Technical Article

Upper Limb Prosthetic Management Hybrid Design Approaches

by John N. Billock, C.P.O.

With the advent of electric powered components and control systems in the past 20 to 25 years, there has been considerable transition in the prosthetic management and rehabilitation of individuals with traumatic and congenital upper limb deficiencies. Furthermore, it has only been within the past 5 years that electrically powered upper limb prostheses have gained clinical acceptance in the U.S. There now exists a complex variety of approaches from which the prosthetics practitioner must choose, in order to provide appropriate prosthetic restoration services. Along with the traditional variety of bowden cable control systems for actuating mechanical components, there now exists a number of myoelectric and switch control systems for use with electrically powered hands, wrists, and elbows. The introduction of these new components and control techniques has greatly increased the complexity of designing an appropriate upper limb prosthesis.

As a result, some researchers and manufacturers have worked to develop total systems for the various levels of upper limb deficiencies. These systems generally are designed around a modular concept, where the batteries, electronics, electrodes, etc., are packaged as individual modules for easier handling and assembly. They also utilize a common electrical connection system, which may or may not be compatible with other components and control systems. The modular systems approach reduces the overall complexity in designing prostheses. However, it does not always provide the patient with the most appropriate prosthesis when his individual physiological and psychological needs are considered. It is in such a situation that thought must be given to the possibility of developing a hybrid prosthesis. A hybrid designed prosthesis utilizing components and control methods from various "systems" can, in many cases, enable the prosthetist to design and develop a prosthesis which is more functional and acceptable.

The hybrid design approach becomes even more important when managing individuals with upper limb deficiencies above the elbow and higher. Many cases require a combination of electrically powered components that are switch and/or myoelectrically controlled and mechanical body powered bowden cable controlled components. A classical example of this situation occurs in the design of an above elbow prosthesis for an individual with a distal humeral deficiency. A limb deficiency at this level generally does not require the use of an electrically powered elbow since the individual should have sufficient range of motion at the shoulder joint and adequate muscle strength to control a mechanical elbow. A myoelectrically controlled hand introduced into the design of the prosthesis, for this level, can significantly improve it's functional capabilities and aesthetics. This particular hybrid design allows the individual to simultaneously control the elbow and hand rather than sequentially. It has been the author's experience that individuals with this particular design infrequently utilize the mechanical elbow lock to maintain the hand and forearm in a fixed locked position for functional activities. Rather, the elbow is allowed to flex freely and is held momentarily stable with cable tension. The overall control of the prosthesis is more natural since use of the elbow lock is not necessary the majority of the time.

Unfortunately, many of the electric powered components and control systems are not designed for hybrid use even though they may have application. In many cases, they are not compatible and require electronic and/or mechanical changes before they can be incorporated into an appropriately designed prosthesis which best meets an individual's needs. Prosthetists of today must expand their technical expertise and knowledge in the areas of electronics and engineering to meet this challenge. With all the complexities surrounding the design and development to today's upper limb prostheses, this additional technical expertise and knowledge becomes even more essential when assessing and evaluating the particular needs of a patient.

The clinical assessment and evaluation of individuals with upper limb deficiencies should involve a careful study of their psychological, as well as their psychological needs. All too often, this is an area of overall prosthetics management that receives too little attention. In the author's opinion, it is an essential foundation for successful prosthetic management and rehabilitation. The psychological aspects of an upper limb amputation and its resulting disabilities are too often considered secondarily when determining what will be the most appropriate prosthesis for an individual patient. As professionals, we tend to stress function over aesthetics, when in fact, a primary concern of the majority of patients is the appearance of the prosthesis. These psychological aspects are the greatest barriers an individual patient must overcome if successful prosthetic management and rehabilitation is to be achieved. Their personal acceptance of their disability and motivation to return to society is essential for successful rehabilitation. Their reaction to the prosthesis plays a major role in this acceptance and motivation.

The reaction of their immediate family and friends also plays an important role in their acceptance of the prosthesis. Many patients have rejected a prosthesis not because of their own personal feelings, but because of the reaction of others. This is most apparent in the management of children with congenital upper limb deficiencies, since in most situations when the child is under the age of 5, you are managing the parent's desires and not the child's. If the parents have difficulty accepting the child's disability or the prosthesis, they will not encourage normal development and use of the prosthesis. Unfortunately, because many profesisonals are not responding to the psychological needs of the parents, many children are going with a prosthesis today.

With adequate information gathered in the initial prosthetic evaluation, further clinical assessment and evaluation procedures should be carried out to determine the most appropriate interface design, control source, and components to be used in the fabrication of the prosthesis. These procedures initially involve the development of a test interface (check socket) for determining the best fitting and suspension techniques to be utilized in the prosthesis. A variety of interface designs and suspension techniques exists for both adults and juveniles at all levels of upper limb deficiencies. All require the development of an appropriate test interface.

The development of a test interface is also necessary for use in establishing definitive E.M.G. potential sites when myoelectric control is being considered. When the E.M.G. potential are not adequate or when the patient requires further E.M.G. training, the test interface becomes essential for maintaining consistent placement of the electrodes relative to muscle stress. Further, the test interface allows the practitioner to evaluate a variety of optional control sources and components by developing a test prosthesis around it. This allows preprosthetic training and evaluation of the prosthesis in a variety of configurations before the development of a definitive prosthesis. The use of a test prosthesis is essential in evaluating "hybrid" and "system" design approaches for the definitive prosthesis.

Myoelectric control systems vary considerably depending on the desired function and availability of adequate muscle sites. In some cases, it is necessary to utilize more than one type of myoelectric control system to achieve the desired functions in a prosthesis. Some systems utilize a single E.M.G. potential from a single site to control a single function, such as in the traditional Otto Bock or Veterans Administration/Northwestern University (VANU) myoelectric control systems. This type of control system would, therefore, require two E.M.G. potential sites to control two functions, such as, hand opening and hand closing. It is suggested that this type of system should commonly be referred to as a "2-site/2-function myoelecric control system." Another system may utilize a single E.M.G. potential from a single site to control two functions, such as in the University of New Brunswick system. This system utilizes one E.M.G. potential site to control two functions. In this type of system a light or low level contraction produces one function and a strong or high level contraction produces another function. It is suggested that this type of system be referred to as a "1-site/2-function myoelectric control system." Yet another system may utilize two E.M.G. potentials from two sites to control multiple functions, such as in the Utah Artificial Arm elbow-hand system. This system utilizes two E.M.G. potential sites to control five functions. In this system a single E.M.G. potential from each site (biceps and triceps) controls one function in each electric powered component (hand

and elbow), while a co-contraction of both muscles together unlocks the elbow, switching from hand control mode to elbow control mode. It is suggested that this myoelectric control technique be referred to as a "2-site/5-function myoelectric control system."

Switch control systems also vary depending upon the desired function and availability of body motions to actuate them. In many cases, in order to provide the desired functions in a switch controlled prosthesis, various types of switch control systems must be incorporated, achieving a hybrid design approach. The most commonly used switch control systems utilize a pull type switch which is actuated by a single body motion to actuate two functions, such as hand opening and hand closing. It is suggested that this switch control technique be referred to as a "1-motion/2-function pull switch control system." Another type of system utilizes a push button type switch, to operate the opposing function. It is suggested that this switch control technique be referred to as a "1-motion/1-function push button switch control system." Yet another type of system utilizes a rocker type switch which is actuated by two body motions to actuate two functions in the prosthesis, which in most cases oppose each other. It is suggested that this control technique be referred to as a "2-motion/2-function rocker switch control system."

When body motion is being used to actuate a bowden cable control system in a hybrid manner along with switch and/or myoelectric control, it should always be remembered to activate the mechanical component with the primary body motion available. The theory behind this approach is that a bowden cable control system requires significant muscle activity and body motion to produce the force and excursion necessary to actuate a mechanical component. Myoelectric and switch control systems require less muscle activity to produce the force and excursion necessary for actuation of an electric component.

The choice of controls utilized in the design and development of an upper limb prosthesis should involve a careful study of an individual's particular needs. Since the terminal device is the most important component of the prosthesis, it is necessary to choose a control technique which will provide the most appropriate actuation of that device. It is felt that myoelectric control provides the most physiological and natural source of control and that whenever possible, it should be given primary consideration. Furthermore, the majority of individuals with upper limb deficiencies generally prefer a hand as a terminal device. In many cases, this desire may be purely psychological, and as professionals we should respect that need. The majoriry of individuals with upper limb deficiencies are unilateral with the prosthesis obviously becoming the nondominant side. Therefore, it is important that the prosthesis first meet the individual's psychological needs, and secondarily, that it be easily controlled and provide adequate prehension for stabilizing objects, which is the primary function of the non-dominant side during bilateral hand activities. This would obviously seem to indicate that myoelectric control, which best utilizes the residual neuro-muscular system, and an electric powered hand, which provides forceful prehension, should be the first choices in developing a functional prosthesis.

Electric powered components have been felt by many not to be sufficiently reliable and durable. This, however, has not proven to be the case when they are appropriately incorporated into a prosthesis and the patient is properly orientated to their care and use. There are those individuals and situations who are abusive to an electric powered prosthesis as well as a mechanical prosthesis. However, they are not the majority and require appropriate consideration prior to design and development of a prosthesis. Hybrid design concepts can also be utilized to enhance the reliability and durability of a prosthesis by allowing the encapsulation of components within the prosthesis that would otherwise be external. This is a concept known as self-containment.

Hybrid prostheses can significantly improve the functional restoration and rehabilitation of an individual with an upper limb deficiency. They are an important consideration in the prosthetic management of such individuals and can be the difference between total rejection or functional use of a prosthesis. Unfortunately, upper limb prostheses of this type will most likely continue to be provided in specialized centers and not find their place in common practice unless developers and manufacturers work towards making their components more compatible and interchangeable with those of other systems.

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