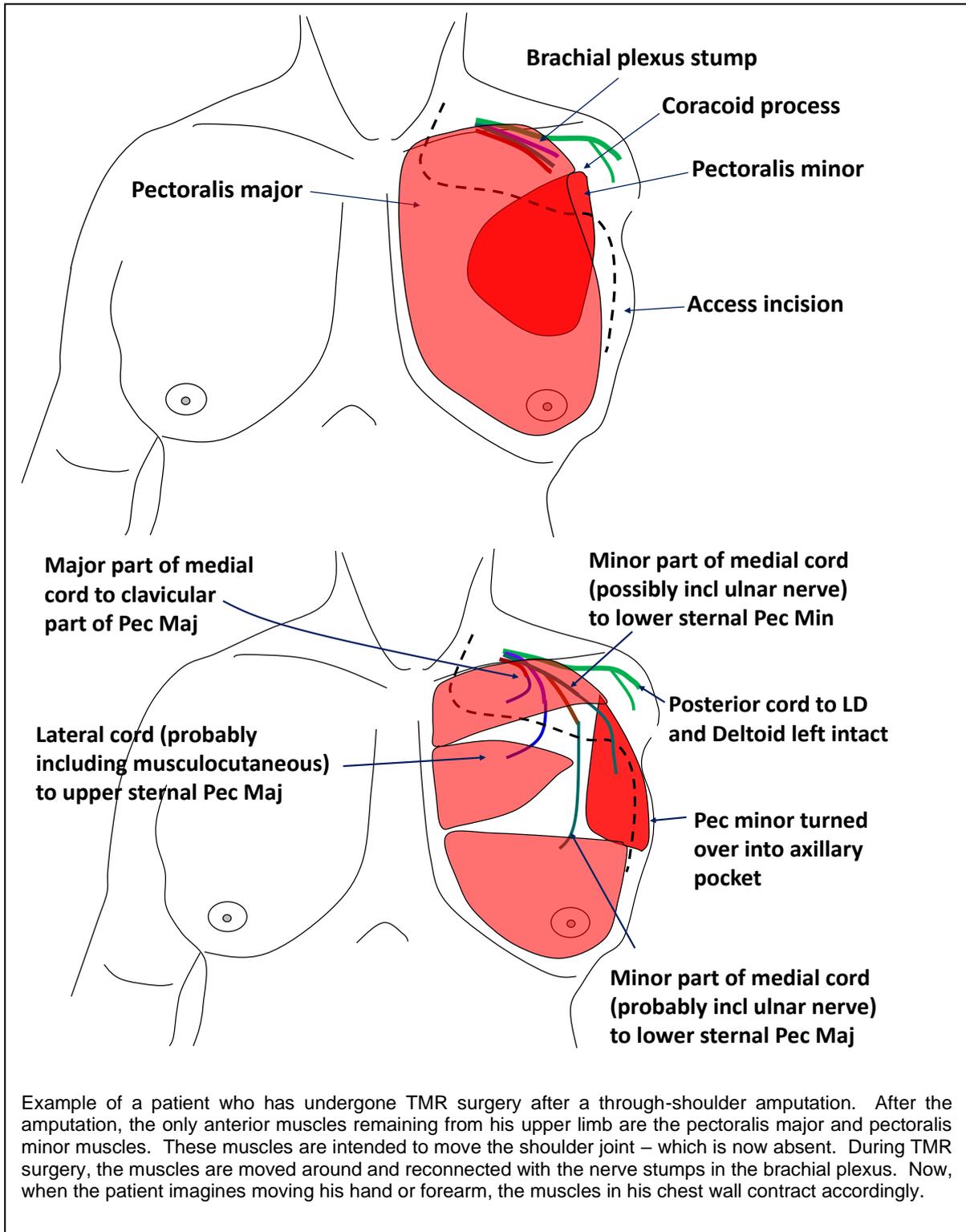


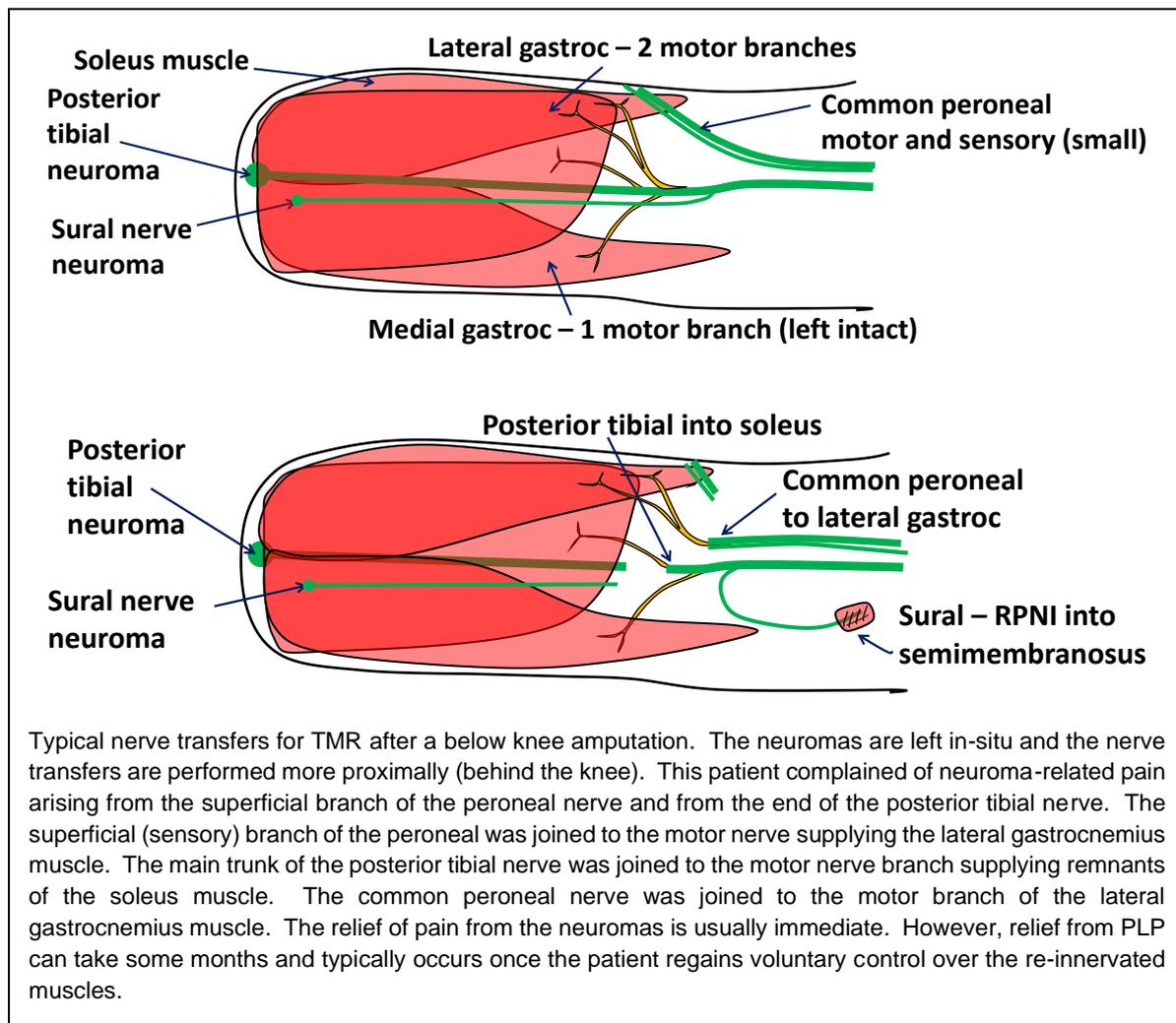
## TARGETED MUSCLE REINNERVATION FOR CONTROL OF NEUROMA AND PHANTOM LIMB PAIN (TMR SURGERY)

Despite the large variety of surgical treatments which have been proposed to address the debilitating effects of neuroma pain after amputation, the only surgical treatment which has been shown to result in sustained, consistent and reproducible improvement is **Targeted Muscle Reinnervation (TMR)** surgery.



The TMR procedure involves transferring the large peripheral nerve stumps in the amputation stump and connecting them to the motor nerves of carefully selected, “target” muscles within or close to the residual limb (stump). The target muscles that we select are usually muscles in the residual limb whose function is now redundant - because of the amputation (i.e. they were intended to move parts of the limb which no longer exist. For example, biceps after a transhumeral amputation).

Within days, axons in the peripheral nerve stumps start to grow into the motor nerves of the target muscles and the reinnervation process begins. However, the reinnervation process takes 12 to 18 months to be complete and you may not notice any changes yourself for 3 to 6 months after surgery. Once the reinnervation process is complete, these muscles will be able to contract voluntarily in response to signals originating in the previously transected peripheral nerves. For example, the median nerve can be joined (coapted) to the motor branch of the medial head of biceps. Now, when the patient imagines moving their thumb or wrist (these are functions normally transmitted down the median nerve), then the medial head of biceps contracts and this muscle can therefore serve as a biological amplifier of the electrical signals in the median nerve stump. Importantly, the electrical activity produced by contractions of



the medial head of biceps can also be detected by electrodes placed on the skin-

surface. So, the biceps muscle can now be used to control a myoelectric prosthetic limb as well.

We now believe that the way in which TMR is able to relieve neuroma pain is by reducing the sensitivity of the peripheral nerve by providing it with feedback from the target muscle. This same feedback also reduces phantom limb pain by providing feedback to the central nervous system that is normally absent when a limb is amputated.

## **AFTERCARE/PAIN CONTROL**

Patients undergoing TMR surgery alone (i.e. not in combination with Osseointegration) will generally go home on the same day as surgery. The only exception is for patients with a very high transhumeral or through shoulder amputation where it is likely that they will need to have exploration of their brachial plexus. Such patients need to be admitted overnight - for pain control.

Patients undergoing TMR surgery alone will need to take all their normal pain medications before surgery and should expect a significant increase in their phantom limb pain (especially in the upper limb) which may be maximal at 3 – 6 months after treatment. We advise our patients that they will need to increase their intake of pain medications (such as pregabalin) in line with their symptoms and may wish to consider doing so 1 -2 weeks before the surgery is performed. The actual pain of surgery is usually minimal and easily controlled with simple analgesics or mild opiates – taken for a few days.

After TMR surgery, your incision will be closed (typically) with absorbable sutures which do not need to be removed. You may wash and shower with running water immediately after surgery but should avoid any heavy use of the limb for 2-3 weeks. Importantly, you must not use your prosthesis until the wound has healed (3 weeks) and any associated soft-tissue swelling has resolved.

Detectable reinnervation of the muscles will occur as early as 4 weeks after surgery but will reach a maximum at 12 – 18 months. During this time, patients who are having TMR surgery for improvement of bionic limb control must undergo close rehabilitation with a rehabilitation unit that is experienced in the use of computerised feedback techniques. This will allow the amputee to learn to use the reinnervated muscles to the best of their ability and helps to reinforce and strengthen the reinnervation pathways.

You do not need any specific rehabilitation exercises if you are undergoing TMR surgery to deal with neuroma pain. However, it has been our experience that patients who learn to use their reinnervated muscles quickly also observe more rapid resolution of their phantom limb pain.

## RESULTS

Multiple trials in the United States and studies of the outcomes of treatment in our own patients have confirmed the effectiveness of TMR surgery for the treatment of neuroma and phantom limb pain.

All of our patients experience immediate relief from their neuroma pain after surgery. The difference between TMR and other forms of neuroma surgery is that this pain should not recur in the long-term. If neuroma pain does recur, the most likely cause for the recurrence is a phenomenon which we have called “unmasking”. This happens because the pain of the dominant neuromas is now abolished. However, patients now become aware of neuroma pain arising from some of the minor nerves. These neuromas were not detected before surgery, because of the overwhelming nature of the pain arising from main neuromas. If unmasking occurs, then it is usually possible to revise the original TMR surgery or improve symptoms with additional procedures such as RPNI.

Relief from phantom limb pain is more complicated. For the TMR to be effective, each nerve which we transfer must be connected to a muscle target that is still under voluntary control. Otherwise, the central nervous system will not receive any feedback from the periphery to trick it into believing that the amputated parts have been restored. **This is often difficult (but not impossible) to achieve in patients who have sustained a brachial plexus injury.** Therefore, each patient must be examined very carefully to determine who will or will not benefit from TMR surgery.

The rate at which patients experience relief from PLP also differs. Once the transferred nerves have made a connection with their muscle targets, the central nervous system starts to receive feedback from the central nervous system which begins the process of changing the way in which the patient perceives their phantom limb. Some patients report a sudden change in their perception over a few weeks as they suddenly realise that they are able to make the target muscles contract voluntarily. For others, this process is more gradual, taking several months or years.

We have observed that our upper limb patients begin to experience an improvement in their PLP limb at about 3 – 6 months after surgery. By 12 months, 80% of our patients will have achieved 80-90% improvement in their PLP, compared to baseline.

The situation in the lower limb is very different. Lower limb patients undergoing TMR surgery seldom experience a sudden increase in PLP after their surgery. Instead, PLP appears to decline slowly over 12 months after the surgery. Moreover, we have observed that PLP only improves in 40 – 50% of our patients who generally experience a 30 – 40% improvement in their PLP compared to baseline. Although not as good as in the upper limb, this is still a very significant improvement in symptoms compared with before surgery. In many cases, it means that patients no longer have to take regular pain medications and are able to use their lower limb prosthesis with greater comfort.