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Nerve stress during reverse total shoulder arthroplasty: a cadaveric study

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Background: Neurologic lesions are relatively common after total shoulder arthroplasty. These injuries are mostly due to traction. We aimed to identify the arm manipulations and steps during reverse total shoulder arthroplasty (RTSA) that affect nerve stress.
Methods: Stress was measured in 10 shoulders of 5 cadavers by use of a tensiometer on each nerve from the brachial plexus, with shoulders in different arm positions and during different surgical steps of RTSA.
Results: When we studied shoulder position without prostheses, relative to the neutral position, internal rotation increased stress on the radial and axillary nerves and external rotation increased stress on the musculocutaneous, median, and ulnar nerves. Extension was correlated with increase in stress on all nerves. Abduction was correlated with increase in stress for the radial nerve. We identified 2 high-risk steps during RTSA: humeral exposition, particularly when the shoulder was in a position of more extension, and glenoid exposition. The thickness of polyethylene humeral cups used was associated with increased nerve stress in all but the ulnar nerve.
Conclusion: During humeral preparation, the surgeon must be careful to limit shoulder extension. Care must be taken during exposure of the glenoid. Extreme rotation and oversized implants should be avoided to minimize stretch-induced neuropathies.
Level of evidence: Basic Science Study; Biomechanics

Keywords: Nerve stress; brachial plexus injury; neurologic complications; reverse total shoulder arthroplasty; shoulder position; cadaveric study

Neurologic lesions in the context of total shoulder arthroplasty (TSA) are poorly documented.[3,11,13,15] The incidence of these lesions was estimated at 1% in a literature review conducted by Bohsali et al.[3] However, the vulnerability of the brachial plexus during the operation is probably

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underestimated. In a systematic review, Lynch et al[13] reported 18 shoulders with neurologic deficits during 417 shoulder arthroplasties (4%). Using continuous intraoperative nerve monitoring by electromyography, Nagda et al[15] recorded nerve dysfunction in 17 of 30 patients.

Nerve topography and its anatomic variations have been well specified to prevent iatrogenic risks.[1,14] Nevertheless, some authors have emphasized that the nerve topography could change during range of motion of the shoulder and surgical procedures.[2,4,5] These changes could increase the risk of nerve injury. Neurologic lesions during shoulder surgery are more likely due to indirect mechanisms.[8] Nerves from the brachial plexus can undergo stretching when they reach their mobility limits. These phenomena were illustrated in studies assessing the adverse effects of patient postures under general anesthesia. Using finger palpation, Jackson and Keats[9] subjectively evaluated the tension on the nerves of the brachial plexus in a cadaveric study. They highlighted the deleterious effects of different postures in abduction, external rotation, and extension. Coppieters et al[7] showed that abduction and external rotation of the shoulder combined with elbow extension induced substantial discomfort for subjects. They concluded that this posture produced increasing strain on the brachial plexus. During TSA, some steps such as the preparation of the glenoid and humerus have been suggested to result in neurologic lesions.[13,15] Moreover, reverse TSA (RTSA) is more prone to brachial plexus palsies, probably because of the lengthening effect.[11,17]

We aimed to evaluate variations in stress on nerves by using a tensiometer in the terminal branches of the brachial plexus in different arm positions of cadavers to highlight the effects of extension, abduction, and rotation. We also aimed to identify high-risk surgical steps that could lead to nerve stress during RTSA and the effect of joint lengthening.

Materials and methods

Anatomic preparation

We used 10 shoulders in 5 fresh-frozen cadavers (mean age at time of death, 77.6 years; range, 71-88 years). Cadavers were thawed at room temperature for 48 hours before experimentation to avoid soft-tissue stiffness. None of the upper limbs showed evidence of previous surgical procedures. Cadavers were placed in the beach-chair position, with the trunk at a 45° angle to the horizontal plane. The brachial plexus was exposed via an extensive deltopectoral approach combining a release of the pectoralis major from its humeral insertion and the pectoralis minor from the coracoid process to allow for positioning of a tensiometer (FK 50T; Sauter, Balingen, Germany). The 5 main branches of the brachial plexus to the arm (axillary, radial, median, musculocutaneous, and ulnar nerves) were carefully dissected distal to the brachial plexus cords. These branches were released from the periplexus adipose tissue and from minor adhesive attachments to the muscle to allow for positioning of the tensiometer to measure stress on each nerve (Fig. 1). No further release of the muscle insertion was necessary for positioning this device. Care was taken to limit dissection to the minimum necessary for placement of the tensiometer.

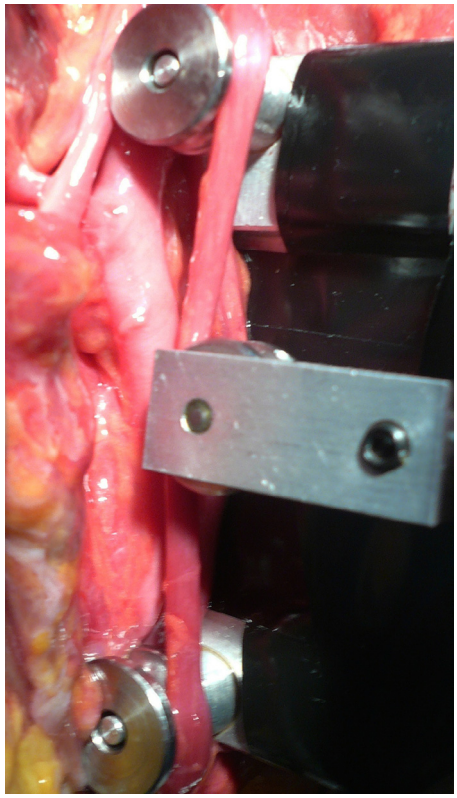

Figure 1 Tensiometer measurement of stress on nerves of cadaveric shoulder undergoing reverse total shoulder arthroplasty.

Effect of shoulder position in anatomic condition

Before the RTSA procedure, we measured nerve stress in different shoulder positions (Table I). Extension was evaluated only with 60° of external rotation with reference to the positions conventionally used during humeral exposition. The other measured positions were those most likely to be used during glenoid exposure, starting with the neutral position of 0° of flexion, 0° of rotation, and 0° of abduction. Nerve tension was separately analyzed for extension, internal rotation, external rotation, and abduction to evaluate the role of each of these positions on nerve stress.

Effect of RTSA procedure

A senior surgeon (H.L.) performed the RTSA procedure (Delta Xtend; DePuy Synthes, Raynham, MA, USA). Measurements were performed during 5 potential high-level stress steps (Fig. 2): In step 1, the retractor was placed between the anterior deltoid muscle and conjoined tendon with the shoulder in a neutral position. In step 2, dislocation of the humeral head was performed by a combination of adduction, maximal external rotation, and 45° of extension (humeral shaft vertically). In step 3, dislocation of the humeral head was performed by a combination of adduction, maximal external rotation, and 60° of extension. In step 4, glenoid exposure (after humeral head resection) was performed by using a forked retractor placed on the