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Prosthetic Options for Difficult Amputations

Technological advancements in prostheses are welcomed by practitioners, but the learning curve can make fitting more complex.

Mary L. Jerrell, ELS

For prosthetists, a multitude of factors influence the complexity of a case. Many different pieces of the equation must be considered before devising a treatment plan and selecting an appropriate prosthetic design for an individual patient. The assessment period represents the first crucial part of the equation and can determine the difficulty or complexity level.

"We spend a lot of time during the assessment period, and we try to look at the patient through at least four different lenses," John Miguelez, CP, FAAOP, president and senior clinical director, Advanced Arm Dynamics, told O&P Business News.

The first lens focuses on the patient's psychological status and examines issues such as how the patient is coping with limb loss and whether other things are going on in the patient's life that could impact the rehabilitation plan. The second lens views the different prosthetic options that are available for the patient's amputation level. All of the different types of prostheses — including the option of not wearing a prosthesis — are described and then related to the patient's short-term and long-term goals. The ultimate goal is to find a solution that allows the patient to return as closely as possible to his or her pre-amputation lifestyle.


John Miguelez

The third lens focuses on what is needed therapeutically to help patients maximize their rehabilitation potential and determine their best option for success. Finally, the fourth lens encompasses spending time with patients as well as their families and friends to identify all of the things that are going on in the patients' lives so that the treatment recommendation is as comprehensive and global as possible.

"Our team is never able just to look at the amputation and have that be the sole determinant," Miguelez said. "A well-healed, healthy-skinned midlevel transradial patient who has some psychological challenges, or some learning issues, or some family issues going on can be as challenging as an interscapulothoracic level patient with a lot of scar tissue."

Psychological vs. physical factors

Complexity can involve psychological factors such as high levels of expectation; personality issues including stubbornness or distrust; and physical factors such as severity of injury, late complications and negligent self-care habits. In fact, the ability to predict the complexity of a certain case is often not possible on initial evaluation, said Zach Harvey, CPO, chief prosthetist at Walter Reed National Military Medical Center (WRNMMC).


Zach Harvey

"At WRNMMC, the complexity of care includes the sheer volume of multi-extremity amputation patients, the high expectations based on close proximity of other successful prosthetic users and what we call prosthetic envy, the complications of blast injuries such as traumatic brain injury or heterotopic ossification and a patient population of previously healthy, active, young adults ambitious to return to high levels of activity," Harvey told O&P Business News. "These demands require a great deal of time to manage and do not discriminate based on the level of amputation."


Image: Scott Sabolich Prosthetics


Jason Lalla

Some physical factors that play into the equation in addition to heterotopic ossification involve problems with fragile skin, scar tissue, bone spurs and neuromas. In addition, the shape of the residual limb may make a certain case complex. A patient who presents with a congenital condition will have different issues than a patient with a trauma-related or disease-related amputation.

"Sometimes in congenital cases, the shape or presentation of the limb may be a little more unusual than an amputation that has resulted from vascular disease or cancer where normally in that case, it is a very clean amputation and there is minimal scarring to deal with," Jason Lalla, CP, Next Step Orthotics & Prosthetics, said. "All of those factors really come into play and certainly can make things far more complex."


Scott Sabolich

Limb length also can increase the level of difficulty when fitting patients with a prosthesis. Usually, two-thirds the length of any bone is the ideal length for fitting and offers the greatest chance of success, according to Scott Sabolich, CP, LP, owner and clinical director of Scott Sabolich Prosthetics & Research.

"Any longer than two-thirds the length of the bone is difficult to fit; any shorter than two-thirds the length of the bone is difficult to fit," Sabolich told O&P Business News. "The length needs to be just that prime optimum green light region of limb between one-half and two-thirds length. Any longer than that is bad, and any shorter than that is bad."

The presence of pain also can be a complicating factor. Patients can have residual nerve pain or even phantom pain in the limb, which can be related to neuromas, the way a nerve was cut or even a stitch that went through a nerve.

"Typically, here at our facility, we do not see the perfect half to two-thirds length limb with no neuromas, no bone spurs, no scar tissue, no heterotopic ossification, no anything, just a perfect limb, because they can usually be fit locally," Sabolich said. "It is when you run into problems like these that patients start seeking out some of the destination facilities and go somewhere with some experts who can handle the hard to fit cases."

Multiple extremity involvement

Multiple amputations always increase the level of complexity. For patients with multiple extremity involvement, donning and doffing a prosthesis can be challenging and must be considered when planning the prosthetic design.

"You can sometimes design the best fitting socket possible, but if the person is not able to manage the donning and doffing, then you have missed the mark," Lalla said.

Harvey recommends figuring out the patient's weakest link and then addressing that aspect of their lives. For example, household ambulation can be a problem for patients with multiple amputations.

"I was highly focused on providing the best pair of legs I could to a quadrilateral marine for community ambulation, but I neglected the fact that at home, he was bound to a wheelchair and had difficulty pushing his wheelchair when not wearing arm prostheses," Harvey said. "We came up with the idea of making him easy to don and doff household shorties that addressed this aspect of his life. The first weekend he wore them, he told me that he cleaned his bathtub, took out the trash, and most of all, his wife thanked me because he was able to move around the house without her help. Since then, I have made 'house legs' for many of my patients desiring more independence around the house."

Certain projects can be complex as well when a patient has a unique request and a device has to be highly customized. Although time consuming, these projects can lead to discoveries and help progress our understanding about biomechanical principles.

Harvey has adapted prostheses to allow patients to resume participating in sports. For several bilateral transfemoral amputees who were bicyclists, the addition of a flexion stop just shy of 90· enabled them to fluidly pedal a bicycle.

"Snowboarding has been one of my passions and something for which I have also spent a great deal of effort in creativity," Harvey said. "This season, I arrived at designs for a bilateral hip disarticulation and bilateral transfemoral to snowboard, keeping in mind low center of gravity and versatility around the lift line."

Technological advancements

In the past 2 decades, advancements in materials, techniques and technologies, including electronics and microprocessors, have significantly improved prosthetic design and components, offering prosthetists and patients a variety of options. At the same time, such advancements have served in some ways to increase the level of complexity and difficulty for prosthetists.

Quadrilateral amputee Merlyna Adams works with John Miguelez, CP, during an initial fitting with a preparatory prosthesis.
Image: Advanced Arm Dynamics

"Advancements in technology in both upper extremity and lower extremity allow us to do more for patients," Miguelez said. "It also puts more pressure on practitioners to understand all of the different technologies that are available, and then once they understand all the options, to be able to decide which is the most appropriate based on the patient's presentation."

For instance, to determine what electric terminal device may be the most appropriate for a patient, the prosthetist must first understand the capabilities of all the terminal devices that are available, as well as the pros and cons of each hand in order to recommend the best component. The prosthetist also must consider the technology as it relates to socket design and socket materials and then understand how different materials will react with the patient's limb presentation.

"One of our responsibilities is to keep our patients apprised of new developments, and that is always a little challenging." Miguelez said. "Sometimes the hype of new technology does not necessarily match the reality of new technology, so we have to manage patients' expectations at the same time that we are all continuing to learn," Miguelez said.

While Lalla noted that the prosthetist's job is to understand the technology in order to use it to its full potential, but the prosthetist also must ensure that the complexity ultimately is not passed on to the patient.

"Our philosophy is to educate ourselves well enough that we are not letting technology that can achieve a better outcome hold us back due to it being complex," Lalla said. "We strive to make things as functional as possible while still trying to keep it relatively simple in the form of management."

In addition, the prosthetist must be able to understand how to program the prosthesis to achieve an optimal outcome.

"It is not as simple as pulling it out of a box and turning a couple of dials and having it work. You can take the most advanced piece of technology and put it on somebody and if it is not adjusted properly, it certainly is not achieving the best outcome," Lalla said. "You certainly see cases where patients are fit with very technologically advanced products that have not been optimized due to lack of experience on the prosthetist's part."

At the same time, Lalla cautions that prosthetists should not overlook less complex options. In some instances, simpler prosthetic options or systems may yield a better outcome than a technologically advanced option.

It may be difficult to discern the complexity of an amputee's care on an initial evaluation, according to Zach Harvey.
Image: Morenatti E.

"If you are dealing with somebody who is a bilateral or maybe if age, strength or balance is a factor, those considerations might make things complex," Lalla said. "Going with a very simple lanyard type of suspension can sometimes yield better results. The nice thing about that lanyard system is you can don it sitting down, so it is simple, and I would venture to say it is almost old technology but still has current applications."

Looking to the future

While Harvey agrees that technology has progressed steadily, he believes that progress has advanced far too slowly in the past decade. He noted that many historic developments, such as sweaty gel liners, socks to manage volume and the same old socket materials we've been using for the last 20 years are highly pervasive in the state-of-the-art prosthetic limb.

"Admittedly, we have many more options of interface material, suspension mechanisms, component design and cosmetic restoration than ever before. New microprocessor knees, ankles and hands now move more similarly to their anatomical counterparts," Harvey said. "The progress I have seen is painstakingly slow, with very few breakthrough inventions having occurred during my career."

However, Harvey acknowledged that this slow progress is what pushes the boundaries and improves prognoses. He noted that an increasing number of wounded warriors have returned to active duty, including combat-related positions, due to great prosthetic fit, function and training.

"When we pay attention to detail, learning from mistakes, it is possible to achieve tremendous outcomes with the current technology. The evolution of socket design is a great example of how we continue to build upon biomechanical and prosthetic principles to create better fitting and better aligned prostheses," Harvey said. "I look forward to progression of powered prosthetic designs as well as more commonly performed surgical techniques such as osseointegration, targeted muscle reinnervation, limb regeneration and composite tissue allografts to improve outcomes within the near and distant future." — by Mary L. Jerrell, ELS

Increase Your Treatment Options With Targeted Muscle Reinnervation

As new technologies continue to emerge in upper limb prosthetics, one option for some patients is Targeted Muscle Reinnervation (TMR). John Miguelez, CP, FAAOP, president and senior clinical director, Advanced Arm Dynamics, discussed the advantages and challenges of this innovative procedure.

"One of the newer and more promising options for some patients is TMR surgery, which actually reinnervates muscles so that there are multiple EMG sites," he said. "Up to eight outputs or eight different signals can be gathered from the patient's residual limb. This can allow a patient to have much more control of their prosthesis and improve their functionality. Of course there are also some challenges that are unique to TMR. After TMR surgery, the involved tissue becomes hypermobile so that when the patient contracts a muscle, much of the reinnervated tissue moves. This can present extra challenge in establishing a good, stable interface and keeping the electrodes in contact with the skin."

The post-surgery recovery phase extends for several months as the muscles become innervated. "During this time it's important for the patient to have therapy to learn how to access the muscles and be able to contract them independently," Miguelez said. "Although therapy is a vital part of every upper limb patient's success, it is even more crucial in TMR where patients are going to really benefit from developing these additional degrees of control."

After the muscles are reinnervated, Miguelez said he may see a patient weekly for therapy, fitting different sockets, or adjusting the electronics or electrodes. He said the muscles continue to move and adjust for up to eight months, so there is usually a need to make adjustments to the prosthesis as the months go by.

"Having a comprehensive team of clinicians that work with the patient and take the time to listen and work with the patient allows the fitting process to go much smoother for the patient," Miguelez told O&P Business News. "For certain patients, it's a great solution. For other patients, there are different solutions that might be more appropriate."

Miguelez empahasized taking time during the assessment period to truly understand the patient's goals and devise a custom treatment plan. He suggested using a simple checklist as a starting point to approach the TMR process.

His team is involved at the outset of TMR surgery. "We will see a patient and based on their limb presentation and their goals, decide that they might be a candidate for TMR surgery. If we think that that's the case, we'll meet with the surgeon to discuss, and then meet with the patient and the surgeon together. There will be times when we might go with the patient to surgery, but more often we facilitate that," Miguelez said. "Our goal is to try to educate the patient as to what the options are in terms of prosthetics and allow the surgeon to do what he needs to be done to maximize the patient's rehab potential.

"Some people wonder if age is a consideration in opting for TMR. I would say that age is really not a major factor. It just depends on where the patient is in terms of their life cycle, their goals and what support they have around them," he said.

One area in which researchers are improving outcomes in TMR surgery is pattern recognition, which involves multiple electrodes within an interface. "We're starting to look at the unique EMG signature of muscle contraction and harness this information using a computer to controls certain grip patterns and prosthetic functions. There is a lot of managing of the electronics both from where the electrodes are located, to programming the graphic user interface for optimal control, to socket design considerations, to training the patient." — Mary L. Jerrell, ELS

Ertl Procedure Presents Socket Fitting Challenge

The Ertl procedure, developed after World War I by Janos Ertl, Sr, MD, addresses treatment of the skin, muscles, nerves and bone in below knee amputations and often results in a pain-free residual limb. Today this procedure is also performed for above-knee amputations as well.

The procedure is not without fitting issues, however. A patient with an osteomyoplastic reconstruction or an Ertl procedure has to be fit with a different style socket than practitioners may have been taught in school, noted Scott Sabolich, CP, LP, owner and clinical director of Scott Sabolich Prosthetics & Research.

"It requires a socket that has distal weight bearing, where most of the time in the last 50 years of prosthetics, we've never wanted distal weight bearing. It changes the whole dynamics of the fit and it makes it much more difficult to fit someone when they have to put weight on the end of their residual limb. It decreases stability, it increases a lot of the problems in fitting the brim, and if you don't know what you're doing it takes a lot more effort."

The procedure is generally performed on young, healthy patients who have experienced significant trauma to their limb. Patients with war injuries are the most appropriate candidates for the procedure, which explains why its use increases during wartime and lessens during peacetime.

"Dr. [William] Ertl is here in Oklahoma. We see a lot of his cases. He's very successful; in fact, he brags about a 97% success rate of all of his surgeries, which is quite high compared to the typical below-knee amputation," Sabolich said. He said Janos Ertl believed that the surgeon's job is to ensure the amputee is left with a living, growing, weight-bearable residual limb, not simply to pass the responsibility of limb health and utility on to the prosthetist.

"We're seeing a lot more of the military orthopedic surgeons jumping on board and doing a lot more Ertl reconstructions in Walter Reed and Brooks Army because the younger soldiers don't have any health complications. They can heal from an invasive surgery like that where you're actually connecting the bones together. We're seeing a lot more of that involved but a lot of prosthetists out there have no idea how to fit these things. It is just a completely different way of building a socket." — Mary L. Jerrell, ELS

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