J Shoulder Elbow Surg (2016) 25, 881–889

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

# Three-dimensional shoulder kinematics normalize after rotator cuff repair

**Arjen Kolk, MD[a,b,*], Pieter Bas de Witte, MD, PhD[a,b], Jan Ferdinand Henseler, MD[a,b], Erik W. van Zwet, PhD[c], Ewoud R.A. van Arkel, MD, PhD[d], Peer van der Zwaal, MD, PhD[d], Rob G.H.H. Nelissen, MD, PhD[a], Jurriaan H. de Groot, PhD[b]**

[a]*Department of Orthopaedics, Leiden University Medical Center, Leiden, The Netherlands*
[b]*Laboratory for Kinematics and Neuromechanics, Department of Orthopaedics and Rehabilitation, Leiden University Medical Center, Leiden, The Netherlands*
[c]*Department of Medical Statistics and Bioinformatics, Leiden University Medical Center, Leiden, The Netherlands*
[d]*Department of Orthopaedic Surgery, Medical Center Haaglanden, The Hague, The Netherlands*

**Background:** Patients with a rotator cuff (RC) tear often exhibit scapular dyskinesia with increased scapular lateral rotation and decreased glenohumeral elevation with arm abduction. We hypothesized that in patients with an RC tear, scapular lateral rotation, and thus glenohumeral elevation, will be restored to normal after RC repair.

**Methods:** Shoulder kinematics were quantitatively analyzed in 26 patients with an electromagnetic tracking device (Flock of Birds) before and 1 year after RC repair in this observational case series. We focused on humeral range of motion and scapular kinematics during abduction. The asymptomatic contralateral shoulder was used as the control. Changes in scapular kinematics were associated with the gain in range of motion. Shoulder kinematics were analyzed using a linear mixed model.

**Results:** Mean arm abduction and forward flexion improved after surgery by 20° (95% confidence interval [CI], 2.7°-36.5°; $P = .025$) and 13° (95% CI, 1.2°-36.5°; $P = .044$), respectively. Kinematic analyses showed decreases in mean scapular protraction (ie, internal rotation) and lateral rotation (ie, upward rotation) during abduction by 3° (95% CI, 0.0°-5.2°; $P = .046$) and 4° (95% CI, 1.6°-8.4°; $P = .042$), respectively. Glenohumeral elevation increased by 5° (95% CI, 0.6°-9.7°; $P = .028$) at 80°. Humeral range of motion increased when scapular lateral rotation decreased and posterior tilt increased.

**Conclusions:** Scapular kinematics normalize after RC repair toward a symmetrical scapular motion pattern as observed in the asymptomatic contralateral shoulder. The observed changes in scapular kinematics are associated with an increased overall range of motion and suggest restored function of shoulder muscles.

The Medical Ethical Committee of Zuidwest Holland (07.116) and the Ethical Review Board of Leiden University Medical Center (P10.026) approved this study.

*Reprint requests: Arjen Kolk, MD, Department of Orthopaedics, Leiden University Medical Center, Postzone J-11-R, PO Box 9600, NL-2300 Leiden RC, The Netherlands.

E-mail address: a.kolk@lumc.nl (A. Kolk).

1058-2746/$ - see front matter 
http://dx.doi.org/10.1016/j.jse.2015.10.021

**Level of evidence:** Level IV; Case Series; Treatment Study

**Keywords:** Rotator cuff; shoulder; kinematics; tears; movement; kinesiology; surgery

Rotator cuff (RC) tears have a prevalence ranging from 20% to 50% in the general population and frequently lead to pain, deficits in shoulder function, and deprived quality of life.[26,34] If conservative treatment (eg, nonsteroidal anti-inflammatory drugs and physical therapy) fails, surgical repair of the RC is a widely used therapeutic option. The number of RC repairs has increased over the past decade because the procedure is generally considered to relieve pain and to effectively restore shoulder function.[6,21,29]

Healthy shoulder function depends on a perfect balance between arm mobility and glenohumeral stability.[30] In patients with a full-thickness RC tear, the balance is disrupted because the affected RC muscle is incapable of exerting sufficient forces on the humerus. As a result, deltoid muscle activity increases to compensate for lost RC forces; this, in turn, will cause additional cranially directed forces on the humerus.[4,13,27] These forces pull the humerus in a more cranial position relative to the glenoid, introducing translation within the glenohumeral joint.[3,7] Clinically, lost RC muscle functionality coincides with pain and reduced elevation of the arm. It has been postulated that lost glenohumeral motion is generally compensated for by an increase in scapular lateral rotation.[14,15] The latter is clinically observed in patients with a RC tear as asymmetry of scapular motion with increased scapulothoracic lateral rotation of the affected side.[14,15,23,28]

Theoretically, RC repair should increase glenohumeral elevation because of the restored insertion of the tendinous part of the RC muscles with subsequent normalization of forces and glenohumeral moment. Observation of shoulder motion before and after RC repair may partly elucidate the observed functional gain. Shoulder motion can be measured quantitatively with 6 *df* by a 3-dimensional (3D) electromagnetic system.[1,9,10,12,16,19,31] However, evaluations of preoperative and postoperative 3D shoulder motion in RC repair with an electromagnetic system have not been published so far. The purpose of this study is to assess 3D shoulder motion in patients before and after RC repair. We hypothesize that after RC repair, arm elevation increases, glenohumeral elevation increases, and scapular lateral rotation decreases. Thus scapulothoracic kinematics normalize toward the scapular motion of the asymptomatic contralateral shoulder.

## Materials and methods

### Participants

From March 2010 to April 2011, patients scheduled for RC repair at a secondary referral center (Medical Center Haaglanden, The Hague, The Netherlands) were evaluated for eligibility in this observational case series. Patients with complaints of a repairable degenerative full-thickness supraspinatus RC tear or full-thickness supraspinatus and infraspinatus RC tear were included. The RC tear was confirmed with magnetic resonance arthrography or computed tomography arthrography. The exclusion criteria were cervical radiculopathy, glenohumeral instability, history of a fracture in the shoulder region, muscle dystrophy, glenohumeral or symptomatic acromioclavicular osteoarthritis, rheumatoid arthritis, previous surgery on the shoulder, restriction in passive shoulder motion (ie, frozen shoulder), and insufficient Dutch-language skills. In addition, patients with bilateral shoulder complaints were excluded.

Patients with an RC tear were invited to the Laboratory for Kinematics and Neuromechanics (Leiden University Medical Center, Leiden, The Netherlands) for 3D electromagnetic motion analysis, clinical evaluation including the Western Ontario Rotator Cuff (WORC) index,[8] and assessment of shoulder muscle activity. The assessment of muscle activity has been previously reported.[4] One year after surgery, participants were invited to undergo a follow-up visit. Thirty-eight patients with an RC tear were eligible for the assessment of shoulder kinematics. Patients who underwent preoperative and postoperative motion analysis were included in this analysis (n = 26). Twelve patients were excluded from analysis because of a technical error (n = 3) or missing baseline measurements (n = 9). Ultrasound was used to evaluate RC integrity after the conducted RC repair. Written informed consent was obtained from every participating individual.

### Surgical procedure

All surgical procedures were performed at the Medical Center Haaglanden by 1 of 2 orthopedic surgeons (E.R.A.v.A. or P.v.d.Z.) with extensive experience in the field of RC repair. Either a mini-open or arthroscopic surgical approach was performed according to the surgeon's personal preference. All patients received general anesthesia and were placed in the lateral decubitus position. The RC was inspected, and the tear was debrided. A bleeding surface was created at the insertion site on the supraspinatus footprint. The RC was repaired using a double-row suture bridge technique. One or two 5.5-mm Corkscrew anchors (Arthrex, Naples, FL, USA) were used for the medial row depending on the size of the RC tear. Similarly, one or two 3.5-mm knotless Bio-PushLock anchors (Arthrex) were used for the lateral row. Postoperatively, the arm was placed in an immobilizing arm sling. Patients followed a standardized rehabilitation protocol under the supervision of a physical therapist. The physical therapist