Justification for Powered Upper-limb Prostheses

When writing a letter of justification for an externally powered upper-limb prosthetic system, consider the following features and benefits and highlight those that would apply to your patient. Focus on the benefits of using a powered prosthesis for the tasks that the user intends to perform for both common activities of daily living (ADL) and work-related duties. Stress the goal of gaining independence, the benefits of a functional opposition device and ability to perform bimanual tasks, work related activities or requirements to return to work if applicable and preservation of the contra lateral limb. If another occupation is preferred and achievable, mention this as well. For example rather than performing the job they did previously, they could become a trainer or supervisor and their prosthesis would enable them to fulfill the requirements for these jobs.

A well designed and fit powered prosthesis may be comfortable enough for the user to wear all day, thus extending their work day. The elimination of body powered control cables may increase their range of motion and enable the user to perform tasks that they might not be capable of doing with no prosthesis or with a body powered prosthesis.

Describing both the improved functionality and cosmeses may also be beneficial (note: one of these may be more important to the user than the other). A natural looking and operating prosthesis can make a significant difference in the user's (and their family's) acceptance of a new prosthesis. Cosmeses is often considered an unnecessary feature, but this can make the difference between acceptance and rejection of a prosthetic system or device. If cosmesis is job related, this should be highlighted in the application. Jobs that are highly visible to the public often justify the use of a good cosmetic prosthesis (vs. a split-hook).

Features & Benefits:

Externally Powered Prostheses: External power is provided to prosthetic systems through batteries and motors. These motors are managed by the prosthetic controller, generally a microprocessor-based circuit. Further, they receive commands of the user's intent from sensors placed on the user's body. These input sensors may be myoelectrodes, linear transducers, pressure sensors or switches. **Myoelectrodes** are sensors that detect small electrical muscle signals from the surface of the skin. They amplify and filter these signals to make them more stable and useful for controlling prosthetic motors. Since they measure the strength or amplitude of the muscle signal they can provide proportional control of the prosthetic device. **Linear Transducers** are sensors that convert motion to an electrical signal that represents the position of a linear potentiometer. As a result the prosthetic device responds to both the speed and direction of this motion, thus providing proportional control of the prosthetic device. Pressure sensors or **Force-Sensing Resistors** (FSR) are often referred to as "Touch Pads". These are also resistor elements that change value based on the applied force. Therefore, they can also provide proportional control of the prosthetic device. Finally, **switches** are used to either control a device or reset a state (i.e. on/off) of a device. Since they are two position (on-off) sensors, they <u>cannot</u> provide proportional control of the prosthetic device. Input sensors require more clinical time for set up and adjustment than conventional body-powered controls or switches.

Hand Prehension: Externally powered (motorized) prosthetic hands and grippers are an alternative to body-powered (cable actuated) terminal devices such as split-hooks and mechanical hands. Externally powered terminal devices are available in two styles; hands and grippers. Since these devices are driven by motors and actuated by sensors, they require little effort from the user. Yet, they can produce grip forces that equal to or exceeding those of body-powered terminal devices. Grip forces of 20 lbs-force are not uncommon. Additionally, powered terminal devices can operate in both directions; open and close, whereas body-powered terminal devices are either voluntary-open or voluntary-close which means that the user can only control the force in one direction.

Externally powered terminal devices are often proportionally controlled which enables the user to perform precise movements by regulating the speed. An additional benefit of these devices is their ability to hold an object for long periods of time with no effort from the user. These devices have anti-back drive mechanisms that enable them to keep a firm grasp on an object when not being driven.

By eliminating the control cables required for a body powered prosthesis, the user often gains greater range of motion. For example externally powered prostheses can often operate above the users head and down at their feet whereas body powered prostheses have a much more restricted envelope of operation. This expanded envelope enables the user to perform tasks that they might otherwise be unable to perform. If such tasks are work related, they are important to the justification for using an externally powered prosthesis.

Externally powered prosthetic hands are now available in two styles; single degree-of-freedom (DoF) and multi degree-of-freedom terminal devices. Single DoF hands provide one grasp whereas multi DoF hands provide multiple grasp patterns. In some cases up to 14 grasp patterns are available and are user-selectable. These patterns enable the user to grasp objects and perform tasks where the hand conforms to the shape of the object it is grasping. As a result less force is usually required to hold or manipulate an object. Presently bebionic and iLimb hands provide this multi-articulating capability and both terminal devices are compatible with the Boston Digital Arm.

Powered grippers are an alternative to powered hands and are often used for work-related tasks or hobbies where functionality is more important than cosmeses. Since quick disconnect wrists are often provided on upper-limb prostheses, the user can easily change terminal devices and substitute the powered hand for the powered gripper when appropriate. Powered grippers are often indicated in addition to a powered hand when work requires the user to perform tasks which would be unsuitable for a prosthetic hand, either because of the damage it would cause or because of the grip forces required for the task. When two terminal devices are supplied, assuming that they are both regularly used, they should last twice as long as a single terminal device. This is especially true if certain tasks require a terminal device, where one device is better suited than the other.

Wrist Rotation: Pro/supination is a valuable degree of freedom for upper-limb amputees and should be recommended in cases where this would benefit the patient. Wrist functions are primarily beneficial for positioning the terminal device (hand or gripper) to perform various functions and achieve certain grasps. Without wrist motion, patients must use awkward body motion to position their terminal device. Not only is this un-natural, but it is also inconvenient and inefficient. Some users will avoid doing certain tasks in public because of the awkward postures and motions required to accomplish it without a functioning wrist.

Presently there are only two powered wrist rotators, no powered flexion/extension or ulnar/radial deviation and both of these can be used with the Boston Digital Arm. There are however, manual wrist flexion/extension units that may also benefit the patient. Many unilateral amputees can manage with passive wrist rotation (rather than a powered wrist rotator). Bilateral upper-limb amputees often benefit from a powered wrist rotator because they have no way to manually position their prosthetic wrist(s).

Elbow Flexion/Extension: Humeral level, shoulder disarticulation and forequarter amputees require an above-elbow prosthetic system. The Boston Digital Arm System (BE300) is designed for this class of prosthesis. It not only provides powered elbow flexion and extension but also friction-adjustable manual internal/external humeral rotation. This enables the user to position the forearm to the most useful position for performing the task at hand. The Boston Digital Arm System also serves as the manager of other prosthetic devices attached to it such as a wrist rotator and/or a prosthetic hand or gripper. The elbow's controller receives input signals from the user (input sensors) and determines which device to operate, what direction to move and how fast. The elbow's controller can also determine how much force or torque to apply. In the case of the Boston Digital Arm, it can operate up to four prosthetic devices (i.e. hand, wrist, etc.) in addition to the elbow and it can run these simultaneously for greater efficiency and more natural motion.

The Boston Digital Arm System can deliver up to 9 ft-lbs of torque, thus enabling it to actively lift various objects often encountered when performing activities of daily living such as lifting a gallon of milk (8½ lb). It has a range of motion of 135 degrees from full extension to full flexion, essentially the same range of motion as an able-bodied individual. The elbow completes a full flexion or extension movement in approximately 1.0 - 1.2 seconds (depending on the direction and load).

All of this motion can be performed with minimal muscle activity or excursion because the powered system is augmenting the user. As a result, users of these powered prostheses are less likely to fatigue as quickly.

Shoulder Flexion/Extension: Forequarter, shoulder disarticulation and very short humeral level amputees may also require a prosthetic shoulder joint. There are no commercial powered shoulder joints available, but there are friction and locking shoulder joints. Friction joints may be suitable for light-weight cosmetic prostheses, but generally are unsuitable for externally powered prosthetic systems because they seldom provide enough friction force to support the weight of the prosthesis. They also remain stiff when the person is walking resulting in an un-natural gait. Shoulder joints that provide both a locking feature and free-swing are most effective. These shoulder joints enable the user to position the humeral section of the prosthesis in an orientation suitable to perform a specific task, and hold it there. This feature is essential for performing most common activities of daily living and for many work-related tasks. The user can also put the joint into "free-swing" so they can walk naturally with their arm swinging.

The LTI Locking Shoulder Joint (SJ90) provides two degrees-of-freedom. In addition to the locking flexion/extension joint, it also has a friction abduction joint. These degrees of freedom enable the user to position the prosthetic arm in many useful orientations including those necessary for performing ADLs and work-related tasks. For bilateral amputees or unilateral amputees with limited range of motion on their sound side, a powered lock actuator can be provided.

Increased Functionality: Externally powered prosthetic devices can often provide increased functionality for the user. Common tasks and activities of daily living (grooming, feeding, toileting, etc.) are the primary goals for upper-limb prosthetic users. Achieving these ADLs often enables the user to regain independence and become self-sufficient. Beyond that are the tasks associated with work and hobbies. These rehabilitation goals vary considerably depending on the users situation as well as their motivation. There is evidence that early involvement in sports and hobbies accelerates the amputee's acceptance of their prosthesis and possibly return to work.

Comfort: Powered prosthetic devices generally weigh more and cost more than body-powered mechanical prostheses, but they have several distinct advantages. The external power provided by the systems battery and motors often enables the user to increase their effective range of motion and sometimes their strength without excessive effort. Sensors (like myoelectrodes and positional transducers) detect the user's intent and command the powered prosthesis to perform the desired function. Conversely, body-powered prosthetic systems require considerable strength by the user and often a significant range of motion to perform common prosthetic movements. Additionally, repeated movements required by body-powered prostheses may eventually result in further damage to the contra-lateral side/arm, thus making the user less able to perform common functions with that limb. Repeated strenuous body movements can also result in fatigue.

Externally powered prostheses also give the prosthetist more freedom to choose a suspension system that appeals to the user and possibly is more comfortable. Harnessing and operating cables can be minimized or possibly even eliminated. The socket design can be driven by the need to properly support the prosthesis rather than the placement of cables and maintaining the range of motion of the remnant limb or contra lateral limb.

To further improve the comfort of the prosthesis on a humeral level amputee, the Boston Digital Arm has a free-swing mode that enables the elbow to swing naturally through 45 degrees when the user is walking. This reduces the load on their socket and creates a natural rhythm of their arms during walking gait.

Appearance - Cosmeses: Externally powered prosthetic systems often have their components and sensors concealed within the prosthesis - there is no need for Bowden cables and control harnessing. As a result, prosthetists have more options for the cosmesis. Cosmetic covers of various types (production PVC, production silicone or even custom high-definition silicone gloves) can be applied to prosthetic hands to improve their appearance and increase their acceptance. Some gloves extend to the elbow (Elegance™), thus further enhancing the appearance of the prosthesis.

Some users are concerned about the appearance of their prosthesis, whereas others are focused on functionality. Externally powered prosthetic systems provide the versatility to achieve either of these goals and sometimes both. The importance of appearance should not be underestimated. In some cases this can be the deciding factor whether a prosthesis will be worn or not. In addition to the user's acceptance, family, friends and even co-workers acceptance may become a factor. Finally, others who the user may encounter (i.e. customers, clients, students, colleagues, etc.) can also be a factor in their acceptance or rejection of a new prosthetic system. Again, do not underestimate the importance of cosmesis. Ask the user how important this is to them and if appropriate, make a case for an enhanced prosthetic cover in your justification letter.

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