**Targeted Muscle Reinnervation (TMR)** is a surgical technique that involves the transfer of residual nerve endings to target muscles elsewhere in the body that serve as biological amplifiers of EMG signals until frankly useful to the brain.

The goal of TMR is to produce strong, isolated EMG signals that can be easily accessed by a myoelectric prosthetic that can transmit and translate this information to perform motor functions.

**WHAT IS TMR?**

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**THE HISTORY OF TMR**

The history of targeted muscle reinnervation dates back to the early 1900's, while the history of prosthetics dates back as far as the ancient Egyptians and has been constantly improving ever since. Starting from the early prosthesis which only served appearance purposes, significant advancements throughout history have been made, such as a prosthetic that could mimic the user’s natural movement and the discovery that several nerves could be transferred to regain function. The first TMR was performed on Jesse Sullivan in 2001 and was a success, especially in combination with the myoelectric prosthetic. Since then, there has been great advancements made within TMR and myoelectric prosthetics, allowing those who are losing a limb to function with greater ease day by day.

**THE SURGICAL PROCEDURE**

During targeted muscle reinnervation surgery, residual brachial plexus nerves (nerve that control hand and wrist function) are relocated to “target muscles” that are located near the site of the amputation. These target muscles are denervated muscles that serve as “biological amplifiers” that magnify the EMG signal sent from the brain to the nerve that it has been reinnervated with. The nerve transfers that take place are different depending on the patient and the amputated limb. However, this shows how much muscle/nerve is available and how much arm length remains. For example, in a transhumeral amputation, nerves are relocated to target muscles in the arm; however, in a shoulder disarticulation amputation, nerves are relocated to target muscles in the chest, as shown in the figures below.

**SUCCESSFUL TMR SURGERY REQUIRES THE FOLLOWING:**

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<td>Physically Separate Target Muscles from one another</td>
<td>Prevents crosstalk (mixed signals) between target muscles and allows for clear, isolated signals to be sent to prosthetic; facilitates better muscle recovery</td>
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<td>Denervate Target Muscle</td>
<td>The EMG signal from the nerve that has been relocated is the only signal that the target muscle and the prosthetic is receiving; makes certain that the relocated nerve is not competing for available nerve sites with a native nerve.</td>
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<td>Fat Removal on Target Muscles</td>
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**COMPLEX CONTROL OF MUSCLE FUNCTIONS**

Myoelectric devices are prosthetics that receive electrical signals from flexed muscles in order to dictate a movement. The use of these without TMR is extremely difficult both mentally and physically. For a lower arm amputee, the only muscles groups that can be re-used reliably are the triceps and biceps. This is due to the fact that the muscles cannot flex at the same time and they must be large enough to give off clear signals. With only two sites for control, amputees can only move one part of their body at a time in a possible two directions. In order to move, they have to flex muscles that are unrelated to the residual limb movement and it read user to switch modes for different joints. These shortcomings make use of prosthetic arms slow and unprecise, as well as incompeting for available nerve sites with a native nerve.

TMR improves arm movements significantly by increasing:

- The complexity and amplitude of EMG signals
- The number of control sites
- The intuitive control of movement
- The degrees of freedom

TMR relocates nerves into muscles that flex in direct relation to movements attempted in the brain. For example, trying to twist your wrist flexes the bottom of the bicep so when it is flexed, the prosthetic hand will rotate in the desired way. Increased control sites also gives the user the ability to control multiple parts of the prosthetic at once, allowing the elbow and rotating the wrist. With the development of more complex algorithms, myoelectric devices are able to use the number of movements performed simultaneously. The complexity of these signals also has the potential to code minute movements that could further increase the quality of life of amputees.

**SUSTAINABILITY**

Our Definition of Sustainability:

- **The increased longevity and long-term improvement of the quality of life on both a mental and physical level.**
- **The ability to transfer this improved quality to life to future generations.**
- **Must be attainable by those who need it.**
- **Highly dependent on a balance of these three different parts of the definition.**

**FUTURE DIRECTIONS**

**What is TMR?**

**TMR** is a surgical technique that involves the transfer of residual nerve endings to target muscles elsewhere in the body that serve as biological amplifiers of EMG signals until frankly useful to the brain.

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**How does TMR improve arm movements?**

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- The complexity and amplitude of EMG signals
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**What does TMR allow amputees to control?**

TMR allows amputees to control their limbs more naturally. Because it allows patients to use the muscle memory that they already have, more seamless actions can be completed with ease. Patients without TMR that use myoelectric prosthetics must embark upon a very long training process to learn which muscles to use to perform a certain action and when a mode switch needs to occur. This can be a very complicated process; however, since TMR optimizes the nerve signals that are already sent from the brain to control the prosthetics, is requires much less training and permits intuitive action.

**What are some of the initial drawbacks to TMR?**

TMR introduces new pain caused by neuromas, which are painful growths caused by disorganized nerve growth at an amputation site. These can cause extreme discomfort in amputees, and the pain can be so extreme that some patients are unable to wear the prosthetic. In some cases, the pain becomes so unbearable that patients cannot wear the prosthetic.

**How does the TMR pain affect amputees?**

TMR can help mitigate this pain by creating more organized growth for the nerve. Because the nerves now have a function and are growing into the target muscles, they have a purpose and do not form these painful growths.

**Are there any negative consequences to TMR?**

There are a few short-term drawbacks to TMR, but these are more likely to be a result of an error by the surgeon. The biggest of these is the sacrifice of the triceps and biceps, which control the arm. This means that the amputee cannot fully control their arm, but this is a short-term sacrifice that the patient makes in order to gain the ability to control their limb.

**What are some of the long-term consequences of TMR?**

Long-term consequences of TMR include the possibility of nerve regeneration and the potential for the amputee to be able to control their limb without the use of a prosthetic. This is a significant benefit for amputees who are looking for a way to control their limb without the use of a prosthetic.

**Is TMR a one-time procedure?**

TMR is a one-time procedure that allows patients to control their limb for the rest of their lives. This is a significant benefit for patients who are looking for a way to control their limb without the use of a prosthetic.

**How does TMR compare to myoelectric prosthetics?**

TMR is a more advanced technique that allows patients to control their limb more naturally than myoelectric prosthetics. This is a significant benefit for patients who are looking for a way to control their limb without the use of a prosthetic.