Rehabilitation After Posterior Deltoid to Triceps Transfer in Tetraplegia

Sabrina Koch-Borner, RPT, a Jennifer A. Dunn, PT, PhD, b,c Jan Fridén, MD, PhD, a,d,e Johanna Wangdell, OT, PhD d

From the aSwiss Paraplegic Center, Nottwil, Switzerland; bBurwood Spinal Unit, Burwood Hospital, Christchurch, New Zealand; cDepartment of Orthopaedic Surgery and Musculoskeletal Medicine, University of Otago, Christchurch, New Zealand; dCenter of Advanced Reconstruction of Extremities, Sahlgrenska University Hospital, Gothenburg, Sweden; and eDepartment of Hand Surgery, Institute of Clinical Sciences, The Sahlgrenska Academy at Göteborg University, Gothenburg, Sweden.

Abstract
Objective: To describe and evaluate the rehabilitation concept after posterior deltoid to triceps transfer in patients with tetraplegia.

Design: Retrospective observational study.

Setting: Rehabilitation units.

Participants: Patients with tetraplegia who had posterior deltoid to triceps tendon transfer and had muscle strength measurements 1 year postsurgery from 2009 to 2013 (N = 44).

Interventions: Posterior deltoid to triceps tendon transfer to restore elbow extension and postoperative rehabilitation.

Main Outcome Measures: Elbow extension range of motion and muscle strength and the modified Canadian Occupational Performance Measure (COPM).

Results: Surgery was performed on 53 arms. No major complications (eg tendon rupture, lengthening) were reported. Muscle strength measured 1 year after surgery was on average grade 3 (out of 5) in the 53 operated arms. The ability to extend the elbow against gravity was achieved in 62% of the arms (muscle strength of grade ≥3). In patients with a preoperative elbow extension deficit (n = 14), the deficit was reduced on average from 16° to 9°. The performance of the prioritized activities as measured with the COPM improved on average 2.6 scale steps, from 3.3 to 5.9. Satisfaction with the performance improved on average 3.2 scale steps, from 2.8 to 6.0.

Conclusions: The posterior deltoid to triceps tendon transfer with the applied rehabilitation protocol is a safe and effective procedure. There were no tendon ruptures, and all patients were able to complete the rehabilitation protocol. The shorter restriction time after surgery allows the patient to be independent at an earlier stage of the rehabilitation and reduces hospitalization or care burden.

© 2016 by the American Congress of Rehabilitation Medicine

Elbow extension against gravity is a necessary function for performing a wide range of activities of daily living. These activities are a challenge for many people with tetraplegia because the loss of triceps brachii muscle function is a common consequence of a cervical spinal cord injury (SCI).1,2 In the early 1970s, Moberg3 described a procedure to restore elbow extension function in people with tetraplegia by transferring the insertion of the posterior deltoid muscle to the triceps aponeurosis using a free tendon graft from the toe extensor muscles. The arm was then immobilized in a plaster cast with the elbow in approximately 10° of flexion for 6 weeks. However, the surgical outcome was frequently impaired by the lack of full extension.1,3 This suboptimal functional result was attributed to an elongation of the reconstructed deltoid-triceps muscle-tendon complex caused by active elbow flexion too early after surgery. In the literature, 2 donor muscles are described for restoring elbow extension function in people with tetraplegia: the posterior deltoid muscle and the biceps brachii muscle.4,5 Because positive results are reported for both procedures, clinical experience and surgeons’ preferences are the main reasons for choosing one method over the other. The surgical techniques for the posterior deltoid to triceps transfer vary with respect to proximal and distal...
increased by 10

Rehabilitation protocols after bicpes to triceps tendon transfer compared with posterior deltoid to triceps differ fundamentally. The different donor muscles require different postoperative restrictions of shoulder and elbow flexion and length of elbow immobilization. The major advantage of the bicpes to triceps procedure is that it is considered to be an easier surgery with fewer postoperative restrictions compared with the posterior deltoid to triceps procedure. Conversely, the training of the new function after posterior deltoid to triceps transfer is considered to be easier and without the risk of coactivation because there is no interaction with the elbow flexor (antagonist). Several generic posterior deltoid to triceps postoperative protocols have been described in previous studies. They typically include a rigid elbow flexion restriction for periods of up to 4 months. Early rehabilitation programs include full elbow immobilization up to 4 to 6 weeks, followed by partial restriction of elbow flexion using an adjustable splint for another 8 to 10 weeks. First, elbow flexion is restricted to 10° to 15°. Subsequently, elbow flexion is increased by 10° to 15° every, or every second, week. In addition, shoulder abductions and flexion are restricted up to 12 weeks postsurgery. In later studies, Wangdell and Friderén have reported to start mobilizing the elbow after 4 weeks with a maximum of 60° of elbow flexion and to increase the flexion by 15° every second week with similar results. However, none of these previous studies have reported a detailed rehabilitation program after posterior deltoid to triceps transfer.

The aim of this article is to describe an updated and detailed rehabilitation program after the posterior deltoid to triceps transfer and the results of the intervention.

Methods

Intervention protocol for the posterior deltoid to triceps tendon transfer

The following protocol has been merged from 3 tetraplegia hand surgery units (fig 1). Minor treatment differences therefore exist between some of the included patients.

Preoperative preparation

Rehabilitation planning begins before surgery. The patient needs to be well informed about the surgical procedure and rehabilitation after surgery. The patient must agree to participate in the postoperative treatment program that includes retraining the new function and restrictions during rehabilitation. Only a well-prepared patient can take an active part in the postoperative rehabilitation. As a result of the restrictions after surgery, a special armrest has to be prepared for the wheelchair, and transfer techniques have to be adjusted. Pressure release techniques are discussed because of the increased risk of a pressure ulcer as a result of the restricted ability to extend the elbow. The need for technical aids and arrangements at home are also addressed.

First day to 3 weeks postsurgery

Restrictions during the first postoperative period

After surgery, motion restrictions are placed on the upper limb by bracing the elbow in an extended position, limiting shoulder abduction to a range from 30° to 90° and restricting shoulder flexion and horizontal flexion to <30°. Horizontal extension is not restricted (fig 2).

Bilateral surgery usually requires the patient to remain in bed for a short period of time (up to 10d) because of the inability to maintain a sitting posture with these restrictions. However, after unilateral surgery, the patient can mobilize using a wheelchair as early as 1 day postsurgery.

To avoid stretching the transferred tendon, the arm’s position in bed must be controlled. In a supine position, the arm should be slightly elevated above the horizontal plane to prevent swelling of the hand but without shoulder flexion >30°. Moreover, the arm should be placed with the shoulder abducted >30°. In lateral recumbence, the operated arm is placed on top and positioned slightly backward to ensure that if the arm slides down, it will slide backward and not forward (fig 3).

After bilateral triceps reconstruction, the patient has the arms fully abducted for the first 7 days. Hip turns at the waist are allowed to perform pressure release and bowel care during this time. After 7 days, the arms may be moved slowly down from the fully abducted position to the side. After this, when side-lying, the upper arm must be fully supported to ensure that it does not cross the midline.

Splint

Immediately after the operation, an elbow splint is used to fix the elbow in extension and the forearm in pronation. If an extension deficit was present before the surgery, fixation of the elbow in the maximal extension is recommended; however, additional pain may occur. To prevent edema, a light compression bandage should be applied on the operated arm. The splint is used 24 hours a day for the first 3 weeks. The splint should be made as light as possible to facilitate arm mobility.

Armrest attached to wheelchair

To avoid excessive tension on the transferred tendon in the sitting position, a customized armrest is strongly recommended. The purpose of the armrest is to position the operated arm in shoulder abduction with minimal flexion of the shoulder (maximum 30°) (fig 4). Care must be taken to prevent swelling of the hand given the position of the arm.

Transfers

The transfer from bed to wheelchair can be performed manually or using a hoist, as long as the shoulder movement restrictions (>30° abduction and <30° horizontal flexion) are controlled. The operated arm needs to be outside the sling during transfer to maintain positioning restrictions.

Training of function

The initial training starts on the first day after surgery. The activation of the transferred muscle on the first day after surgery

<table>
<thead>
<tr>
<th>List of abbreviations:</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR brachioradialis</td>
</tr>
<tr>
<td>COPM Canadian Occupational Performance Measure</td>
</tr>
<tr>
<td>SCI spinal cord injury</td>
</tr>
</tbody>
</table>

www.archives-pmr.org
represents no risk as long as the arm is positioned so as to avoid excessive tension on the transferred tendon. Of course, it is crucial that the tendon to tendon attachments are made with a suture technique that can withstand the tension produced when activating the posterior deltoid muscle.\textsuperscript{17} Double-sided back and forth running sutures with a minimum 5cm of tendon overlap can be loaded up to 200N, making early isometric or unloaded dynamic training possible, without the risk of rupturing the attachments.\textsuperscript{17,18}

The initial training is primarily focused on 2 aspects: isometric activation of the transferred posterior deltoid muscle and prevention of tendon adhesions. The starting position for training is at 90° of shoulder abduction, with the elbow fully extended in the splint. Some movement in the splint is allowed. To make it easier to activate the transferred muscle, therapists apply slight external resistance on the posterior deltoid muscle in horizontal shoulder extension (the original function of the donor muscle). External resistance increases muscle activation and facilitates the achievement of full active range of motion. The splint may be removed for training, but only under the supervision of a therapist, and it must remain on at all other times. The patient is instructed to perform unsupervised training sessions wearing the splint and performing approximately 3 sets of 7 to 10 repetitions 4 times a day.

To maintain muscle fitness in the shoulder and to prevent adhesions, the training should also include active shoulder movements, within the restrictions. Passive and active shoulder movements within 30° to 90° abduction and limited to 30° horizontal flexion and extension are important for maintaining the strength of the shoulder muscles, enhancing blood circulation, and activating the muscle pump to avoid oedema. Patient education is critical to ensure that patients understand how to perform the exercises and that they adhere to the restrictions. Therefore, the therapist must be familiar with the operation and the restrictions during rehabilitation.

**Daily activities**

Activities of daily living (eg, getting dressed, pressure relief activities) must be performed within the shoulder abduction and flexion restrictions to ensure that the transferred tendon does not overstretch. These restrictions limit the usual daily activities of the patient. To prevent a patient from experiencing low mood as a result of the restrictions, it is important to motivate a patient to be as active as possible during the initial restriction time. Therefore, preservation of general fitness and maintaining social activities should be encouraged. A positive patient is more likely to perform the training required and stay motivated.

**4 weeks postsurgery**

**Restrictions**

There are no change from the initial restrictions: shoulder abduction from 30° to 90°, shoulder flexion and horizontal flexion limited to 30°, and restriction of the elbow flexion with a dynamic splint (see fig 2).

**Splint**

From the third to the fourth week postsurgery, the static splint is replaced with a dynamic brace in the daytime. The 22 patients of the Swedish center wore the static splint at night until 9 weeks postoperatively, whereas the others wore the dynamic brace at night. With the dynamic brace, the degree of elbow flexion and extension is adjustable. Elbow flexion starts at 30° to 45°, depending on the patient’s level of resistance (stiffness) during passive elbow flexion. Thereafter, the brace is adjusted by increasing elbow flexion 15° every week.

**Training of function**

The training now changes to dynamic activation of the posterior deltoid muscle to facilitate voluntary control of elbow extension. The muscle reeducation program is directed at learning to isolate elbow extension (vs shoulder extension), coordination, and force modulation during elbow extension. During training, an active full range elbow extension should be achieved with maintained shoulder stability. Substitution or trick movements (eg, rotation) from the shoulder are not allowed. Slight resistance against horizontal extension is acceptable at the beginning of dynamic training in order to voluntarily activate the posterior deltoid muscle to extend the elbow. The training is performed with the arm in different positions in the horizontal plane with no resistance, within the restricted range of motion, to train the ability to activate the posterior deltoid muscle as an elbow extensor in various positions that require different muscle tension. The goal of this exercise is to train the cocontraction of the posterior deltoid muscle and the pectoral muscles (as the antagonist). Dynamic training is preferably done as 4 sets of 10 repetitions, evenly distributed over the day.

If scar adhesions are present, manual scar treatment can now be started along with triceps activation in different shoulder positions (within restrictions) to facilitate efficient tendon gliding.
6 weeks postsurgery

Restrictions
There are no change from the initial restrictions: shoulder abduction from 30° to 90°, shoulder flexion and horizontal flexion limited to 30°, and restriction of the elbow flexion with a dynamic splint (see fig 2).

Training of functions
At 6 weeks postsurgery, elbow extension can be trained against gravity. Supine recumbence is the best position to start antigravity training. The arm(s) should be abducted at 90° and horizontally flexed at 30°. The splint may be kept on during the first sessions to control the maximal elbow flexion. Later on, it is important to remove the splint during training to help the patient to learn eccentric control of the elbow movement. The goal is to reach full elbow extension with every repetition (fig 5).

Shoulder stability is essential for obtaining good elbow extension. Therefore, training the cocontraction of specific muscles—posterior deltoid muscle and pectoral muscles—is important. The most important muscle groups to train are the pectoral muscles, which perform horizontal flexion as an antagonistic movement to the horizontal extension realized by the posterior deltoid muscle. Ideally, the pectoral muscles need to be as strong as the posterior deltoid muscle because their cocontraction opposes the posterior deltoid muscle action and is translated as an efficient elbow extension moment. All shoulder exercises are allowed, within restrictions. The shoulder restrictions are still 30° to 90° abduction and 30° flexion and horizontal flexion. There are no restrictions for horizontal extension. The
recommended weight during all exercises ranges from 0 to 3kg, depending on the muscle strength. However, at this stage, the primary aim of the training is good arm control and efficient cocontractions. Therefore, antigravity training is performed and full elbow extension is enforced in every repetition. Strength training is the focus later on in the process.

7 to 9 weeks postsurgery

Depending on the degree of flexion when initiating the dynamic splint at three to four weeks post-surgery, the patient should reach elbow flexion over 90° seven to nine weeks after surgery.

Restrictions
The remaining restriction is shoulder adduction over the midline. No passive elbow flexion over 90° is allowed. The structures will be gradually softened during the active exercises.

Splint
When the patient reaches 90° of elbow flexion, the dynamic splint can be removed during the day. Night splinting continues until the ninth week postsurgery, thereafter it is discontinued.

Training of function
From now on, training focuses on strength training. Patients are allowed to train with as much weight as the muscle can tolerate and still reach full elbow extension.

Training in activities
The patient is allowed to start propelling a manual wheelchair. Analysis of the pushing pattern is important because it may have changed as a result of the new triceps function. After posterior deltoid to triceps surgery, the patient can produce longer push cycles because the starting hand position and the forward propulsion power are improved because of elbow extension. This change in the propulsion pattern may require seating and/or wheel position adjustments to optimize the propulsion within the limitations of trunk balance. Wheelchair skill training is important at this stage to ensure the patient has confidence with community mobility in the manual wheelchair.

Training can now include activities such as reaching up into a cupboard or coordinating the arm during activities. Eating, drinking, and brushing teeth can be started as soon as the active elbow flexion range is sufficient and as long as the arm does not cross the midline. Using passive force to increase the elbow flexion is not allowed.

Swimming and boxing training are examples of training activities promoting good arm control that can be started at this stage of the rehabilitation process.

10 weeks postsurgery and beyond

Restrictions
There are generally no restrictions. However, if patients wish to play wheelchair rugby, they are advised to wait a further 4 weeks because of the possibility of falling out of the wheelchair onto a flexed elbow and potentially damaging the posterior deltoid to triceps transfer.

Training of functions and activities
The patient is encouraged to gradually increase both the muscle function and activity level. There are now no restrictions that interfere with activity skills training. The activity skills training can therefore be intensified. Activities and goals differ between patients. However, activities such as sitting up, propelling and maneuvering a wheelchair, transfers from the bed, undressing, meal preparations, driving a car, and using a computer are common and prioritized activities. The level of achievable independence varies between individuals and depends on factors such as the level and completeness of the SCI, constitution of the body, and motivation. Therefore, not all patients achieve the same level of independent activities. Improvements in activities after triceps reconstruction continue to occur for at least 1 year after surgery, with significant improvements between 6 and 12 months. It is therefore important to encourage the patients to continue to train daily activity skills for at least 1 year after surgery.

Study design

Participants
All patients undergoing a posterior deltoid to triceps transfer at the tetraplegia hand surgery units in Christchurch, New Zealand, Gothenburg, Sweden, and Nottwil, Switzerland, from 2009 to 2013 were included in this retrospective study.

Patients with no elbow extension strength measurement at the follow-up visit 1 year postsurgery were excluded. Patients
undergoing unilateral and bilateral procedures were included. Simultaneous bilateral surgery was only performed in New Zealand.

Even though different tendon grafts had been used at the 3 sites, the postoperative rehabilitation protocols were similar.

**Outcome measures**
Data were collected from the medical records of presurgery assessments and the routine clinical follow-up visit 1 year postsurgery.

**Outcome measures 1 year postsurgery**

**Triceps and posterior deltoid muscle strength**
The muscle test was performed in different standard positions in the 3 units. In Nottwil, Switzerland, the muscle strength was assessed with the patient in a supine position, according to the British Medical Council Scale. In Gothenburg, Sweden, and Christchurch, New Zealand, patients were assessed in a sitting position in a wheelchair with the arm positioned in 90° of abduction. To assess the strength of the triceps muscle against gravity and resistance, the arm was placed in approximately 130° of abduction. To assess the strength of the triceps muscle against gravity and resistance, the arm was placed in approximately 130° of abduction. To assess the strength of the triceps muscle against gravity and resistance, the arm was placed in approximately 130° of abduction.

**Activity outcome**
A slightly modified version of the Canadian Occupational Performance Measure (COPM) was used as an activity outcome measurement. Before surgery, patients were asked which specific activity limitations they would like to improve. Thereafter, the standardized COPM format was followed, and patients chose up to 5 prioritized activity limitations and rated them on a scale from 1 to 10 for performance satisfaction with the performance. The prioritized activity limitations were reassessed at the 1 year follow-up.

**Elbow extension range of motion**
The elbow extension range of motion was measured using a handheld goniometer.

**Data analysis**
Data are presented as means ± SDs, unless noted otherwise. To detect differences between pre- and postsurgery values, the Wilcoxon signed-rank test was used. A P value of <.05 was considered significant.

**Results**
The evaluation of the treatment protocol included 22 patients from Gothenburg, Sweden, 11 patients from Christchurch, New Zealand, and 11 patients from Nottwil, Switzerland. Nine patients had bilateral surgery (all from New Zealand). All others had unilateral surgery. Therefore, the study sample includes 44 patients and 53 arms. All patients were able to complete the rehabilitation protocol.

There were 33 men and 11 women. The mean age was 35 years (range, 18–61), and the time after injury varied from 1 to 26 years (mean, 6y). The most common level of injury was C5 (American Spinal Injury Association motor level), occurring in 28 of 43 persons (table 1). The International Classification for Surgery of the Hand in Tetraplegia ranged from O1 to Ocu4, with most patients classified as O1 (table 2).

Tendon grafts were used in all reconstructions. The most commonly used graft was the tibialis anterior tendon (n = 31). Other grafts were the hamstrings tendon (n = 20) or the tensor fascia latae tendon (n = 2). One patient had a combined surgery: triceps reconstruction and tendon transfer from the brachioradialis (BR) muscle to the extensor carpi radialis brevis muscle with passive key pinch.

**Complications**
For the 53 operated arms, no major complications (eg, rupture, major graft lengthening) were reported. However, 1 patient suffered from a postoperative hematoma, which made a tenolysis procedure necessary.

**Outcome at 1-year follow-up**
The muscle strength of the 53 operated arms measured 1 year after surgery was on average 3.0 ± 0.9 (fig 6). The ability to extend the elbow against gravity (muscle strength ≥ 3) was reached in 62% of the patients (New Zealand: 80%, Switzerland: 77% and Sweden: 45%). The participants from New Zealand, Sweden, and Switzerland reached an average muscle strength of 3.4 ± 0.8, 2.6 ± 0.9, and 3.1 ± 0.9, respectively, after posterior deltoid to triceps transfer (table 3).

Forty-three percent of the patients (6/14) with a preoperative elbow extension deficit did not have any extension deficit 12 months postsurgery. The extension deficit was reduced from a mean 16° to 9° (fig 7).

A total of 28 COPM follow-up measurements were available for the 53 operated arms. One reason for the reduced number of COPM assessments is that the patients who have undergone bilateral surgery only completed 1 COPM for

---

**Table 1**

<table>
<thead>
<tr>
<th>ASIA Motor Level</th>
<th>Total</th>
<th>Sweden</th>
<th>New Zealand</th>
<th>Switzerland</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>28</td>
<td>16</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>C6</td>
<td>16</td>
<td>6</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>22</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

NOTE. Values are the number of participants.
Abbreviation: ASIA, American Spinal Injury Association.

**Table 2**

<table>
<thead>
<tr>
<th>Preserved Muscles in the Forearm</th>
<th>Total</th>
<th>Sweden</th>
<th>New Zealand</th>
<th>Switzerland</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/Ocu1 BR</td>
<td>23</td>
<td>16</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>0/Ocu2 BR, BR, ECRL</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>0/Ocu3 BR, ECRL, ECRB</td>
<td>12</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>0/Ocu4 BR, ECRL, ECRB, PT</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>22</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

NOTE. Values are the number of participants.
Abbreviations: ECRB, extensor carpi radialis brevis; ECRL, extensor carpi radialis longus; ICSHT, International Classification for Surgery of the Hand in Tetraplegia; PT, pronator teres.

---

www.archives-pmr.org
both arms. Moreover, some patients have had their follow-up in other rehabilitation centers and therefore were lost to follow-up.

The performance of the prioritized activities improved significantly, on average 2.6 scale steps (from 3.3 to 5.9). Satisfaction with the performance also showed a significant improvement of 3.2 scale steps, from 2.8 to 6.0. All units showed a clinically relevant increase (ie, minimum change of 2 scale steps) in both performance and satisfaction (fig 8).

A subanalysis of the activity change (COPM) for patients with a low muscle strength outcome after 1 year was performed. Patients with triceps muscle strength 2 (n=12) rated their activity improvement similar compared with the whole group, with an activity performance improvement of 2.5 scale steps (from 3.4 preoperatively to 5.9 postsurgery) and a satisfaction improvement of 3.2 scale steps (from 3.1 to 6.3). The patient with a muscle strength of 1 one year after surgery showed restricted triceps muscle activity because of biceps spasticity. However, the patient was still satisfied with the results because of the improved control over of the arm. The COPM performance improved by 3.6 scale steps, from 2.0 to 5.6, and the satisfaction improved by 4.2 scale steps, from 1.2 to 5.4. The patient has also elected to have surgery on the other elbow before grip reconstruction because he appreciates the elbow extension control he has gained (tables 4 and 5).

Discussion

The results of this study show that the described rehabilitation protocol is a safe and successful procedure. Compared with previous rehabilitation protocols, the herein described protocol allows the patient to be independent at an earlier stage of the rehabilitation and reduces the restriction and hospitalization or care time. Increased dependence is one of the most important factors in the decision-making process concerning surgery. The current rehabilitation protocol therefore not only has economic advantage but also represents a major advantage for the patients.

The most important changes compared with the old protocol are the earlier active elbow flexion, focused shoulder stability training, earlier propelling of a manual wheelchair, and other activity trainings. Another important change is the direct activation of the transferred muscle. Letting the patient feel the movement on the first day after surgery is an important motivator for the patient to proceed in this relatively demanding rehabilitation.

Our results after posterior deltoid to triceps transfer with the described rehabilitation protocol are comparable with previous studies. Mohammed et al. reported that 71% of the evaluated arms reached muscle strength of grade ≥3 for the reconstructed triceps function after posterior deltoid to triceps transfer. In our study, there was a slightly lower number of arms (62%) that reached a muscle grade ≥3 at 12 months after reconstruction. This was mainly because of the lower number (45%) in the Swedish cohort. In the New Zealand and Swiss cohort, 80% and 77%, respectively, of the operated arms reached muscle strength of grade ≥3. One reason for the lower percentage of grade ≥3 muscle strength in the Swedish cohort is a higher SCI level. A total of 73% had a motor level C5 and were classified as International Classification for Surgery of the Hand in Tetraplegia O1 (compared with 27% in New Zealand and 36% in Switzerland). The severity of SCI level affects the postoperative outcomes (eg, a weak deltoid muscle [donor muscle], weak pectoral muscles, and other trunk muscles limiting shoulder stability for triceps action). Interestingly, the Swedish patients reported a greater activity improvement than the patients from the other 2 units regarding performance and satisfaction with the performance. This result highlights the importance of measuring not just the improvements in muscle strength but also how this translates into improvements in activity and participation in individuals with SCI. It also demonstrates both the

---

**Table 3** Muscle strength measurement (MRC score) in the study group

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Total (N=53)</th>
<th>Sweden (n=22)</th>
<th>New Zealand (n=20)</th>
<th>Switzerland (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative PD</td>
<td>4.1±0.83</td>
<td>3.7±0.65</td>
<td>4.7±0.47</td>
<td>4±1.1</td>
</tr>
<tr>
<td>Preoperative triceps</td>
<td>0.2±0.41</td>
<td>0.1±0.29</td>
<td>0.2±0.49</td>
<td>0.1±0.47</td>
</tr>
<tr>
<td>Postoperative PD-T</td>
<td>2±0.91*</td>
<td>2.6±0.85</td>
<td>3.4±0.81</td>
<td>3.1±0.94</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD.

Abbreviations: MRC, British Medical Research Council Scale; PD, posterior deltoid; PD-T, posterior deltoid to triceps transfer.

* Significant difference to preoperative triceps (P<.0001).
importance of an informed patient with realistic goals and the improvements even more impaired patients can gain from this surgery. Further studies are needed to explore these findings in more detail.

Active elbow extension facilitates the possibility to use the arm in a more controlled manner during daily activities. It improves the ability to perform activities overhead and in the horizontal plane. It also improves activities requiring less strength: activities in front of the body and controlling the arm in a supine position. A previous study showed that activities performed above the horizontal plane together with activities in a supine position presented the most significant improvements after surgery.16 This indicates that both gravity- and non–gravity-dependent activities are important activities for patients, and these activities are also improved after triceps reconstruction. In our study, the overall prioritized activity limitations improved a mean 2.6 scale steps. It is generally accepted that a scale change of >2 is clinically relevant.23 Interestingly, the improvement in activity limitations does not seem to correlate with the muscle strength. The subanalysis of patients with muscle grade 2 at 1 year after surgery showed a similar activity performance and the same satisfaction compared with patients with stronger arms. Furthermore, the person with only a muscle grade 1 reported an above average performance and satisfaction. These findings are similar to those of a previous study on correlations between activity and body function outcome after grip reconstruction in tetraplegia.24 In other words, to use Bunnell’s classic quote: “To those who have nothing a little is a lot.” The possibility to improve one’s functional ability can mean even more when the limitations are greater, even if the gained muscle strength is minor.

In our study sample with 53 posterior deltoid to triceps surgeries, there was no tendon elongation, which is a well-known complication in early reports of posterior deltoid to triceps reconstructions.4 Furthermore, there were no ruptures and therefore no revision surgery because of ruptures. In comparison, in a study of 77 arms with biceps to triceps surgery, 14% (n = 11) were ruptured during rehabilitation.25 In our study sample, 1 revision

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Activity limitations in the study group, as measured by the COPM, including all centers</th>
</tr>
</thead>
<tbody>
<tr>
<td>COPM</td>
<td>Total (N=28)</td>
</tr>
<tr>
<td>Performance</td>
<td>Preoperative</td>
</tr>
<tr>
<td></td>
<td>12mo postoperative</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Preoperative</td>
</tr>
<tr>
<td></td>
<td>12mo postoperative</td>
</tr>
<tr>
<td>NOTE: Values are mean ± SD.</td>
<td></td>
</tr>
<tr>
<td>* Significant difference to preoperative in the total group (P&lt;.0001).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Activity limitations in patients with low triceps muscle strength outcome at 12 months, as measured by the COPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>COPM</td>
<td>Total (n=28)</td>
</tr>
<tr>
<td>Performance</td>
<td>Preoperative</td>
</tr>
<tr>
<td></td>
<td>12mo postoperative</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Preoperative</td>
</tr>
<tr>
<td></td>
<td>12mo postoperative</td>
</tr>
<tr>
<td>NOTE. Values are mean ± SD or n.</td>
<td></td>
</tr>
<tr>
<td>Abbreviation: MRC, British Medical Research Council Scale.</td>
<td></td>
</tr>
<tr>
<td>* Significant difference to preoperative in the total group (P&lt;.0001).</td>
<td></td>
</tr>
</tbody>
</table>
surgery was performed. It was a tenolysis as a result of adhesions after a postsurgical bleeding.

Based on the clinical results in the 3 units over the last 5 years, we conclude that the posterior deltoid to triceps surgery with the aforementioned rehabilitation concept is a safe and effective procedure. Further studies are needed to quantify donor muscle strength and to identify key factors of the rehabilitation protocol and the patient to improve the predictability of the outcome. Having more data concerning subgroups of patients, the rehabilitation could be more individualized and the outcomes further improved. An emphasis on preoperative training could also be a factor for future outcome improvements. Multicenter studies will be necessary to collect enough data for subgroup analysis.

The strength of our study is the merging of data from 3 units from around the world with a similar rehabilitation concept. All 3 units use the same outcome assessments at the same time points. Although all 3 units have slightly different rehabilitation protocols, the main rehabilitation goals and restrictions are the same and have been summarized in this article. This provides the potential for future collaborative studies with faster data collection and a greater number of participants.

**Study limitations**

Because of the retrospective study design, the protocols of the 3 units are not identical. One major difference is the assessment positions for the muscle testing, which were not standardized. In New Zealand and Sweden, the position of the triceps muscle for testing against gravity and resistance was with the arm placed in approximately 130° of shoulder flexion/abduction (the arm against the ear). However, in Switzerland, the supine position was used. It is possible that the posterior deltoid to triceps transfer muscle strength in the Swiss group was greater because of this position.

There are also differences in the treatment protocols between the participating units, mostly in terms of minor differences in the restriction times and the length of hospital stay.

In the New Zealand and Swiss patients, there is more focus on therapist-guided shoulder training because they stay in the hospital for the whole duration of their rehabilitation. The Swedish patients leave the hospital at the end of the first week and come back for training in week 4. Additionally, the Swiss patients wear the splint for up to 9 weeks postsurgery, whereas in the other 2 units the splint is removed once the patient reaches 90° of elbow flexion. Some patients were not allowed to cross midline up to 12 weeks. Moreover, the surgery technique differs slightly between the units, mostly because of different tendon graft material and performing bilateral or unilateral surgery.

**Conclusions**

The posterior deltoid to triceps surgery with the current rehabilitation protocol is a safe and effective procedure. The shorter restriction time after surgery allows the patient to be independent at an earlier stage of the rehabilitation, and the shorter limitations reduce hospitalization or care time. There were no ruptures in this study sample of 53 reconstructed triceps muscles. The mean triceps muscle strength after 1 year was British Medical Research Council Scale grade 3.0. Patient activity performance after 1 year had improved by 2.6 scale steps, and the satisfaction with the performance had improved 3.2 scale steps.

**Keywords**

Quadriplegia; Reconstructive surgical procedures; Rehabilitation; Spinal cord injuries; Tendon transfer; Upper extremity

**Corresponding author**

Sabrina Koch-Borner, RPT, Swiss Paraplegic Center, Guido A.Zäch Strasse, CH-6207 Nottwil, Switzerland. E-mail address: sabrina.koch@paraplegie.ch.

**References**

17. Friden J, Shillito MC, Chehab EF, Finneran JJ, Ward SR, Lieber RL. Mechanical feasibility of immediate mobilization of the