A BIOMECHANICAL ANALYSIS OF TENDON TRANSFER FOR A DYSFUNCTIONAL ROTATOR CUFF

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INTRODUCTION

Repair of most rotator cuff tears can be performed conventionally by suturing the muscles, although massive atrophy and large rotator cuff tears are not easily repaired. To compensate for loss of rotator cuff function other techniques like muscle transfers are developed. For the more common rotator cuff dysfunction of supraspinatus, three transfer options exist: the latissimus dorsi transfer, the teres major transfer and the transfer of both muscles.

The aim of this study is to find which transfer (latissimus dorsi, teres major or both) and what attachment site would be the most effective. Since it is impossible to test the different procedures on patients due to ethical aspects, the effects on functional outcome of the transfers will be quantified using a biomechanical musculoskeletal model of the upper extremity. Selected tendon transfer procedures were performed in the model and subsequently the ability to perform functional tasks was tested.

METHODS

Inputs to the model were the motions of the thorax, humerus, clavicle, scapula and forearm of twenty-four healthy female subjects (36.8 ± 11.8 yr.) with no history of shoulder complaints during six activities of daily living (combing hair, perineal care, lifting a 4kg bag, washing the axilla, eating with a spoon and reaching above shoulder level) and three range of motion (anteflexion, abduction and retroflexion) tasks. These upper extremity motions were measured using a six degree-of-freedom electromagnetic tracking device, the Flock of Birds (Ascension Technology Inc, Burlington, Vermont, USA).

The Delft Shoulder and Elbow Model (Van der Helm, 1994) is a finite element musculoskeletal model consisting of 31 muscles divided into 139 muscle elements. The model calculates the muscle forces required for each measured position to satisfy equilibrium and stability constraints. When the model was able to meet these constraints, the simulations were classified as successful. The success of a particular tendon transfer procedure was defined as the increase in the total number of successful simulations. Given the variation in movement patterns, this simulation procedure can be seen as a Monte Carlo simulation.

Latissimus dorsi, teres major or both were transferred in the model. Four locations for insertion were chosen: the teres minor insertion, the infraspinatus insertion, the supraspinatus insertion and the upper subscapularis insertion. It is not known what the effect of tear size is on rotator cuff force. It is assumed that a large supraspinatus tear causes a dysfunctional rotator cuff. Therefore all simulations were performed with a 100% reduction in supraspinatus force, but since it is likely that neighbouring rotator cuff muscles are also affected in case of a tear, 100 different combinations (5 levels of infraspinatus (10% - 50%) x 5 levels of teres minor (10% - 50%) x 4 levels of subscapularis (10% - 40%) of reductions in infraspinatus, teres minor and subscapularis were used. It appeared that the amount of subscapularis force did not affect the number of successful simulations, therefore each tendon transfer was only simulated with 25 different combinations of infraspinatus and teres minor force.

Differences between procedures were evaluated with a one-way ANOVA and a Bonferroni Post Hoc test.

RESULTS AND DISCUSSION

All tendon transfer procedures produced a significant improvement in the number of successful simulations. Except for the tasks that involve retroflexion all tasks improve significantly after tendon transfer. Transfers of the latissimus dorsi and lattismus dorsi combined with teres major show a 5% decrease in successful simulations after transfer. Transfer of the teres major does not show any decrease in the number of successful simulations.

The most important denominator for success of the procedure appeared to be the choice of attachment site (Figure 1). The best results were obtained by transferring the muscle or muscles to the supraspinatus or infraspinatus insertion.

Figure 1: Percentage of successful simulations in the case of a supraspinatus tear, a teres major transfer to the infraspinatus and a teres major transfer to the subscapularis insertion.

In conclusion, a tendon transfer of either latissimus dorsi, teres major or both muscles to the infraspinatus or subscapularis insertion is a very effective procedure in the case of large irreparable rotator cuff tears and strongly atrophied rotator cuff muscles. The teres major tendon transfer to the infraspinatus is the best transfer option because with 10% rotator cuff force 92% of the functional tasks could be performed, there are no limitations with respect to the retroflexion tasks and a transfer to the infraspinatus requires less stretching of the muscle, tendon, nerves and arteries. However the success of the procedure is dependent on the surgical technique and on the willingness of the patient to participate in the rehabilitation process.