PVC: polyvinyl chloride; TD: terminal device; TH: transhumeral; VO: voluntary opening

Surgical Considerations

A. Surgical Considerations

a. Partial Hand Amputation

The mangled or mutilated hand is a common traumatic injury, most commonly occurring from agricultural, industrial, household, and motor vehicle mishaps, as well as combat-related injuries. The surgical goal is to retain or reestablish an acceptable hand, defined as "one which has three fingers of near normal length with near normal PIP joint motion and good sensibility along with a functioning thumb."(39) Because of the thumb's functional importance, special consideration should be taken to preserve it.(40, 41) The ring and small finger are also critical for grip strength and power grasp, essential in activities of daily living.(42) 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.(43) While outside the scope of this CPG, the decision to perform digital salvage versus 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 TR 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 the 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 TR level. However, this may be changing with advanced prosthesis technology and the emergence of hand transplantation procedures.

b. Wrist Disarticulation Amputation

The advantages of wrist disarticulation level amputation include:

- 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 TR 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 (TD), while attempting to achieve an acceptable limb length and cosmetic result. A survey of U.S. surgeons by Tooms (1972), before the introduction of modern wrist components, indicated a preference for distal TR amputations over wrist disarticulations.(44) However, advances in prosthesis design and materials have greatly improved function for the wrist disarticulation patient.(45)

c. Transradial Amputation

The TR level amputation is the most common major ULA.(46) This level of amputation also has the highest prosthesis acceptance rates in the upper limb. In distal TR amputations, the long lever arm, available forearm rotation, and preserved shoulder and elbow function allow the patient to easily position the TD and prosthesis in space. The TR 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 6 – 8 centimeters (cm) of bone is recommended to offer a robust soft-tissue envelope and permit a wide variety of prosthetic options. At least 5 cm of the residual ulna is required to allow for prosthetic fitting and elbow motion.(47, 48) At this level, consideration should be made to transfer the distal biceps tendon to the proximal ulna.(49) The obvious prosthesis and mechanical advantages of the TR 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.

d. Elbow Disarticulation Amputation

Elbow disarticulation and distal TH 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.(47, 50) However, the improved suspension and rotational control usually outweigh any cosmetic considerations for most patients. Shortening osteotomy of the humerus to improve the cosmetic result may be considered, but this is rarely indicated or performed.

e. Transhumeral Amputation

If the condyles of the distal humerus are not preserved, the ideal level for TH amputation is approximately 3 – 5 cm proximal to the elbow joint. Adequately suspended and standard prosthetic components are expected at this level, but rotational control is decreased compared to elbow disarticulation. Anterior angulation osteotomy, described by Neusel et al. (1997), can be performed to the distal humerus to improve the rotational stability of the prosthesis while still allowing a free-moving shoulder.(51) 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.

With a proximal TH amputation level, maintenance of length is critical, with most sources recommending the preservation of at least 5 – 7 cm of length from the glenohumeral joint to preserve maximum function. As in the TR amputation level, the use of dermal substitutes, skin grafting, and local and free flaps are strongly considered to preserve adequate length.(52) Preservation of the deltoid, pectoralis major, and latissimus dorsi insertions to the humerus will allow for body-powered or myoelectric prosthesis control.

f. 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 of the amputation as well as possibly aid in force transmission during prosthesis use. 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.(45, 48, 50)

g. Forequarter Amputation

Forequarter amputation consists of removal of the entire upper limb plus the scapula, part or all of the clavicle, and potentially part of the chest wall, typically as treatment for solid tumors. Free flaps, harvested from the amputated limb, are a reliable method for wound closure.(53) Preservation of as much of the shoulder as possible will enhance cosmesis and fitting for any prostheses. The primary purpose of a prosthesis in this group is to protect the chest wall; rehabilitation and prosthesis fit is challenging.(54) While rare, traumatic forequarter amputations do occur. The majority of those are traction injuries although other etiologies can include direct trauma to the upper quarter.(55) These cases present greater management difficulties as there may not be an amputated limb or viable tissue available to harvest for wound closure.

h. Surgical Muscle Balancing Strategies and Wound Closure Techniques

Myodesis, the process of attaching muscle tendon units directly to the 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 the 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 before closure. While there is no data to support the superiority of myodesis over myoplasty, the expert consensus is myodesis in ULA provides the most stable residual extremity and best isolates muscle signals for use in 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 provides robust coverage over the distal bone end, providing comfortable padding for the prosthetic socket while preventing the 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.

Local tissue flaps or free tissue transfer should be considered in the following cases to preserve:

- A functional shoulder joint and a TH amputation level
- A functional elbow joint and a TR amputation level
- 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 and when optimizing the length of the TH and TR 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. The use of dermal substitutes as an adjunct to skin grafting has proven successful in ULA, providing a more durable skin graft prosthetic interface, and allowing direct surgical approaches for future reconstructive procedures.(56, 57)

The use of microvascular free tissue transfer in well-selected patients to maximize length and provide durable soft tissue coverage has been successful in ULA.(52, 58, 59) Indications for free tissue transfer include:

- Shoulder joint preservation by preserving a TH amputation level
- Elbow joint preservation
- Preservation of bone greater than 7 cm 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 5 - 7 cm 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.

B. Emerging Surgical Techniques

At this time, some emerging surgical techniques may support greater patient function, reduce pain, and integrate with evolving technological advances in prosthetic devices. These techniques show promise in early studies but may not yet be considered standard of care. Providers need to be aware that such procedures exist and understand that there are implications for length and type of rehabilitation, types of prostheses, and other considerations over the continuum of care.

a. Targeted Muscle Reinnervation

Targeted muscle reinnervation involves "transferring distally innervating peripheral nerves from muscles that are no longer present or functional to more proximal available or functional musculature."(60) This technique allows the creation of up to six sites for myoelectric control of the prosthesis.(61) Emerging research shows additional potential for reduced PLP and residual limb pain, although 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.(60, 62)

b. Regenerative Peripheral Nerve Interface

The RPNI is another form of neural interface that may decrease neuroma formation, post-amputation pain, PLP, and sensation.(63) The described procedure involves implanting the free end of a transected peripheral nerve into a segment of free autologous muscle. This surgical procedure can be performed prophylactically at the time of the index amputation or as a staged procedure for symptomatic neuromas.

c. Agonist Antagonist Myoneural Interface

The AMI is another emerging technology in limb amputation surgical management that has shown promise to improve patient outcomes by providing bidirectional neural feedback and proprioceptive feedback in the residual limb.(64) This theory was developed using a rat animal model to connect agonist and antagonist muscles in the healthy tissues of the distal residual limb following amputation.(64, 65) The first description of AMIs being used in the human extremity was a case series of three below the knee amputations (BKA) with encouraging results for increased proprioception of the distal residual limb and decreased PLP.(66) Although trialed in persons with ULA, there is currently no published literature supporting the safety or outcomes of the AMI procedure in this population.(67)

d. Osseointegration

For the attachment of the prosthesis to the residual limb, OI has been used in Europe for more than 20 years for both lower and upper extremities and in the U.S. for over a decade. This includes emerging work with osseointegrated digits.(60, 67-69) It involves inserting a titanium implant into the distal bone of the residual limb. A percutaneous implant component 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 complications commonly associated with the use of a socket suspension system and is available for tactile feedback. The inclusion criteria for this procedure include skeletal maturity, sufficient bone stock to support the fixture, and the ability to complete rehabilitation.(70) Minor complications are most common, such as soft tissue infections, and may be mitigated in the future by improvements in surgical technique and implant design.(71)

Control Strategies for Body-Powered and Externally Powered Prostheses

A. 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 TD.(72, 73) Specific combinations of proximal motions produce tension through the cable that results in prosthetic function.

For a TR amputation patient, glenohumeral flexion and scapular protraction will produce TD 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.(72)

For a TH amputation patient, the cable from the harness to TD 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 TD open or closed, depending on the type of TD used (voluntary open or voluntary close).(72, 73) 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.(74) To unlock the elbow, the locking strap must recoil first and then the same motion for locking is used to unlock.(73) 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.(72)

B. 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 through one or more control inputs.

The most common control inputs for externally powered prostheses are electromyography (EMG) 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 to consider externally powered components. Other control inputs, such as force sensitive resistors (FSRs), linear transducers, toggle and rocker switches, and inertial measurement units (IMUs) are available to increase the potential for using externally powered joints.

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. Various control configurations 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" (e.g., "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 strategies such as co-contraction of two myosites, use of a hard/fast versus a soft/slow contraction, or use of a separate input. Alternatively, it 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 TH prosthesis that uses a linear transducer to control a powered elbow and two antagonistic myosites that are programmed to control the powered TD and/or wrist. This setup allows the user to simultaneously activate the elbow with the TD or wrist since the elbow is always active. Control of the wrist and TD would be navigated using a sequential strategy as described above.

Electromyography pattern recognition systems designed for use with prostheses may improve the ability of a patient with ULA 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. Pattern recognition may benefit patients with higher amputation levels and those who have undergone TMR.(75-77)

Another developing control strategy option is that of "end-point control." This strategy allows the user to actuate multiple powered joints, in simultaneous coordinated movement, to bring the TD to a desired point in space. Inertial measurement units or EMG pattern recognition inputs are more suited for this control. As an example, an externally powered upper limb prosthesis which includes a powered shoulder, elbow wrist, and hand has a large number of powered degrees of freedom. Rather than plan the motion of each powered joint to get the prosthetic TD into a desired position, the control commands, using endpoint control, may be simplified as "hand up/down," "hand left/right," "hand forward/back," etc. Endpoint control reduces the number of required control inputs in the system and can enable coordinated movement of the shoulder, elbow, wrist, and hand. This control strategy provides an alternative reference point for prosthetic control and provides the potential to improve anthropomorphic movements in prostheses for more proximal levels of limb loss.(78)

Training for Body-Powered and Externally Powered Prostheses

A. Overview of Training

Quality training in the use of a prosthesis is essential to ensure the best outcomes for the limb loss population. Occupational and physical therapists train the limb loss patient from basic operation of the device up to seamless incorporation of the device in complex tasks without having to think about movement. Coaching and practice assists the patient in motor relearning, normal quality of motion, anticipatory skills, and carry over of learned techniques to a variety of tasks. Among other goals, therapy aims to teach the patient how best to operate a prosthetic device and how to analyze tasks to incorporate the device into daily activities. The real skill of prosthesis training comes in the patient looking at the environment with a critical eye of anticipating how the prosthesis will best assist them and or how to adapt to the environment. Having another efficient functional grasp helps the patient be more functional as well as gives them a sense of fulfillment. If a patient has learned the following essential skills with a trained professional, then they have achieved a level of competence and are encouraged to use or not use a prosthesis at their discretion. The following is a general guideline for clinicians to follow to ensure general concepts are covered in training.

B. Residual Limb Management

- Scar massage and desensitization: Important for reducing scarring and preparing to tolerate weight and pressure of a socket. This also serves to make them aware of any sensitive areas of their residual limb.
- Therapeutic exercise for residual limb: Use of cuff weights, theraband, or strap with metal D-ring for use with cable machine.
    - Important to initiate in preparation for a prosthesis. Promotes tolerance of the weight of the prosthesis, pressure, and muscular endurance for long-term wearing.
- Range of motion (79):
    - Prevent loss of ROM in the proximal joints of the residual limb initiate early in rehabilitation.
    - Myosite deep pressure massage to stretch muscle site.
    - Stretching of residual musculature is important long-term to ensure symmetry due to compensatory movements, loss of weight of the limb, and less use of the distal extremity.
- Strengthening:
    - Increase strength to tolerate weight of a prosthesis with use of cuff weights or cable machine to strengthen and desensitize the residual limb.
    - Strengthening proximal joints will promote symmetry and may decrease atrophy to the affected limb.
    - Postural training, exercise, and yoga/pilates may prevent pain and deformity due to asymmetry.

- Skin checks and wearing schedule:
  - Limit prosthesis wear time to 1 to 2 hours initially, then increasing an hour or so every few days.
  - Monitor skin for signs of excessive pressure, blister, or wound formation. This is especially important if there is impaired sensation or skin grafts.
  - Use a mirror to self-monitor daily.

C. Prosthesis Training Concepts

Prosthesis training provides the opportunity for a patient to become familiar with the device and progress to a level of expertise. Patients should be encouraged to experiment through this process with how tasks are performed and be assisted with determining how the device may best assist the individual. The ability to accurately control a device may vary from person to person and from body powered to myoelectric, but the therapist's role is to help each individual identify appropriate challenges and have realistic expectations in task performance. Expectation management and appropriate sub-task selection is key to success. Therapists are encouraged to review these concepts with their patients to ensure covering the necessary skills (see below).

- Control of prosthesis: operating all joints individually and combined.
  - Body powered: teach the patient to operate all device motions by gross body movements. Challenge patient to operate the device at various heights and distances away from the body.
  - Myoelectric: begin by using software programs to maximize control accuracy, especially for patients with more complicated muscle activation controls like quick/slow, double/triple impulse, linear potentiometer, and pattern recognition.
    - Perform accuracy testing: have the patient perform four motions of wrist and TD outlined below. Repeat three times for open, rotate clockwise, close, and rotate counterclockwise. Then record if they were a) correct, b) performed the wrong motion/stalls with number of attempts, or c) were unable. The individual 1) opens the TD ¾ of the full finger extension, 2) supinates 180 degrees, 3) closes TD to ¼ extension, and 4) pronates 180 degrees. This is repeated three times and the therapist should cue the patient to the next motion, so they don't have to guess the next motion. The clinician can make a list of 1 to 12, mark when there is an error or delay, and get a percentage of accuracy by dividing the correct motions from the 12 motions to track progress over time.
    - Make sure to involve the prosthetist as they may have more adjustments available to improve myoelectric signal and control.
- Quality of movement: teach the patient to maintain supporting joints in the appropriate positions to prevent strain and awkward movements. Use mirrors and therapist cues to help patients be aware of compensatory movements such as shoulder hiking, extreme shoulder flexion, elbow abduction, or excessive internal humeral rotation. Therapist cues, mirrors, and video feedback (with patient permission) may be used so patients learn to maintain thoracic

spine extension, ensure scapular retraction/depression, keep the elbow adducted, and avoid aberrant compensatory movements listed above.

- Prepositioning: educate the patient to anticipate the appropriate position that the prosthetic devices need to be in for optimal engagement in a selected task. For example, make sure when preparing to grasp that the tines or fingers face the appropriate direction to optimize grasp. Or more explicitly, having the prosthetic hand open and rotated to face the intact hand prior to receiving an object from the other hand.
- Rote tasks:
    - Pass objects to and from prosthesis to contralateral hand in different positions. Do this without vision, behind the back, between the legs, and in all positions of elbow and shoulder movement.
    - Grasp and release objects in various planes of movement to optimize use of the prosthesis for all tasks.
        - Body powered difficulties: operating with full elbow flexion, shoulder at 90 degrees of flexion, overhead, or behind back. Patients should be educated about the 3-dimensional functional envelope for using the prosthesis (the area around the body where the prosthesis can be operated most easily) in front of them.
        - Myoelectric power difficulties: overhead, reaching, holding heavy items, and maintaining grasp to prevent dropping items.
- Experiment with use of the TD with bilateral tasks: have the patient try to perform bilateral tasks (see below task list) in a few different methods/strategies and see what works best for them. Discuss advantages and disadvantages of performance, focus on efficiency of movements.
    - Tying shoe or lacing board: have the patient identify how many pinches are the most efficient and how fast they can perform once they find the best method.
    - Try performing other tasks three different ways and discuss what works best.
- Adjustments to the arm: patients should learn, when appropriate, how to make adjustments to the prosthesis or prosthetic control system and master the subtleties of control.
    - Body powered: how to adjust control cable length. How to tighten or lock TD in place. Pad or prevent chafing from prosthesis. How to repair a broken control cable or strap.
    - Myoelectric: how to alter gain of the electrodes. When to turn the device off or disable features, such as turning off the hand/wrist or locking a joint.
    - Sockets: how to relieve or change pressure from the socket or strapping and how to make various socket suspension adjustments.
- Holding objects while performing tasks. Developing trust and learning where and when tasks can be performed consistently. Three points of control on the object is optimal.
    - Holding coffee while operating keys and open door.
    - Holding stabilizing utensil while cutting.
    - Leather lacing tasks.

- Beading strings.
- Cutting fruit and placing on a wooden skewer.

- Dexterity: encourage performing things rapidly to increase efficiency and improve function.
  - Timing simple tasks with a stopwatch such as stacking cones or moving blocks.
  - Asking the patient to anticipate how long it will take to perform a particular task and see if they were correct.
  - Challenge the patient to find a way to perform faster or compete for fun against another patient.
- Light touch: practice performing light touch to prevent deforming or breaking certain objects. Can be performed with foam blocks or thin disposable plastic cups.
- Performing tasks without vision, such as in the dark or with vision excluded to facilitate proprioceptive knowledge and skill with TD in space. For example, tasks such as: don/doff glove, pants, shirt, jacket, and tie shoes.
- Rote complete task performance: more practice with repetitive tasks to increase automatic performance and increase dexterity
  - Folding laundry/towels, washing dishes, cleaning tasks, vacuum, or sweeping.
  - Wallet management tasks, filing files, lacing, or sewing tasks.
- Bimanual task list: therapist reviews the list of activities in Table 11, identifies meaningful activities to the patient, and then coaches and discusses what approaches are efficient and what works best for the patient. Therapist discusses strategies for adapting tasks or objects to be adapting tasks or objects to be adapted to perform tasks more easily.

Table 11. Prosthetic Training: Bimanual Task List

Bimanual 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 TD
• 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	• Wash clothes
• 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

Bimanual Task List

- Open/close bottle of pills or pillbox
- Manipulate pills
- Shave
- Perform residual limb care
- Wash back
- Apply deodorant
- Wash/dry hand
- Bathe/dry upper body
- Bathe/dry lower body
- Wash/blow dry hair
- Blow nose
- Toilet paper management
- Feminine hygiene
- Flushing toilet
- Wipe self
- Apply lotion
- Apply make-up
- Clean fingernails
- Cut and file fingernails
- Polish fingernails
- Use/remove contacts
- Place and remove glasses
- Patient specific tasks
- Open/close safety pin
- Change diapers
- Brush/arrange child's hair
- Use phone and take notes simultaneously
- Operate door knob
- Place chain on chain lock
- Plug/unplug cord into wall outlet
- Set time on watch
- Receive change/ count coins
- Remove keys or wallet from pocket
- Take dollar bill from wallet
- Write signature
- Answer phone
- Text message on cell phone
- Open mail
- Hold/turn pages of paperback, magazine, newspaper
- Operate lamp
- Use an umbrella
- Change a light bulb
- Hang a picture
- Use scissors
- Use ruler
- Remove and replace ink pen cap
- Sharpen pencil
- Fold and seal letter
- Use wet and dry mop
- Sweep/mop the floor
- Dust the furniture
- Clean countertops
- Clean the toilet/sink/tub
- Make bed/change sheets
- Change garbage/trash bag
- Open/close jar – tight or new
- Open lid of can
- Cut vegetables
- Peel vegetables
- Peel banana
- Crack an egg
- Stir food in bowl
- Manipulate hot pots
- Turn an egg or pancake with spatula
- Use measuring cups
- Use measuring spoons
- Scoop ice cream
- Use toaster
- Open pop-top
- Wrap/unwrap food in foil and or plastic wrap
- Put dishes in overhead cabinet
- Pour milk from carton
- Use mixer
- Use lock-type plastic bags
- Light a match
- Sew a button
- Turn key in lock
- Carry a suitcase
- Operate window blinds
- Open pet food container
- Attach and hold dog leash
- Change litter box
- Fill water dish
- Play cards or board game
- Operate TV remote control
- Manipulate radio
- Use computer: typing, mouse
- Use CD/DVD player
- Grocery shopping – push a cart, load, unload
- Carry grocery bags
- Use vending machine
- Make change/receive change
- Use ATM
- Use public transportation
- Open and close car doors, trunk, and hood
- Perform steps required to operate vehicle

Bimanual Task List	
• 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
• Assembling a tent	• Making a fire in a fire pit
• Rowing a boat	• Cooking on a grill
• Mowing lawn	• Weed whacking/hedge trimming
• Painting a room	• Setting up and climbing a ladder
• Construct a moving box	• Operate controls

Abbreviations: TD: terminal device

- Compare and contrast different TDs and advantages/disadvantages with a variety of tasks.
- Unilateral performance with prosthesis: increases proficiency with control and creative use of the prosthesis with more complex challenges.
    - Eat a snack and drink with only the prosthesis.
    - Using a key to unlock a door.
    - Build a construction task only with the TD like Lincoln Logs or large LEGO bricks.
    - Make a sandwich or cook an egg with only the prosthesis.
- Adaptive sports/fitness/recreation/leisure tasks:
    - Complex, multi-step tasks such as setting up a campsite and tent.
    - Activity specific devices for specific sports or activities. How to find a way to make other devices work if needed.
    - Educate patient on how to incorporate prosthesis into high level fitness tasks.
    - Select whole tasks to be performed and how to perform them, such as going camping, going to the beach, packing for a picnic, taking photographs, and planning to go on vacation with devices needed.
    - Practice return to meaningful recreational or leisure tasks that the patient may want to resume performing.
- Multitasking with prosthesis: increase cognitive load to increase difficulty to process prosthesis use.
    - Make a three-course meal simultaneously.
    - Perform a construction task quickly while listening to a podcast. Attempt to remember all details of the podcast to be questioned after task completion.
- Adapting tasks or objects for success with prosthesis.
    - Increase or reduce friction of some objects with use of self-adherent wrap (e.g., Coban™), Dycem™ non-slip, or moisturizer.

  - Prevent scratching from metal hooks by adding rubber tubing to prosthesis tines.
  - Adding built up foam handles or making custom interface to allow grasp to be performed easier with prosthesis and prevent rotation of the object in the device.
- Work tasks: practice set up and performance.
  - Ergonomics assessment and look at how to incorporate prosthesis into office tasks while ensuring good body mechanics.

D. Education Topics

Medical providers should take every opportunity to educate patients early and often throughout the rehabilitation process. The patient can make informed decisions when educated about prostheses and various prosthetic limb options for control and function. However, the information presented must not be overwhelming for the patient. These topics serve to stimulate awareness about the field of prosthetics to encourage the patient to advocate for their needs and seek out answers to the many new physical challenges they face daily.

- Scar massage
- Adaptive equipment
- How prosthetics realistically assist function
- How to protect and decrease stress on an intact limb
- The importance of humor in recovery
- The importance of peer support and success stories
- Casting and prosthesis fitting process
- Prosthesis suspension types
- How to best exercise, stretch, and strengthen
- Educate about the muscles involved in operation of devices
- How myoelectric prostheses operate
- How myoelectric software can identify a switch between prostheses actions (quick/slow, co-contraction, double/triple impulse)
- Pattern recognition systems such as CoApt and Myo Plus from Otto Bock
- Clarify that although there are more devices and control systems available, using microvolts traveling in muscles to act as switches is not a perfect system. Errors happen and precise control is not guaranteed.
- Review safety and situations that would be dangerous, such as holding on to heavy machinery without a way to automatically release/open TD
- Types of TDs for body powered or myoelectric prostheses
- Advantages and disadvantages of different TDs

References

1. VHA Amputee Data Repository. VHA Support Service Center.Aug 2021. Available from: https://vssc.med.va.gov.
2. U.S. Department of Veterans Affairs/Department of Defense Health Executive Committee (HEC). Evidence Based Practice Work Group Charter [updated January 9, 2017]. Available from: https://www.healthquality.va.gov/documents/EvidenceBasedPracticeWGCharter123020161.pdf.
3. Society for Medical Decision Making Committee on Standardization of Clinical Algorithms. Proposal for clinical algorithm standards. Medical decision making : an international journal of the Society for Medical Decision Making. 1992;12(2):149-54. Epub 1992/04/01. PubMed PMID: 1573982.
4. U.S. Department of Veteran Affairs, Department of Defense. Guideline for Guidelines. Veterans Health Administration, Office of Quality & Performance, Evidence Review Subgroup; Revised January 29, 2019.
5. Ransohoff DF, Pignone M, Sox HC. How to decide whether a clinical practice guideline is trustworthy. Jama. 2013;309(2):139-40. Epub 2013/01/10. doi: 10.1001/jama.2012.156703. PubMed PMID: 23299601.
6. Andrews JC, Schunemann HJ, Oxman AD, Pottie K, Meerpohl JJ, Coello PA, et al. GRADE guidelines: 15. Going from evidence to recommendation-determinants of a recommendation's direction and strength. Journal of clinical epidemiology. 2013;66(7):726-35. Epub 2013/04/11. doi: 10.1016/j.jclinepi.2013.02.003. PubMed PMID: 23570745.
7. Andrews J, Guyatt G, Oxman AD, Alderson P, Dahm P, Falck-Ytter Y, et al. GRADE guidelines: 14. Going from evidence to recommendations: the significance and presentation of recommendations. Journal of clinical epidemiology. 2013;66(7):719-25. Epub 2013/01/15. doi: 10.1016/j.jclinepi.2012.03.013. PubMed PMID: 23312392.
8. Martinez Garcia L, McFarlane E, Barnes S, Sanabria AJ, Alonso-Coello P, Alderson P. Updated recommendations: an assessment of NICE clinical guidelines. Implementation science : IS. 2014;9:72. Epub 2014/06/13. doi: 10.1186/1748-5908-9-72. PubMed PMID: 24919856; PubMed Central PMCID: PMCPmc4067507.
9. National Institute for Health and Care Excellence. The guidelines manual. London: National Institute for Health and Care Excellence, 2012.
10. Robinson JH, Callister LC, Berry JA, Dearing KA. Patient-centered care and adherence: Definitions and applications to improve outcomes. Journal of the American Academy of Nurse Practitioners. 2008;20(12):600-7. Epub 2009/01/06. doi: 10.1111/j.1745-7599.2008.00360.x. PubMed PMID: 19120591.
11. Stewart M, Brown JB, Donner A, McWhinney IR, Oates J, Weston WW, et al. The impact of patient-centered care on outcomes. J Fam Pract. 2000;49(9):796-804. Epub 2000/10/14. PubMed PMID: 11032203.
12. National Learning Consortium. Shared Decision Making 2013. Available from: https://www.healthit.gov/sites/default/files/nlc_shared_decision_making_fact_sheet.pdf.
13. Institute of Medicine. Crossing the Quality Chasm: A New Health System for the 21st Century. Washington DC: National Academies Press, 2001.
14. World Health O. International classification of functioning, disability and health : ICF. Geneva: World Health Organization; 2001.
15. Cieza A, Brockow T, Ewert T, Amman E, Kollerits B, Chatterji S, et al. Linking health-status measurements to the international classification of functioning, disability and health. J Rehabil Med. 2002;34(5):205-10. Epub 2002/10/24. doi: 10.1080/165019702760279189. PubMed PMID: 12392234.

16. Cieza A, Geyh S, Chatterji S, Kostanjsek N, Ustün B, Stucki G. ICF linking rules: an update based on lessons learned. J Rehabil Med. 2005;37(4):212-8. Epub 2005/07/19. doi: 10.1080/16501970510040263. PubMed PMID: 16024476.

17. Fayed N, Cieza A, Bickenbach JE. Linking health and health-related information to the ICF: a systematic review of the literature from 2001 to 2008. Disabil Rehabil. 2011;33(21-22):1941-51. Epub 2011/02/10. doi: 10.3109/09638288.2011.553704. PubMed PMID: 21303198.

18. Hill W, Kyberd P, Norling Hermansson L, Hubbard S, Stavdahl Ø, Swanson S. Upper Limb Prosthetic Outcome Measures (ULPOM): A Working Group and Their Findings. JPO: Journal of Prosthetics and Orthotics. 2009; 21(9):P69-P82. doi: 10.1097/JPO.0b013e3181ae970b. PubMed PMID: 00008526-200910001-00004.

19. Lindner HY, Nätterlund BS, Hermansson LM. Upper limb prosthetic outcome measures: review and content comparison based on International Classification of Functioning, Disability and Health. Prosthet Orthot Int. 2010;34(2):109-28. Epub 2010/05/18. doi: 10.3109/03093641003776976. PubMed PMID: 20470058.

20. Wright V. Prosthetic Outcome Measures for Use With Upper Limb Amputees: A Systematic Review of the Peer-Reviewed Literature, 1970 to 2009. JPO: Journal of Prosthetics and Orthotics. 2009;21(9):P3-P63. doi: 10.1097/JPO.0b013e3181ae9637. PubMed PMID: 00008526-200910001-00002.

21. 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. doi: 10.1097/JPO.0b013e31826ff91c. PubMed PMID: 00008526-201210000-00005.

22. England DL, Miller TA, Stevens PM, Campbell JH, Wurdeman SR. Assessment of a Nine-Item Patient-Reported Outcomes Measurement Information System Upper Extremity Instrument Among Individuals With Upper Limb Amputation. Am J Phys Med Rehabil. 2021;100(2):130-7. Epub 2020/07/18. doi: 10.1097/phm.0000000000001531. PubMed PMID: 32675705.

23. Postema SG, Bongers RM, Van der Sluis CK, Reneman MF. Repeatability and Safety of the Functional Capacity Evaluation-One-Handed for Individuals with Upper Limb Reduction Deficiency and Amputation. J Occup Rehabil. 2018;28(3):475-85. Epub 2017/09/22. doi: 10.1007/s10926-017-9723-0. PubMed PMID: 28932940; PubMed Central PMCID: PMCPMC6096508.

24. Resnik L, Borgia M, Acluche F. Brief activity performance measure for upper limb amputees: BAM-ULA. Prosthet Orthot Int. 2018;42(1):75-83. Epub 2017/01/17. doi: 10.1177/0309364616684196. PubMed PMID: 28091278.

25. Kearns NT, Peterson JK, Smurr Walters L, Jackson WT, Miguelez JM, Ryan T. Development and Psychometric Validation of Capacity Assessment of Prosthetic Performance for the Upper Limb (CAPPFUL). Arch Phys Med Rehabil. 2018;99(9):1789-97. Epub 2018/05/20. doi: 10.1016/j.apmr.2018.04.021. PubMed PMID: 29777713.

26. Resnik L, Borgia M, Acluche F. Timed activity performance in persons with upper limb amputation: A preliminary study. J Hand Ther. 2017;30(4):468-76. Epub 2017/05/11. doi: 10.1016/j.jht.2017.03.008. PubMed PMID: 28487130.

27. Resnik L, Borgia M, Cancio JM, Delikat J, Ni P. Psychometric evaluation of the Southampton hand assessment procedure (SHAP) in a sample of upper limb prosthesis users. J Hand Ther. 2021. Epub 2021/08/18. doi: 10.1016/j.jht.2021.07.003. PubMed PMID: 34400030.

28. 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. 2002;83(6):776-83. Epub 2002/06/06. doi: 10.1053/apmr.2002.32737. PubMed PMID: 12048655.

29. 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. J Rehabil Med. 2014;46(8):788-97. Epub 2014/05/23. doi: 10.2340/16501977-1827. PubMed PMID: 24850374.

30. 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. Prosthet Orthot Int. 2016;40(1):123-8. Epub 2014/08/20. doi: 10.1177/0309364614545417. PubMed PMID: 25134531.

31. Fougner AL, Stavdahl O, Kyberd PJ. System training and assessment in simultaneous proportional myoelectric prosthesis control. J Neuroeng Rehabil. 2014;11:75. Epub 2014/04/30. doi: 10.1186/1743-0003-11-75. PubMed PMID: 24775602; PubMed Central PMCID: PMCPMC4041142.

32. Bouwsema H, van der Sluis CK, Bongers RM. Changes in performance over time while learning to use a myoelectric prosthesis. J Neuroeng Rehabil. 2014;11:16. Epub 2014/02/27. doi: 10.1186/1743-0003-11-16. PubMed PMID: 24568148; PubMed Central PMCID: PMCPMC3944783.

33. van der Niet O, Bongers RM, van der Sluis CK. Functionality of i-LIMB and i-LIMB pulse hands: case report. J Rehabil Res Dev. 2013;50(8):1123-8. Epub 2014/01/25. doi: 10.1682/jrrd.2012.08.0140. PubMed PMID: 24458898.

34. Dalley SA, Bennett DA, Goldfarb M. Preliminary functional assessment of a multigrasp myoelectric prosthesis. Annu Int Conf IEEE Eng Med Biol Soc. 2012;2012:4172-5. Epub 2013/02/01. doi: 10.1109/embc.2012.6346886. PubMed PMID: 23366847; PubMed Central PMCID: PMCPMC4474230.

35. 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):1331-48. Epub 2013/02/15. doi: 10.1682/jrrd.2011.09.0179. PubMed PMID: 23408215.

36. 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. Prosthet Orthot Int. 2011;35(3):285-93. Epub 2011/09/23. doi: 10.1177/0309364611418554. PubMed PMID: 21937574.

37. Ramirez IA, Lusk CP, Dubey R, Highsmith MJ, Maitland ME. Crossed four-bar mechanism for improved prosthetic grasp. J Rehabil Res Dev. 2009;46(8):1011-20. Epub 2010/02/17. doi: 10.1682/jrrd.2009.01.0004. PubMed PMID: 20157858.

38. Resnik L, Borgia M. Reliability, Validity, and Responsiveness of the QuickDASH in Patients With Upper Limb Amputation. Arch Phys Med Rehabil. 2015;96(9):1676-83. Epub 2015/04/29. doi: 10.1016/j.apmr. 2015.03.023. PubMed PMID: 25912667.

39. Agarwal R, Agarwal D, Agarwal M. Approach to mutilating hand injuries. J Clin Orthop Trauma. 2021;15:172-5. Epub 2019/08/14. doi: 10.1016/j.jcot.2019.08.011. PubMed PMID: 33717934; PubMed Central PMCID: PMCPMC7920121.

40. Andersson G, Cocchiarella L. Guides to the evaluation of permanent impairment. 5th ed: American Medical Association; 2000. 613 p.

41. Lahiri A. Managing Mutilating Hand Injuries. Clin Plast Surg. 2019;46(3):351-7. Epub 2019/05/20. doi: 10.1016/j.cps.2019.02.009. PubMed PMID: 31103080.

42. Neumeister MW, Brown RE. Mutilating hand injuries: principles and management. Hand clinics. 2003;19(1): 1-15, v. Epub 2003/04/10. PubMed PMID: 12683442.

43. Moran SL, Berger RA. Biomechanics and hand trauma: what you need. Hand clinics. 2003;19(1):17-31. Epub 2003/04/10. PubMed PMID: 12683443.

44. Tooms RE. Amputation surgery in the upper extremity. The Orthopedic clinics of North America. 1972;3(2): 383-95. Epub 1972/07/01. PubMed PMID: 5037524.

45. Tintle SM, Baechler MF, Nanos GP, 3rd, Forsberg JA, Potter BK. Traumatic and trauma-related amputations: Part II: Upper extremity and future directions. The Journal of bone and joint surgery American volume. 2010;92(18):2934-45. Epub 2010/12/17. doi: 10.2106/jbjs.j.00258. PubMed PMID: 21159994.

46. Wright TW, Hagen AD, Wood MB. Prosthetic usage in major upper extremity amputations. J Hand Surg Am. 1995;20(4):619-22. Epub 1995/07/01. doi: 10.1016/s0363-5023(05)80278-3. PubMed PMID: 7594289.

47. Krajbich JIP, Michael S.; Potter, Benjamin K.; Stevens, Phillip M. Atlas of amputations and limb deficiencies: surgical, prosthetic, and rehabilitation principles. 4th ed. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2016.

48. Pasquina PF, Bryant PR, Huang ME, Roberts TL, Nelson VS, Flood KM. Advances in amputee care. Arch Phys Med Rehabil. 2006;87(3 Suppl 1):S34-43; quiz S4-5. Epub 2006/02/28. doi: 10.1016/j.apmr.2005.11.026. PubMed PMID: 16500191.

49. Shawen S, Doukas W, Shrout J, Ficke J, Potter B, Hayda R, et al. Care of the combat amputee. Washington, DC: Dept. of the Army, Borden Institute; 2009.

50. Cho MS. Elbow Disarticulation and Transhumeral Amputation: Surgical Management. 2016. In: Atlas of Amputation and Limb Deficiencies: Surgical Prosthetic, and Rehabilitation Principles [Internet]. Rosemont, IL: American Academy of Orthopaedic Surgeons. 4th.

51. Neusel E, Traub M, Blasius K, Marquardt E. Results of humeral stump angulation osteotomy. Archives of orthopaedic and trauma surgery. 1997;116(5):263-5. Epub 1997/01/01. PubMed PMID: 9177800.

52. Baccarani A, Follmar KE, De Santis G, Adani R, Pinelli M, Innocenti M, et al. Free vascularized tissue transfer to preserve upper extremity amputation levels. Plast Reconstr Surg. 2007;120(4):971-81. Epub 2007/09/07. doi: 10.1097/01.prs.0000256479.54755.f6. PubMed PMID: 17805127.

53. Tukiainen E, Barner-Rasmussen I, Popov P, Kaarela O. Forequarter Amputation and Reconstructive Options. Ann Plast Surg. 2020;84(6):651-6. Epub 2020/03/10. doi: 10.1097/sap.0000000000002204. PubMed PMID: 32149840.

54. Elsner U, Henrichs M, Gosheger G, Dieckmann R, Nottrott M, Hardes J, et al. Forequarter amputation: a safe rescue procedure in a curative and palliative setting in high-grade malignoma of the shoulder girdle. World J Surg Oncol. 2016;14(1):216. Epub 2016/08/17. doi: 10.1186/s12957-016-0973-7. PubMed PMID: 27526689; PubMed Central PMCID: PMCPMC4986170.

55. Barry T, Herron T, Lorch S, Ciesla D. Complex reconstruction following traumatic forequarter amputation. The Journal of Cardiothoracic Trauma. 2019;4(1):55-8. doi: 10.4103/jctt.jctt_15_19.

56. Foong DP, Evriviades D, Jeffery SL. Integra permits early durable coverage of improvised explosive device (IED) amputation stumps. Journal of plastic, reconstructive & aesthetic surgery : JPRAS. 2013;66(12):1717-24. Epub 2013/08/07. doi: 10.1016/j.bjps.2013.07.007. PubMed PMID: 23916387.

57. 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. Journal of orthopaedic trauma. 2007;21(6):394-9. Epub 2007/07/11. doi: 10.1097/BOT.0b013e318070c028. PubMed PMID: 17620998.

58. 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. 1991;26(5):469-73. Epub 1991/05/11. PubMed PMID: 1952722.

59. 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. 1987;11(2):71-4. Epub 1987/08/01. PubMed PMID: 3309883.
60. Zlotolow DA, Kozin SH. Advances in upper extremity prosthetics. Hand clinics. 2012;28(4):587-93. Epub 2012/10/30. doi: 10.1016/j.hcl.2012.08.014. PubMed PMID: 23101609.
61. Mioton LM, Dumanian GA, Shah N, Qiu CS, Ertl WJ, Potter BK, et al. Targeted Muscle Reinnervation Improves Residual Limb Pain, Phantom Limb Pain, and Limb Function: A Prospective Study of 33 Major Limb Amputees. Clin Orthop Relat Res. 2020;478(9):2161-7. Epub 2020/05/27. doi: 10.1097/corr. 0000000000001323. PubMed PMID: 32452928; PubMed Central PMCID: PMCPMC7431223 Related Research® editors and board members are on file with the publication and can be viewed on request.
62. Agrawal N, Gfrerer L, Heng M, Eberlin KR, Valerio I. Targeted Muscle Reinnervation as a Surgical Approach for Phantom Limb Pain Management Following Amputation. Current Physical Medicine and Rehabilitation Reports. 2021. doi: 10.1007/s40141-021-00329-0.
63. Frost CM, Ursu DC, Flattery SM, Nedic A, Hassett CA, Moon JD, et al. Regenerative peripheral nerve interfaces for real-time, proportional control of a Neuroprosthetic hand. J Neuroeng Rehabil. 2018;15(1):108. Epub 2018/11/22. doi: 10.1186/s12984-018-0452-1. PubMed PMID: 30458876; PubMed Central PMCID: PMCPMC6245539.
64. Srinivasan SS, Carty MJ, Calvaresi PW, Clites TR, Maimon BE, Taylor CR, et al. On prosthetic control: A regenerative agonist-antagonist myoneural interface. Sci Robot. 2017;2(6). Epub 2017/05/31. doi: 10.1126/scirobotics.aan2971. PubMed PMID: 33157872.
65. Srinivasan SS, Diaz M, Carty M, Herr HM. Towards functional restoration for persons with limb amputation: A dual-stage implementation of regenerative agonist-antagonist myoneural interfaces. Sci Rep. 2019;9(1):1981. Epub 2019/02/15. doi: 10.1038/s41598-018-38096-z. PubMed PMID: 30760764; PubMed Central PMCID: PMCPMC6374452.
66. Clites TR, Herr HM, Srinivasan SS, Zorzos AN, Carty MJ. The Ewing Amputation: The First Human Implementation of the Agonist-Antagonist Myoneural Interface. Plast Reconstr Surg Glob Open. 2018;6(11):e1997. Epub 2019/03/19. doi: 10.1097/gox.0000000000001997. PubMed PMID: 30881798; PubMed Central PMCID: PMCPMC6414116.
67. Bates TJ, Fergason JR, Pierrie SN. Technological Advances in Prosthesis Design and Rehabilitation Following Upper Extremity Limb Loss. Curr Rev Musculoskelet Med. 2020;13(4):485-93. Epub 2020/06/04. doi: 10.1007/s12178-020-09656-6. PubMed PMID: 32488625; PubMed Central PMCID: PMCPMC7340716.
68. Jonsson S, Caine-Winterberger K, Branemark R. Osseointegration amputation prostheses on the upper limbs: methods, prosthetics and rehabilitation. Prosthet Orthot Int. 2011;35(2):190-200. Epub 2011/06/24. doi: 10.1177/0309364611409003. PubMed PMID: 21697201.
69. Sierakowski A, Watts C, Thomas K, Elliot D. Long-term outcomes of osseointegrated digital prostheses for proximal amputations. The Journal of hand surgery, European volume. 2011;36(2):116-25. Epub 2010/09/03. doi: 10.1177/1753193410382720. PubMed PMID: 20807721.
70. Sabharwal S, Shores JT, Forsberg JA. Osseointegration. Techniques in Orthopaedics. 2021;36(4):349-52. doi: 10.1097/bto.0000000000000551. PubMed PMID: 00013611-202112000-00007.
71. Gerzina C, Potter E, Haleem AM, Dabash S. The future of the amputees with osseointegration: A systematic review of literature. J Clin Orthop Trauma. 2020;11(Suppl 1):S142-s8. Epub 2020/01/30. doi: 10.1016/j.jcot.2019.05.025. PubMed PMID: 31992935; PubMed Central PMCID: PMCPMC6977164.

72. Atkins D. Prosthetic training. Atlas of amputations and limb deficiencies: Surgical, prosthetic, and rehabilitation principles 3ed. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2004. p. 275-84.

73. Smurr L YK, Gulick K, et al. . Occupational therapy for polytrauma casualty with limb loss. Atlas of amputations and limb deficiencies: Surgical, prosthetic, and rehabilitation principles. 3 ed. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2009. p. 275-84.

74. Fletchall S. Upper Limb Prosthetic Training and Occupational Therapy. Atlas of amputations and limb deficiencies: Surgical, prosthetic, and rehabilitation principles. 3 ed. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2016. p. 351-62.

75. Myers H, Lu D, Gray SJ, Bruscino-Raiola F. Targeted muscle reinnervation to improve electromyography signals for advanced myoelectric prosthetic limbs: a series of seven patients. ANZ J Surg. 2020;90(4):591-6. Epub 2020/01/29. doi: 10.1111/ans.15664. PubMed PMID: 31989741.

76. Hargrove LJ, Miller LA, Turner K, Kuiken TA. Myoelectric Pattern Recognition Outperforms Direct Control for Transhumeral Amputees with Targeted Muscle Reinnervation: A Randomized Clinical Trial. Sci Rep. 2017;7(1):13840. Epub 2017/10/25. doi: 10.1038/s41598-017-14386-w. PubMed PMID: 29062019; PubMed Central PMCID: PMCPMC5653840 sells myoelectric control systems. No Coapt products or materials were used in this study.

77. Hargrove LJ, Lock BA, Simon AM. Pattern recognition control outperforms conventional myoelectric control in upper limb patients with targeted muscle reinnervation. Annu Int Conf IEEE Eng Med Biol Soc. 2013;2013:1599-602. Epub 2013/10/11. doi: 10.1109/embc.2013.6609821. PubMed PMID: 24110008.

78. Phillips SL, Resnik L, Fantini C, Latlief G. Endpoint Control for a Powered Shoulder Prosthesis. JPO: Journal of Prosthetics and Orthotics. 2013;25(4):193-200. doi: 10.1097/jpo.0000000000000006. PubMed PMID: 00008526-201310000-00008.

79. Osborn LE, Moran CW, Johannes MS, Sutton EE, Wormley JM, Dohopolski C, et al. Extended home use of an advanced osseointegrated prosthetic arm improves function, performance, and control efficiency. J Neural Eng. 2021;18(2). Epub 2021/02/02. doi: 10.1088/1741-2552/abe20d. PubMed PMID: 33524965.

Access to the full guideline and additional resources are available at the following link:

https://www.healthquality.va.gov/

VA/DoD Evidence-Based Practice