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ORIGINAL ARTICLE

Dynamic contrast-enhanced ultrasound and elastography assess deltoid muscle integrity after reverse shoulder arthroplasty

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Background: The outcome after reverse shoulder arthroplasty (RSA) depends on the condition of the deltoid muscle, which we assessed with new ultrasound modalities and electromyography (EMG). Contrast-enhanced ultrasound (CEUS) and acoustic radiation force impulse (ARFI) were applied to assess perfusion and elasticity of the deltoid muscle compared with the clinical and functional outcome.

Methods: The study recruited 64 patients (mean age, 72.9 years) treated with RSA between 2004 and 2013. The deltoid muscle was examined with EMG and ultrasound imaging. Functional scores such as Constant score and American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form score were assessed. Among other CEUS parameters, the wash-in perfusion index, time to peak, and rise time were compared between the operated-on and contralateral shoulders as well as between patients with above-average and below-average outcome. The stiffness of the deltoid muscle was analyzed with ARFI.

Results: After RSA, deltoid perfusion (wash-in perfusion index, $\Delta = -12\% \pm 22\%$, $P = .0001$) and shoulder function (Constant score, $\Delta = -14 \pm 24$, $P < .0001$) were both inferior compared with the contralateral side. This perfusion deficit was associated with a limited range of motion (time to peak and anteversion: $r = -0.290$, $P = .022$). Deltoid perfusion was higher in patients with above-average outcome (rise time, $\Delta = 33\% \pm 13\%$, $P = .038$). The operated-on deltoid muscles showed higher stiffness than the contralateral muscles (ARFI, $\Delta = 0.2 \pm 0.9$ m/s, $P = .0545$). EMG excluded functionally relevant axillary nerve injuries in the study population.

Conclusions: CEUS revealed reduced mean perfusion of the deltoid muscle after RSA. Reduced perfusion was associated with limited range of motion and below-average outcome. Functional shoulder impairment after RSA might be predicted by noninvasive CEUS as a surrogate parameter for the integrity of the deltoid muscle.

This study was approved by the Medizinische Fakultät Heidelberg Ethics Committee (S-626/2014) and was conducted in accordance with the Declaration of Helsinki.

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Current reverse shoulder arthroplasty (RSA) was developed by Grammont et al[5] in the 1980s to treat cuff tear arthropathy (CTA). Reverse designs had been developed previously, with less success. Inversion of the glenohumeral joint combined with a medial shift of the rotational center and lengthening of the humerus increases tension on the deltoid muscle which enables the deltoid muscle to compensate for a deficient rotator cuff.[7,8,20] Consequently, partial functional restoration of the shoulder is achieved. In case of pseudoparalytic shoulders with CTA and a functional deltoid, alternative surgical methods, such as arthroscopic débridement,[9,10] arthrodesis,[12] resection,[11] or arthroplasty[4,34] are inferior. RSA is therefore the treatment of choice in CTA.[28,31]

Deltoid muscle functionality is highly relevant for the success of treatment after RSA.[17] However, RSA strains the deltoid muscle,[20] with the risk of acute and chronic traction injury to muscles and nerves in addition to the damage caused by the standard deltopectoral approach for exposure of the proximal humerus.[17,20,33] Fatty atrophy and damage to the deltoid muscle might evolve and negatively affect clinical and functional outcome after RSA, among other factors.[17,29,30]

Since the first guidelines in 2004,[2] the use of dynamic CEUS has spread rapidly in clinical routine. The current 2011 guidelines of the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB)[25] introduced CEUS in nonhepatic applications. It can be used to assess the vitality of muscle tissue[1,21] because the perfusion of the muscle correlates with the amount of newly recruited muscle.[27] Contrary to magnetic resonance imaging and computed tomography, the cost-effective CEUS can be safely used in patients with renal impairment, without ionizing radiation and fear of claustrophobia. Moreover, it is easily accessible, quick to use, well tolerated by patients, and allows a real-time diagnostic workup.

The SonoVue contrast agent (Bracco Imaging, Milan, Italy) used for the CEUS examination consists of sulfur hexafluoride bubbles with a phospholipid shell and is considered to be very safe, with a low incidence of adverse effects (complication rate <0.001%).[24] The SonoVue microbubbles are almost as large as erythrocytes and therefore remain intravascular in the capillary beds. They are visualized by the Cadence (Siemens Medical Solutions USA, Inc, Malvern, PA, USA) contrast mode of the ultrasound device and thus provide information about muscle microperfusion not available from other imaging modalities.[26] The elasticity of the deltoid muscle was visualized with acoustic radiation force impulse imaging (ARFI).[13]

The aim of this study was to correlate quantitative ultrasonographic parameters (size, elasticity, microcirculation) of the deltoid muscle with the clinical, functional, psychosocial, and neurophysiologic outcome after RSA. If CEUS were able to assess the vitality of the deltoid muscle, it could be used as a surrogate parameter to monitor the influence of operative techniques and postoperative treatment on the deltoid integrity.

Materials and methods

Patient population and study protocol

This pilot study was designed as a cross-sectional study to investigate a little known topic. The study enrolled 65 patients who received RSA between 2004 and 2013 at our institution. All participants were in accord with the study protocol and gave their written informed consent before any study-relevant intervention.

Patients were excluded if there was a history of recent myocardial infarction, severe respiratory disease, known allergic reaction to SonoVue, or any previous surgery of the contralateral shoulder.

Because this was a cross-sectional study and preoperative scores were not completely available or possible (RSA as fracture treatment), the results of the clinical, functional, neurologic, and ultrasonographic evaluation were compared with the contralateral shoulder and between groups.

Surgical technique

RSA was performed through a deltopectoral standard approach in the beach chair position by 5 orthopedic and trauma consultants at our hospital. Fukuda retractors were used to expose the glenoid. The approach did not change over time. Postoperative rehabilitation included a shoulder abduction sling for 6 weeks with immediate mobilization, except for abduction and anteversion above 90° as well as external rotation.

Clinical, functional, and psychosocial evaluation

We assessed the range of motion (ROM) for both shoulders and used the following questionnaires to determine functional and psychosocial outcomes:

- the Constant score normalized after Katolik et al,[19] with shoulder-specific objective and subjective criteria on a scale of 0 to 100 (with 100 representing the best function);
- the American Shoulder and Elbow Surgeons (ASES) Standardized Shoulder Assessment Form that focuses on activities of daily living on a scale of 0 to 100 (with 100 representing the best quality of activities of daily living)[3];
- the Disabilities of the Arm, Shoulder and Hand (DASH), which measures the symptoms and functional disability of the upper extremity on a scale of 0 to 100 (with 100 being no function and maximal symptoms)[3];