Rotator cuff degeneration in the rheumatoid shoulder : 'the issue is soft tissue'

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Chapter 2.3

Functional and Biomechanical Assessment of Teres Major Tendon Transfer as Primary Treatment of Massive Rotator Cuff Tears

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Surgery of the Shoulder and Elbow. An International Perspective 2006; Chapt 6: 36-41

J.H. de Groot , M.A.J. van de Sande, C.G.M. Meskers, P.M. Rozing.
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Steenbrink F, de Groot JH, Veeger HE, Meskers CG, van de Sande MA, Rozing PM.
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Summary

Mechanical deficit due to massive rotator cuff tears coincide with a pain induced decrease of maximum arm elevation and peak elevation torque. The purpose of this study was to measure shoulder muscle coordination in patients with massive cuff tears, investigating the additional effect of subacromial pain suppression.

Three patients, with MRI-proven cuff tears, performed an isometric force task in which they were asked to exert a force in 24 equidistant intervals in a plane perpendicular to the humerus. By means of bi-polar surface EMG the direction of maximum muscle activation or Principal Action of six muscles was identified prior to and after subacromial pain suppression, as was maximum arm muscle force.

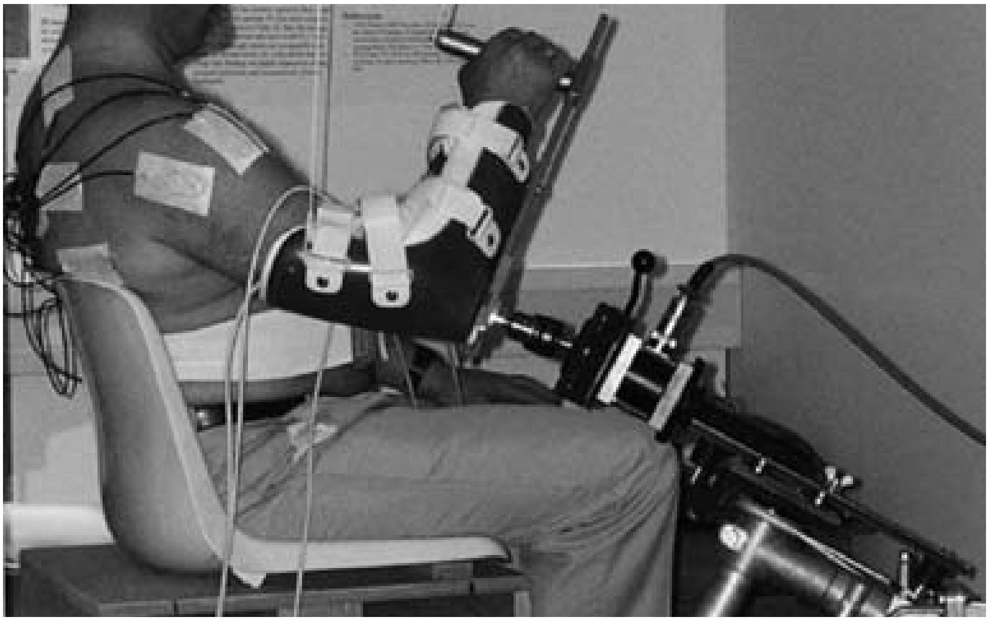
We observed a pathological activation of the arm adductors (Pectoralis Major pars clavicularis, Latissimus Dorsi, Teres Major) during abduction force delivery. We hypothesize that the Deltoid muscles take over the function of the Supraspinatus to produce its elevation torque, but introduce destabilizing forces in the glenohumeral (GH) joint, with subsequent upward translation and pain. Arm adductors are co-activated in absence of stabilizing inward forces by the Supraspinatus muscle in order to reduce this superior translation force resulting in pain at the cost of arm force.

This study presents the application of a reliable and applicable technique in measuring the principal action of rotator cuff muscles using electromyography, applied to evaluate a rotator cuff repair procedure using Teres Major tendon transfer. It is demonstrated that a sole transfer of the Teres Major tendon can be a successful primary salvage procedure for massive rotator cuff tears, decreasing pain and improving range of motion. The expected function shift of the Teres Major from being active during adduction to become active during abduction after transfer could be confirmed

Introduction

Transfer of the Latissimus Dorsi and Teres Major tendon from the humeral shaft to the superolateral humeral head is used for both primary and salvage reconstruction of massive rotator cuff tears.[1] This type of transfer is thought to increase the external rotation of the arm and depress the humeral head to allow effective action of the Deltoid muscle. If these changes are evident, it is assumed that a functional adaptation of the Teres Major muscle has occurred. A method to evaluate the function of an individual muscle, however, is absent. We evaluated the principal action of the Teres Major muscle using an isometric method of electromyography (EMG).[112; 113] The measurements of the principal muscle action were compared with clinical outcomes and assessments of the level of force to help determine the clinical relevance of the proposed methods.

Figure 1. Experimental set-up patient and arm positioning.



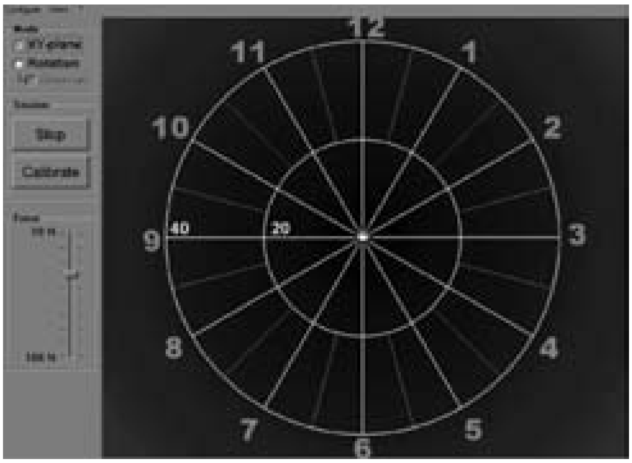
The arm was fully supported in rest and the weight of the arm and the axial moment of the lower arm around the long axis of the humerus were compensated for by means of a weight-and-pulley system. The tip of the splint could rotate along all axes of a ball-and-socket joint and the arm could freely move forward and backward along a rail. Forces perpendicular to the humerus were recorded by means of a 6 degrees-of-freedom force transducer (AMTI).

Materials and Methods

In 2004, three primary transfers of the Teres Major tendon were performed to treat rotator cuff tears that could not otherwise be repaired with surgical methods. Each patient had a full tear of the Supraspinatus muscle and a large tear of the Infraspinatus muscle. The muscle tears were diagnosed by MRI and arthrography. The initial diagnoses were subsequently confirmed during surgical procedures. Patient characteristics are presented in Table 1. Subjects were seated with the affected arm in a splint with the elbow in 90° of flexion. The humerus was elevated 60° in the scapular plane, creating a 30° angle with the frontal plane. The forearm was positioned in a 45° angle with the horizontal plane (Figure 1). The splint was attached to a 3D force transducer capable of measuring force in an x-y plane perpendicular to the longitudinal axis of the humerus (Figure 1).

The arm was suspended in order to compensate for gravity. The force transducer was mounted on a sled so that it could move freely in a direction parallel to the humeral longitudinal axis. Axial rotation of the humerus was mechanically restricted to prevent the subjects from generating supplementary moments. The force measured by the force transducer was visible to the subject by a cursor on a video screen (Figure 2). To help the subjects control both force direction and magnitude, the cursor was to be moved over a target drawn as a wheel. The spokes of the wheel denoted the force direction and concentric circles denoted the force magnitude. The Teres Major muscle was assessed using a bipolar surface electrode. The distance between electrodes was 21.5 mm. Before placement of the electrodes, the skin was abraded and defatted. Electrode gel was applied. After electrode placement, skin resistance was tested. Electrodes were replaced when the skin resistance exceeded 10kW. The same positioning of the electrodes was used for both pre- and postoperative evaluations. Prior to the experiment, the subjects performed maximal voluntary contractions in 12 planar directions with steps of 30°. The maximum force that could be exerted in every direction was then set as the force in the outer ring. After sufficient training, the subjects were asked to exert this force in 24 directions with steps of 15° in a random order. The force was maintained for 3 seconds in each direction. Mean EMG activity in each of the 24 force directions was recorded. The maximum force that could be exerted in all directions and the maximum force in internal and external rotation were measured using the same experimental setup. To reduce the influence of pain on force exerted, preoperative measurements were obtained both before and after a subacromial injection of 5 mL 1% lidocaine. These measurements were obtained once without the lidocaine treatment 4 months postoperatively. The EMG measurements of shoulder muscles were obtained during an isometric external load. A force was exerted in multiple directions covering 360° in a plane perpendicular to the

Figure 2. *Experimental set-up force visualisation.*



External arm force was visualised by means of a cursor on a computer display. The subjects moved the cursor to the outer circle (coinciding with a pre-defined force) for 3s at each 'half hour' of the display: 12 (o'clock) = forward flexion, 3 = abduction, 6 = retroflexion and 9 = adduction.

humeral axis. For EMG analyses of principal muscle action, the activation patterns obtained were parameterized after fitting data to a least-squares function. This analysis determined force-direction-dependent parameters including on- and off-set direction of the activity peak, and the direction of highest EMG activity or principal action. Fitting a function in a least squares model to the data points parameterized the relationship between EMG amplitude and force direction. The resulting five parameters were: baseline amplitude, principal action, two baseline intercepts, and maximum EMG amplitude (Figure 3). Data acquisition and processing were completed as previously described.[112; 113] Errors were estimated for within-trial, intertrial, interday, and intersubject variability.[113] With a group of 10 subjects, the 95% confidence interval for measurements taken at different times on the same day was approximately ± 5° on a scale of 360° for the principal action and just less than ± 10° for the intercepts. The method appears to be sufficiently accurate with regard to measurements of an individual patient on different days, and thus evaluation of shoulder muscle coordination before and after interventions should be valid. Pain relief was determined with the use of a 10-point visual analogue scale (VAS). The Dutch Shoulder and Elbow Model (DSEM) was used to compare both transfers in a patients with rotator cuff disease. The muscle parameters of the DSEM were modified to simulate a rotator cuff tear.[114; 115]

T*able 1. Clinical and function patient characteristics and results*

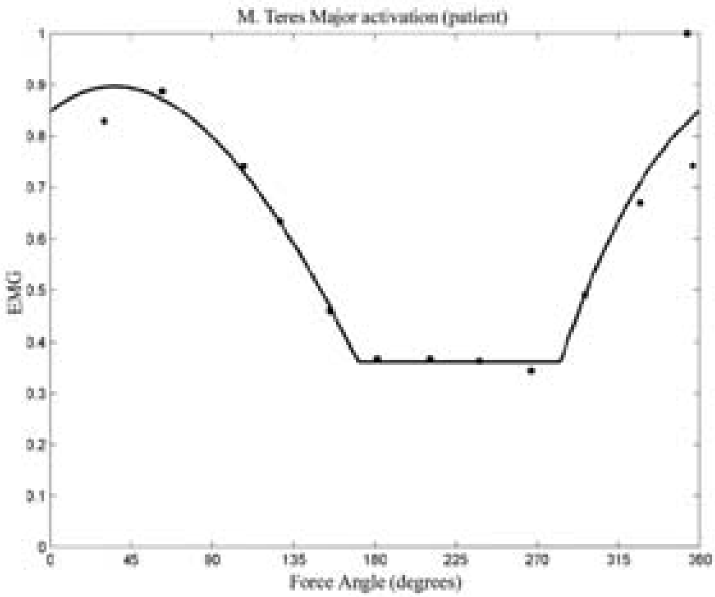
	age, sex	*VAS pain rest / activities*	*Constant*	*VAS pain rest / activities*	*Constant*
patient 1	69, m	5 / 8	28	0 / 1	80
patient 2	60, m	5 / 8	33	0 / 1	87
patient 3	54, m	3 / 7	64	0 / 2	81

* All three patients were men
* VAS = Visual Analogue Scale

Results

Compared to healthy volunteers, our patients had decreased maximum voluntary contraction (MVC) in every direction for all muscles evaluated preoperatively. The Infraspinatus muscle showed very little EMG activity in external rotation and abduction. Treatment with lidocaine reduced pain relief from a mean of 7.7 to 0.9 on the VAS. In addition, lidocaine treatment was associated with an increased MVC, muscle strength, and EMG amplitude for all shoulder muscles evaluated. Figure 4 shows the force measurements in the horizontal and vertical planes obtained preoperatively, following preoperative subacromial lidocaine injection, and postoperatively. The average muscle force increased from 13.3 N to 23.6 N. Both before and after subacromial injection of lidocaine, the Teres Major muscle was predominantly active during retroflexion and adduction. Pre- and postoperatively patients showed difference in principal action of the Teres Major muscle (Figure 5). The first patient showed the highest muscle activity during forward flexion pre and postoperatively. The second and third patient showed a 'normal' activation pattern during retroflexion pre-operatively. In both patients this changed to an activation pattern during abduction and forward flexion. Postoperatively, the Constant score increased by 41 points, on average, from 42 to 83. The mean VAS score decreased to 1.3. The shoulder muscle force increased from an average of 13.3 N to 25.6 N in all directions (Table 1, Figure 4). Internal rotation force increased from an average of 9 N preoperatively to 24.7 N postoperatively. External rotation force increased from a mean of 14.6 N preoperatively to 19.0 N postoperatively. Thus the mean increases in internal and external rotation after the tendon transfer were similar to those observed after subacromial injection of lidocaine. Following the tendon transfer, the highest EMG signals were observed during abduction and forward flexion, indicating a change in the principal action of the Teres Major muscle compared with preoperative results (Figure 5). The other shoulder muscles showed no relevant change in principal action. No intra- or postoperative complications were reported.

Figure 3. *Graph depicts the estimated muscle activation before surgery (abnormal activation pattern). The EMG measured during the isometric task is plotted against the degree of force angle. Teres Major shows most activity during forward flexion and abduction.*



Discussion

Although measurements of EMG are usually related to muscle force during movements, a number of problems are associated with these measurements. Potential problems include displacement of the electrodes, limits on the number of muscles that can be assessed, and nonlinear changes in velocity during muscle contraction. By relating EMG to force direction, these problems can be circumvented.[112; 113] When EMG is related to force direction, a typical activation pattern including an active and an inactive (or silent) part can be identified. In our patients the silent part showed a rather high base level, which can probably be explaned by co-contraction during activity in order to preserve shoulder stability. The top of the active part is the most favourable direction in which a muscle is activated and is called the principal action. Other parameters are the two intercepts of the active part with the silent part, and the level of EMG activity at the silent part and at the principal action. For patients with an irreparable posterosuperior rotator cuff tear, a primary Latissimus Dorsi tendon transfer reliably restores flexion and relieves pain. The transfer is thought to increase external rotation of the arm and depress the humeral head to allow effective action of the Deltoid muscle.[116] The Teres Major tendon transfer onto the greater tuberosity also restores continuity of the cuff and depresses the head of the humerus.[117] Both techniques have been reported to produce good functional results in primary and salvage surgical procedures for treatment of a massive rotator cuff tear.[118] The DSEM was applied to compare both transfers in a patient with rotator cuff disease.[114; 115] On the basis of mechanical parameters such as moment arms, muscle length, and force, it was concluded that a tendon transfer of the Teres Major to the Supraspinatus insertion produced the best functional outcome in the treatment of massive rotator cuff tears. To our knowledge, no clinical studies confirming these results have been reported. Our experience indicates that the use of a Teres Major tendon transfer for irreparable rotator cuff tears results in successful clinical outcomes. We observed that the principal action of the Teres Major muscle changed from being primarily active during adduction preoperatively to primarily active during abduction postoperatively. Not all patients, however, exhibited these changes in function of the Teres Major muscle. Perhaps some patients did not complete the process of learning how to activate the Teres Major muscle during abduction. The change in function of the Teres Major muscle was not observed after subacromial injection of lidocaine.

Conclusion

We successfully used an isometric method of EMG to measure the principal action of rotator cuff muscles in three patients. Based on postoperative decreases in pain and improvements in range of motion, we conclude that the sole transfer of the Teres Major tendon can be successful as a primary salvage procedure for massive rotator cuff tears. The expected shift of function of the Teres Major muscle after the tendon transfer was confirmed. Normally active during adduction, the muscles were shown to be active during abduction following the tendon transfer.

Figure 4. *Representation of force measurements in the horizontal and vertical planes obtained preoperatively (A), following preoperative injection of lidocaine (B), and postoperatively (C). The same degree of pain relief and the same improvement of force in all directions were produced by both the preoperative subacromial lidocaine injection (5 mL) and the Teres Major tendon transfer (Force in N).*

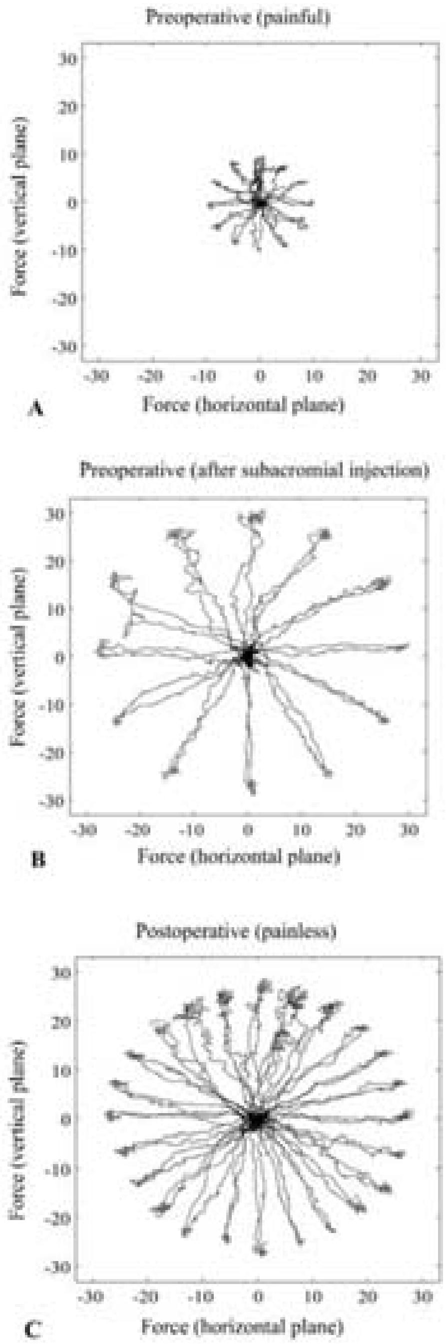
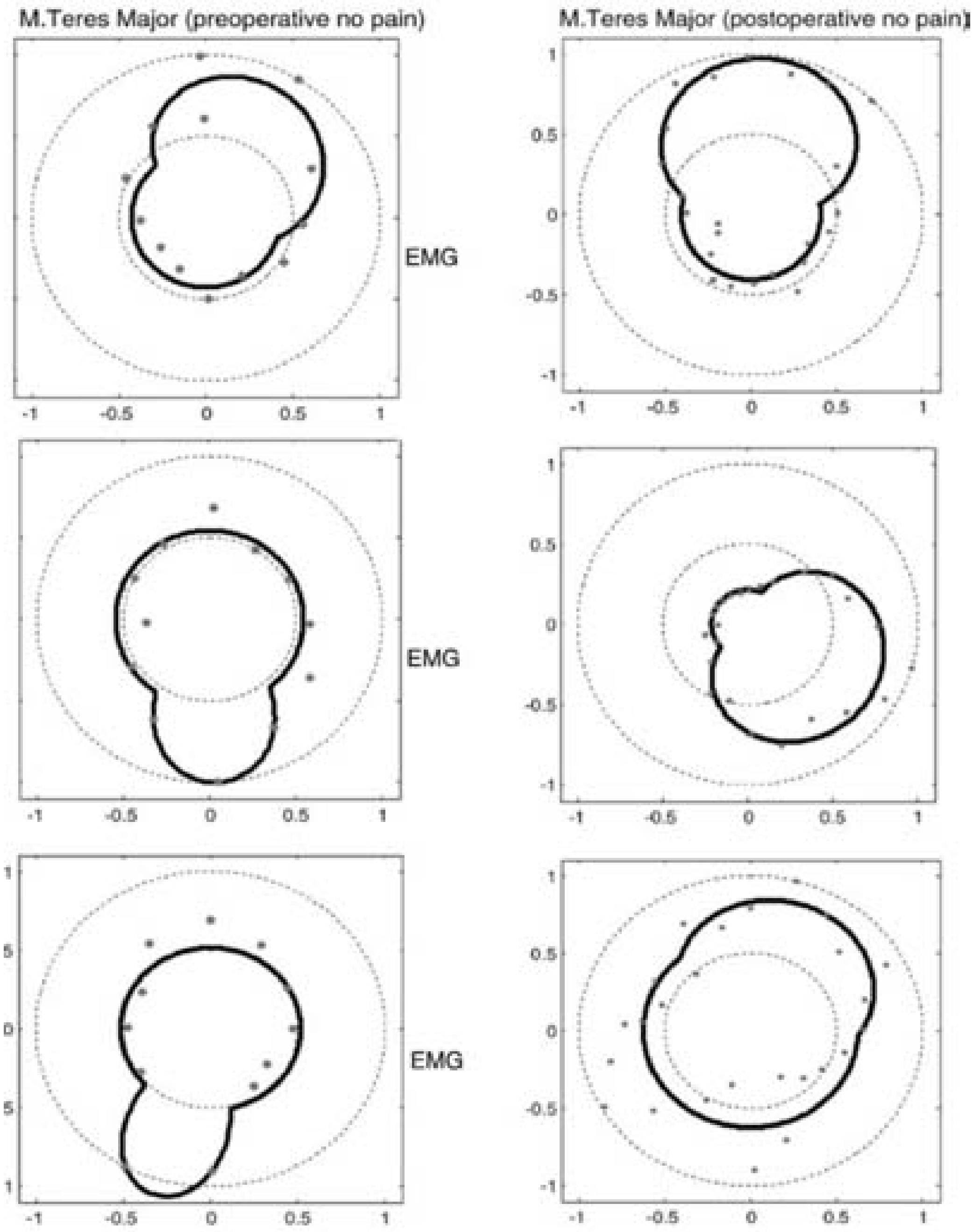


Figure 5. *Illustrations representing the principal action of the Teres Major muscle preoperatively and postoperatively. Preoperatively, the Teres Major muscle showed the most activity during adduction and retroflection. Postoperatively, the most activity was observed during abduction and forward flexion (Force in N).*



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