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Long-term clinical outcomes, motion, strength, and function after total claviculectomy

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Background: Total excision of the clavicle is rarely performed. No previous study has documented long-term outcomes with objective measurements of strength, motion, and patient-centered outcomes. We present the long-term consequences of total claviculectomy on shoulder girdle function, global upper extremity function, and overall general health.
Methods: Five total claviculectomy patients were evaluated at 2 time points (2005 and 2010, mean 4.8 and 9.4 years postoperatively) by use of the DASH, SF-36, Simple Shoulder Test, ASES, UCLA, HSS, and Constant shoulder scores. Isokinetic strength, clinical range of motion, and kinematic analysis were performed on each limb pair.
Results: All clinical scores allowing side-to-side comparison were poorer for the aclaviculate side, with significance reached for 2005 ASES scores and 2010 ASES, UCLA, HSS, and Constant scores. DASH scores and SF-36 scores were not significantly inferior to age- and sex-matched population norms. Deficits in strength were present in the aclaviculate limbs, with significance reached for adduction in 2005 and for forward flexion and external rotation in 2010. Kinematic and clinical range of motion analysis revealed scapular dyskinesis and significant deficits in external rotation in the aclaviculate limb.
Conclusions: We found that the clavicle contributes to the strength, coordinated scapulohumeral rhythm, and overall range of motion of the shoulder girdle. Patients compensate for loss of the clavicle with minimal functional deficit. With time, patients gradually lose some compensatory ability as evidenced by deteriorating limb-specific, patient-centered outcome measures, diminished strength in certain planes of shoulder motion, and scapular dyskinesis at long-term follow-up. Despite objective deficits, these patients continue to have normal self-perceptions of overall health and global upper extremity function.
Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Claviculectomy; shoulder kinematics; scapular dyskinesis; clavicle function; clavicle excision

This study, CHRMS 05-034, was approved by the Institutional Review Board (IRB) of the University of Vermont College of Medicine.

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The function of the clavicle has been described as 3-fold: (1) to protect the underlying neurovascular structures, (2) to provide a rigid point of attachment for muscles, and (3) to serve as a strut to support the scapula.[16]

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However, the bone's function as a strut and its importance to the functionality of the human shoulder girdle have been the subjects of debate, and conclusions about this issue are based mostly on anecdotal findings.[7,9,10,13,23,33] Some authors reject the role of the clavicle as a prop or strut altogether, advocating that it is a disposable bone.[9,10,13,16] This debate has been waged largely over theories generated by cadaveric studies and in vivo clinical observations with sparse objective data reported. Cases of the rare, hereditary disease cleidocranial synostosis have also been cited in this context.[9,10,16] However, no comprehensive analysis including objective measurements of strength, range of motion, and kinematics of the shoulder has been reported to support or to refute the argument that humans can function well without clavicles.

Total claviculectomy is rarely performed despite diverse published indications, including osteomyelitis, severely comminuted fracture, fracture nonunion, and unipolar or bipolar dislocation of the clavicle; vascular injury or compression in the thoracic outlet; adjunct to surgical collapse of the chest wall; adjunct to surgical glenohumeral fusion; surgical exposure of the brachial plexus and great vessels at the root of the neck; and to facilitate an anterior approach to the thoracic vertebrae.[6,12,22,29,31,34,41] In modern medicine, claviculectomy is used as a salvage procedure when the normal osseous anatomy of the clavicle cannot be restored or reconstructed, as in the setting of life- or limb-threatening disease without viable conservative treatment options.[22] Regardless of specific indications, claviculectomy patients offer a unique opportunity to study the effects of clavicle removal and to gain insight into the role of the clavicle in shoulder function. The purpose of this study was to obtain a comprehensive and objective evaluation of the range of motion (ROM), strength, kinematics, function, and patient-centered outcomes in a case series of total claviculectomy patients with a normal contralateral shoulder to serve as a control.

Methods

Conforming to a protocol approved by the Institutional Review Board, we identified 11 patients who had undergone total claviculectomy between 1998 and 2003 at our institution under the care of a vascular surgeon (S.S.) for vascular compromise as a result of a closed clavicular fracture. Two patients were lost to follow-up and 4 patients were ultimately disqualified from our study on examination: one was diagnosed with an ipsilateral long thoracic nerve palsy requiring scapulothoracic fusion; the second was found to have a contralateral, symptomatic clavicle nonunion; the third had a chronic massive rotator cuff tear with anterior-superior instability of the contralateral shoulder; and the fourth patient was unable to participate in a second round of testing because of an acute contralateral rotator cuff tear requiring surgical repair. Thus, 6 claviculectomy patients (1 woman and 5 men; mean age at initial follow-up: 51.5 ± 8.3 years; range, 39-59 years) with a healthy contralateral shoulder were included in the first round of testing (2005), and 5 patients (1 woman and 4 men; mean age at final follow-up: 57.8 ± 8.8 years; range, 44-64 years) completed the second round of testing (2010). Of these 5 patients, 4 underwent total claviculectomy with subclavian vessel decompression, and 1 underwent total claviculectomy and subclavian artery reconstruction after a pseudoaneurysm formed as the result of screw perforation from a prior open reduction and internal fixation of a clavicle fracture and the patient presented with pain and embolic phenomena distally. In all cases, subperiosteal removal of the clavicle was performed, and the periosteal sleeves containing the muscle attachments of the sternocleidomastoid, trapezius, deltoid, and pectoralis major were repaired longitudinally. The clavicle did not re-form after this surgery as was radiographically documented.

Subjects were evaluated in 2005 (4.8 ± 2.5 [range, 1.3 to 7.3] years after total claviculectomy) and in 2010 (9.4 ± 2.8 [range, 6.4 to 13.0] years after total claviculectomy). Data collected included validated patient assessment tools: the American Shoulder and Elbow Surgeons (ASES)[32] shoulder score; University of California, Los Angeles (UCLA)[5,11] shoulder score; Simple Shoulder Test (SST)[25]; Hospital for Special Surgery (HSS)[4,27] shoulder score; Disabilities of the Arm, Shoulder and Hand (DASH)[14] score; and Medical Outcomes Study 36-Item Short Form (SF-36).[30] In addition, 2010 data collection included calculation of a Constant[8] score.

Active shoulder kinematics was mapped digitally. Data were averaged over 4 trials for forward flexion/extension, shoulder adduction/abduction from neutral (in the thoracic and scapular planes), external rotation (ER) starting with the hand on the abdomen, internal rotation (IR) to the highest reachable posterior thoracic spinous process, and cross-body adduction. The position and orientation of the thorax, scapula, and humerus were tracked independently by electromagnetic motion sensors (miniBIRD 800, Ascension Technology, Milton, VT, USA). Sensor positions were referenced to digitally mapped bone landmarks relative to a stationary base sensor with patients in a neutral anatomic stance. The proximal humerus was located by the center of rotation method.[37] Euler angle rotations and joint translations were described by the consensus definitions of the International Shoulder Group.[39]

In 2010, the computer-generated data mapping scapular position became corrupted and impossible to interpret. Goniometer measurements of bilateral glenohumeral ROM were then substituted for the electromagnetic motion studies and included forward flexion, extension, elevation in the scapular plane, abduction, and cross-chest adduction. IR and ER were measured at 0° and 90° of abduction and with the arm at the side.

Concentric shoulder and accessory muscle strength was tested bilaterally with the Biodex System 3 isokinetic dynamometer (Biodex Medical, Shirley, NY, USA) at a speed of 60°/second according to System 3 Pro application/operation manual protocol.[36] Biceps and triceps strength was tested from 0° to 160° of flexion of the elbow. Strength of shoulder forward flexion, adduction, and abduction in the frontal and scapular planes was assessed through a range from approximately 0° to 160°. Strength of IR and ER was tested through a comfortable range with the limb placed in a neutral position at 50° of abduction. In addition, the 2010 data set included testing of IR and ER strength with the limb in 90° of abduction. After 5 warm-up trials, the peak torque (N-m) generated during 5 maximal-effort trials was averaged and normalized to 2005 self-reported body weight for each subject.