Effects of Subscapularis Deficiency on Total Shoulder Arthroplasty

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INTRODUCTION

The incidence of abnormal subscapularis (SC) function after total shoulder arthroplasty (TSA) has been reported to be higher than 60% [1]. The detachment of the SC tendon during the surgical procedure and the complications related to its re-attachment are probably the causes of muscular deficiencies of the SC after TSA. Different surgical techniques are being evaluated to overcome this issue but the best way to perform the re-attachment is still controversial [2].

The muscular imbalance induced by rotator cuff tears has already been analyzed by a numerical model [3]. This model assumed a ball-socket glenohumeral (GH) joint, which prevents humeral head translation. However, translations of the humeral head are observed in vivo, and are likely to increase with deficient rotator cuff muscles.

Therefore, the aim of this work was to analyze the effect of a deficient SC on the stability of the GH joint by studying the humeral head motion and contact forces after TSA.

METHODS

A numerical musculoskeletal shoulder model was extended to simulate SC deficiency [4]. The model included 6 muscles: middle deltoid (MD), anterior deltoid (AD), posterior deltoid (PD), supraspinatus (SS), subscapularis (SC) and infraspinatus combined with teres minor (IS). Abduction in the scapular plane was simulated from 0° to 150°, using a fixed scapulo-humeral rhythm (2:1).

Variable muscular force ratios during abduction were estimated from experimental EMG measurements [5]. A constrained linear least square algorithm was developed using MatLab (www.mathworks.com) to minimize the difference between predicted and measured muscle activity. It was constrained by a system of equations that represented the mechanical equilibrium of muscle and contact forces acting on the GH joint.

A Hill model was used to link the muscle activity to the muscle force. Isometric force-length relationship, physiological cross sectional area (PCSA), maximum muscle force, optimal muscle length, and tendon slack length were estimated from literature [6,7].

An anatomical total shoulder prosthesis (Acqualis, Tornier) was virtually positioned in the shoulder by a senior surgeon. Bone, cement and polyethylene were assumed elastic while metallic parts were rigid.

Two cases were compared: TSA with a normal muscular function, and TSA with a partial SC deficiency. The partial SC deficiency was simulated by decreasing its normal PCSA by 50%. We evaluated the muscular forces, the translation of the humeral head, the articular contact pressure, the von Mises stress in the polyethylene component and the maximum principal stress within the cement mantle. The numerical analysis was achieved with Abaqus 6.9 (www.simulia.com).

RESULTS

SC deficiency induced a lower (41%) IS muscle force to satisfy equilibrium of the arm in the scapular plane. It also induced a higher (8%) MD force which was needed to compensate for the loss of muscular elevation torque. In overall, the muscular activation pattern with a deficient SC induced a more vertical muscular force resultant.

DISCUSSION

As a consequence, SC deficiency increased the upward migration of the humeral head by 0.5 mm and induced a posterior translation of 0.3 mm (Fig. 1).

It also induced a more eccentric (superior-posterior) GH contact pattern (Fig. 2) and increased the maximal/average contact pressure (29/11 vs. 27/10 MPa). Stress increased by 18% within the polyethylene glenoid component and by 20% within the cement mantel.

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REFERENCES