Critical Factors in Electrically Powered Upper-Extremity Prosthetics

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ABSTRACT

The patient population who elects electrically powered prosthetic intervention is limited, as are the practitioners who have sufficient experience to meet the patients' myriad of goals. Maximizing a patient's rehabilitation potential when using an electrically powered prosthesis involves several critical success factors. Formation of a rehabilitation plan via a team approach insures that all aspects of care are addressed simultaneously and is essential to a positive result that includes significant improvement in function and long-term prosthetic use. This paper examines aspects that should be considered while formulating and executing an electrically powered prosthetic rehabilitation plan. (*J Prosthet Orthot.* 2002;14:36–38.)

KEY INDEXING TERMS: Myoelectric, prosthetic rehabilitation plan, diagnostic interface, therapeutic intervention

Essential in the formation and execution of successful prosthetic rehabilitation is the knowledge of design theory. Design theory takes into consideration volume containment, suspension, comfort, range of motion, component considerations, stabilization, anatomical contouring, and cosmesis. This knowledge allows the team to select the appropriate interface design, componentry, and control schemes that best suit the patient's level of amputation, skin, tissue, musculature condition, range of motion, learning ability and desire, and vocational and avocational goals.[1] Although knowledge of design theory in itself does not guarantee successful prosthetic rehabilitation, a lack of knowledge can often overshadow the contributions of the rehabilitation team. At the center of the rehabilitation team is the patient and insuring his involvement and "buy in" is also critical to a successful outcome.[2] One should view the patient as the hub of the wheel, whereas the physician, nurse, case manager, therapist, psychologist, prosthetist, and reimbursement agency form the spokes of the wheel. The purpose of this paper is to detail a protocol to address the critical factors that should be considered when an electrically powered upper-extremity prosthesis is prescribed.

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METHODS

Begin with the patient evaluation phase, which should include an introduction to the patient and a description of the purpose of the evaluation and resulting formation of the rehabilitation plan. Discussing the patient's goals, concerns, and observations should follow, taking into account vocational, avocational, and family considerations. Throughout the evaluation process, the team should focus on listening and observing the patient because the patient's psychological condition and expectations factor heavily into the resulting rehabilitation plan. A thorough physical evaluation should include observation of skin condition, tissue condition, skeletal anatomy, muscle strength, range of motion, EMG testing, and contralateral side involvement (Figure 1). Education of the patient as to the prosthetic options available, their advantages and disadvantages, is time well spent, as many patients fit with electrically powered prostheses that elect not to utilize their prostheses long term can be traced back to unrealistic expectations of function, comfort, and fit. Once the above has been accomplished, a strategy that includes interface design, primary and secondary control schemes, suspension, and cosmesis can be formulated by combining data collected throughout the evaluation with knowledge of design theory. This strategy will dictate componentry selection and interface design. Interface design criteria include residual limb length, skeletal protuberances, range of motion sensitive regions (Figure 2), electrode placement, suction interfaces, "pull in" versus "push in," self-donning versus assisted donning, and vocational and avocational requirements.

The diagnostic phase begins with obtaining a plaster impression of the patient's residual limb, taking careful attention to prepare the patient both physically and psychologically for the procedure. Consideration to interface material, donning and doffing, and suspension should occur before modification as they will dictate modification requirements. Once a clear diagnostic interface has been fabricated, the analysis is divided into two components: static and dynamic. During the static diagnostic analysis, auxiliary suspension should be included if dictated

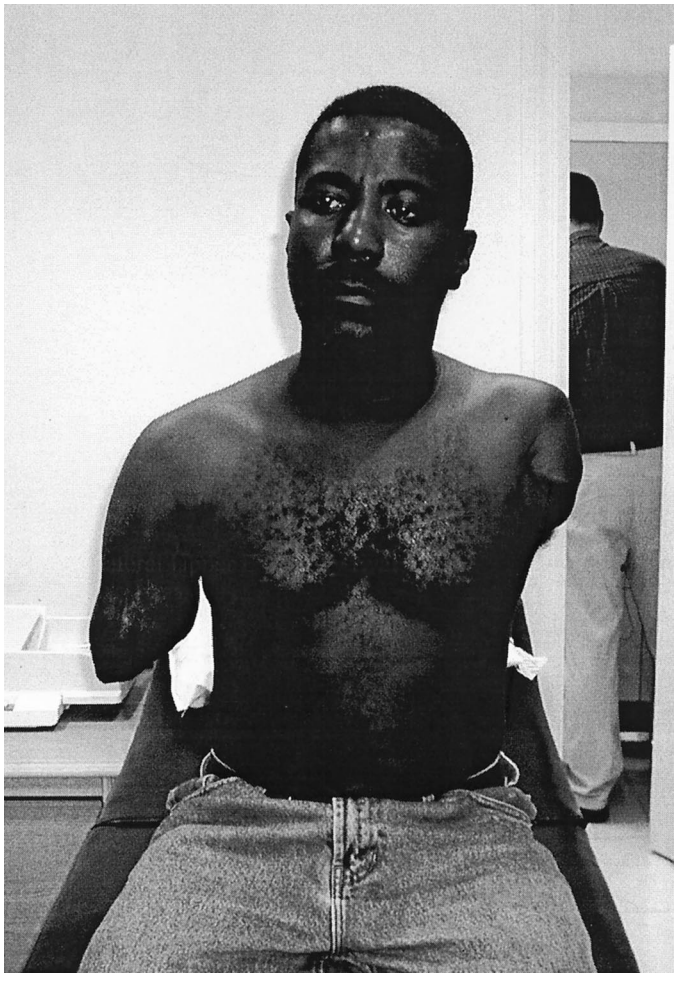

Figure 1. Bilateral upper-extremity evaluation.

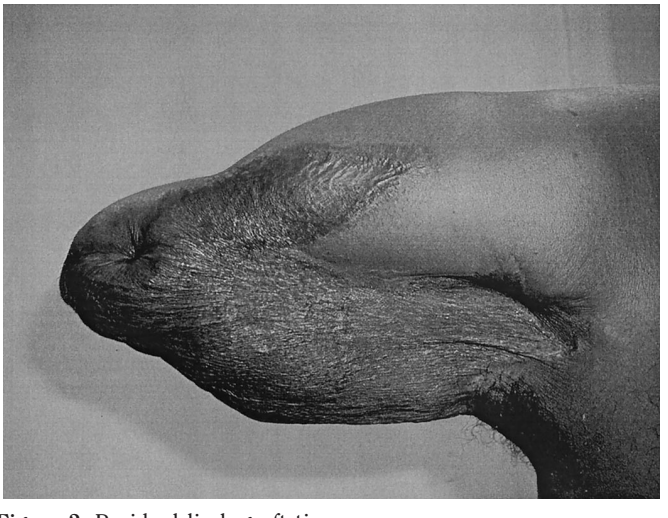

Figure 2. Residual limb-graft tissue.

by the initial strategy. This is an important factor because interface to skin contact can often change once auxiliary suspension is incorporated. Several modifications to the interface and auxiliary suspension maybe required to obtain a static, total contact, comfortable interface. Once an acceptable static interface has been achieved, the dynamic diagnostic analysis follows insuring maximum range of motion with minimal skin to interface contact loss.

Primary control inputs/schemes, which in most instances involve terminal device and elbow control, are now reevaluated to insure that the final interface design allows for optimal function. Several primary control schemes to consider are myoelectric, force-sensing resistors, servo, and switch. If myoelectric control is selected as the primary control scheme, site identification should take into consideration EMG signal level, EMG separation, and skin condition (Figure 3). Marking an area on the skin surface that has acceptable EMG signal strength and separation and then donning the interface and transferring this site provides the best results. Once electrodes are mounted into the diagnostic interface, an EMG analyzer should be attached to insure that the tissue-containment strategy of the interface does not adversely affect EMG signal strength and separation both in static and dynamic conditions. After optimal electrode sites are determined, a diagnostic frame with componentry attached should be fabricated and aligned to maximize the patient's functional envelope and cosmetically resemble the contralateral limb (Figure 4). Now that the interface is under load, reevaluation of the interface should take into account donning/doffing effort, contralateral limb involvement, comfort, range of motion, stabilization, electrode site contact, suspension, alignment, and cosmesis. For higher levels of deficiency, secondary control options should be considered at this time. Secondary control options may include remote on/off, wrist rotator, mode selector, elbow lock/unlock, sensory feedback activation/deactivation, humeral lock/unlock, and shoulder lock/unlock. After determining the type and amount of secondary control options, secondary control inputs can be selected. Secondary control inputs are defined as inputs that can be isolated from primary control inputs/schemes and, therefore, similar options exist (myoelectric, force-sensing resistor, servo, and switch). The most efficient manner of

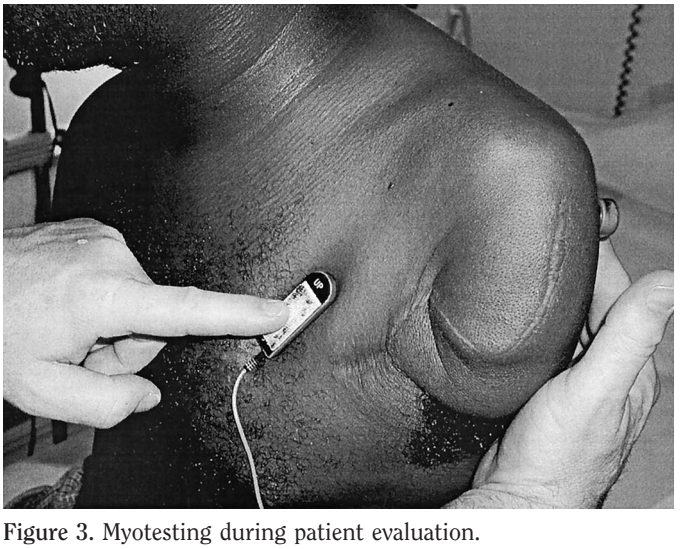

Figure 3. Myotesting during patient evaluation.

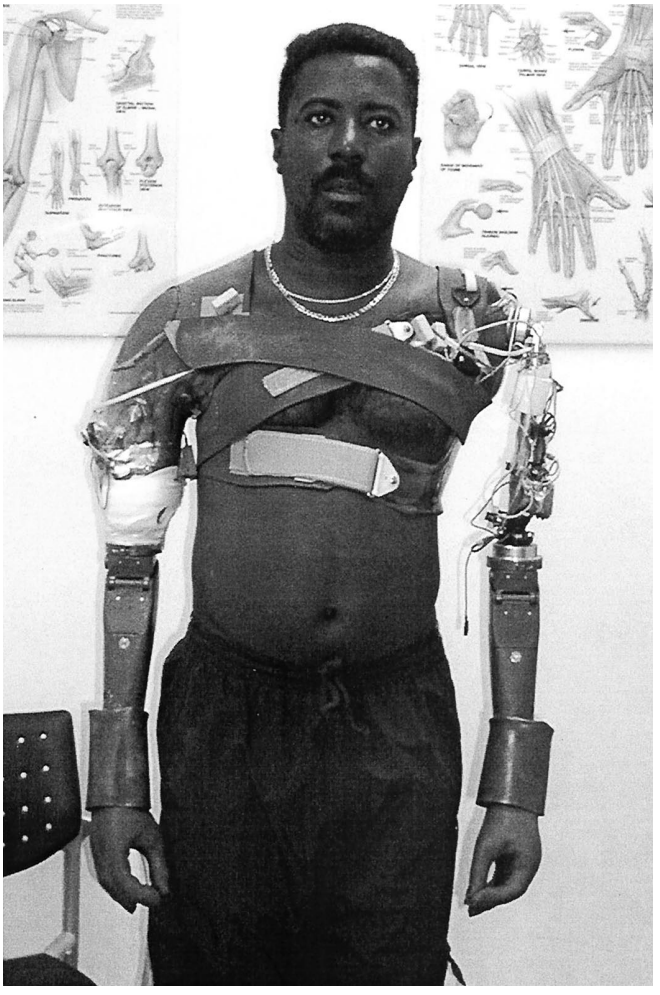

Figure 4. Expedited fitting finalization.

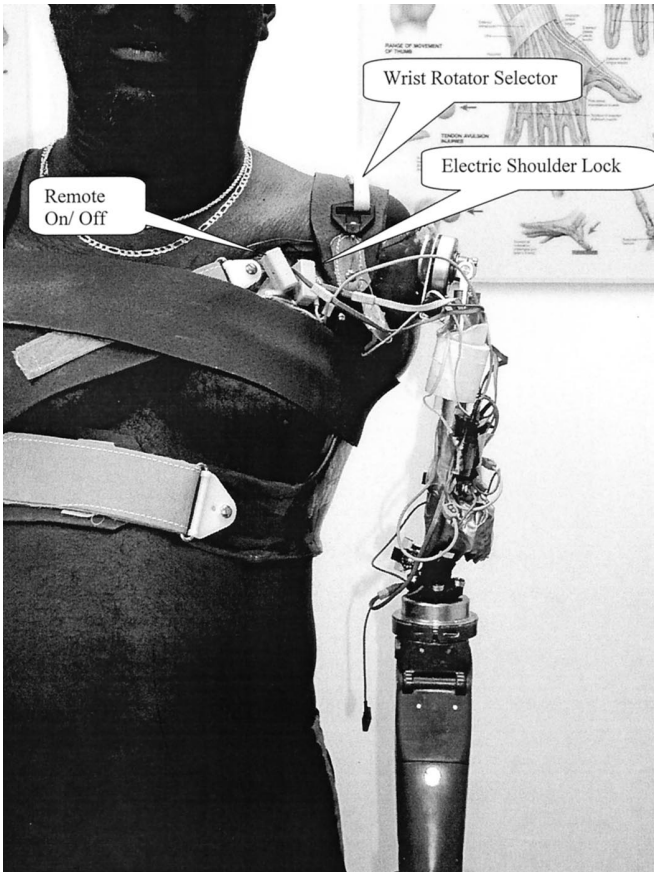

Figure 5. Secondary control scheme integration.

selecting secondary control inputs is through an analysis of functional range of motion without activation of primary controls. Once an activation movement can be isolated, installation of the secondary input followed by verification of control isolation can occur to insure that the patient can easily activate the desired function (Figure 5).

Prefabrication issues that must be determined are inner-socket material, frame material and shape, component orientation, and measurement information (linear, circumferential, and special functional or cosmetic considerations). Analysis of fit, comfort, function, and cosmesis are important considerations during system delivery. Initial prosthetic training includes basic operations instruction and care and maintenance. Initial system optimization should occur during this phase. Evaluation of the patient's function, comfort, and cosmesis should be included in the post delivery evaluation plan and communicated to the rehabilitation team to insure efficient transition.

Therapeutic intervention is essential and can be divided into three phases: preprosthetic, interim-prosthetic, and postprosthetic rehabilitation. Preprosthetic rehabilitation can include wound healing, range of motion, scar tissue manipulation, and adaptation training. Interim-prosthetic rehabilitation can include EMG site selection, enhancement, and separation. Post-prosthetic rehabilitation can include controls training, simple task training, advanced activities of daily living tasks, and vocational training. Identification of an experienced therapist at onset will have a dramatic effect on maximizing the patient's rehabilitation potential.

CONCLUSION

Due to the finite number of candidates for electrically powered prosthetic intervention and the limited number of experienced practitioners in this discipline, a prosthetic rehabilitation plan addressing these specific critical factors and executed by a knowledgeable and cohesive team will improve the function and long-term success of patients fit with an electrically powered prosthesis.

REFERENCES

1. Heger, H, Millstein, S, Hunter, GA. Electrically powered prostheses for the adult with an upper limb amputation. *J Bone Joint Surg.* 1985;67B:278–281.

2. Meier RH. Evaluation and planning for acquired upper limb amputee rehabilitation. In: Meier RH, Atkins DJ, eds. *Comprehensive Management of the Upper Limb Amputee*. New York, Springer-Verlag; 1989:16