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Adolescent clavicle nonunions: potential risk factors and surgical management

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Background: Clavicle nonunions in adolescent patients are exceedingly rare. The purpose of this study was to evaluate a series of clavicle nonunions from a pediatric multicenter study group to assess potential risk factors and treatment outcomes.

Methods: A retrospective review of all clavicle nonunions in patients younger than 19 years was performed at 9 pediatric hospitals between 2006 and 2016. Demographic and surgical data were documented. Radiographs were evaluated for initial fracture classification, displacement, shortening, angulation, and nonunion type. Clinical outcomes were evaluated, including rate of healing, time to union, return to sports, and complications. Risk factors for nonunion were assessed by comparing the study cohort with a separate cohort of age-matched patients with a diaphyseal clavicle fracture.

Results: There were 25 nonunions (mean age, 14.5 years; range, 10.0-18.9 years) identified, all of which underwent surgical fixation. Most fractures were completely displaced (68%) initially, but 21% were partially displaced and 11% were nondisplaced. Bone grafting was performed in 24 of 25 cases, typically using the hypertrophic callus. Radiographic healing was achieved in 96% of cases. One patient (4%) required 2 additional procedures to achieve union. The primary risk factor for development of a nonunion was a previous history of an ipsilateral clavicle fracture.

This study was approved by the University of California, San Diego, Human Research Protections Program: No. 151076.

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Conclusions: Clavicle nonunions can occur in the adolescent population but are an uncommon clinical entity. The majority occur in male patients with displaced fractures, many of whom have sustained previous fractures of the same clavicle. High rates of union were achieved with plate fixation and the use of bone graft.

Level of evidence: Level III; Retrospective Cohort Design; Treatment Study

Keywords: Clavicle; nonunion; clavicle fracture; clavicle refracture; pediatric; adolescent

The clavicle is one of the most commonly fractured long bones in the pediatric population, with an annual incidence of 13-19 fractures per 10,000 children younger than 16 years.[11] Traditional management of these injuries in both children and adults has been nonoperative, with low complication rates.[8] Recent adult literature, however, has shown that nonunions are not as rare as previously published and may be as high as 15% in cases of displaced fractures.[12] Multiple studies have now shown that a potential benefit of surgical stabilization of displaced clavicle fractures in adults is a more predictable union rate.[5] Although this potential benefit of surgical treatment may be applicable to the adult population, clavicle nonunions in the pediatric and adolescent population remain an exceedingly rare complication. To date, fewer than 15 cases have been documented in the literature, with half of these representing single case reports.[1,2,4,10,13-16] In 2012, a multicenter study group was formed to study adolescent clavicle fractures in an attempt to optimize treatment for these younger patients. The purpose of this study was to evaluate a series of clavicle nonunions from 9 pediatric hospitals to assess potential risk factors and treatment options.

Materials and methods

Retrospective data were collected on all clavicle nonunions treated at 9 pediatric hospitals between 2006 and 2016. Patients were included if they were 18 years old or younger and were diagnosed with a diaphyseal clavicle nonunion, defined as failure of radiographic bone bridging 6 months or longer after injury. Fractures lateral to the attachment site of the coracoclavicular ligament or involving the sternoclavicular joint were excluded. In addition, patients with a congenital pseudarthrosis of the clavicle were excluded. All patients identified underwent surgical treatment of the nonunion. Preoperative demographic and clinical variables were documented, including age of the patient at the time of injury, gender, laterality, hand dominance, mechanism of injury, primary sport, and treatment of the fracture preceding the nonunion. More specific nonunion risk factors were also investigated, including prior clavicle fractures, previous clavicle surgery, smoking history, and diabetes.

Radiographs were reviewed by attending orthopedic surgeons at each site, all of whom are members of the previously mentioned adolescent clavicle fracture research study group. This study group had developed a series of standardized radiographic measurement techniques and definitions, which were used to evaluate the radiographs. Skeletal maturity was assessed on the injury films, based on the proximal humerus physis being open or closed. Each fracture was classified using the AO (*Arbeitsgemeinschaft für Osteosynthesefragen*) classification and was additionally classified as completely displaced (defined as no cortical contact between 2 or more fracture fragments), partially displaced or angulated (defined as having fracture ends in contact but with either angulation between fragments or superior-inferior displacement at both cortices), or nondisplaced or minimally displaced (defined as showing no step-off between cortices). Fracture shortening among completely displaced fractures was measured using 2 different techniques to reflect the variability of approaches currently used in clinical practice or described in the literature.[7] End-to-end shortening was measured from the ends of the fracture fragments that were at the greatest distance from each other. Cortex–to–corresponding cortex shortening was measured from the ends of the fracture fragments that would be apposed if the fracture were anatomically reduced. Superior to inferior fracture displacement was measured in millimeters. Fracture angulation was measured as the maximal deformity between the medial and lateral fragments measured in degrees. The time from the initial injury to the diagnosis of the nonunion was documented, and all of the nonunions were classified on the basis of their radiographic appearance: hypertrophic, oligotrophic, or atrophic.

Intraoperative variables were recorded for the surgeries performed to treat the nonunions, including type of fixation (plate vs. intramedullary device), use of bone graft (defined as local/clavicle callus/autograft, iliac crest cancellous autograft, or allograft), and any intraoperative complications. When a plate was used, its length (number of screw holes), size (screw size), precontouring, and position (superior or anterior) were recorded. Postoperative clinical course was detailed, including length of follow-up, rate of union (defined as advanced radiographic bone bridging on 3 or more cortices), time to union, return to sports, use of physical therapy, range of motion deficits, need for implant removal, and postoperative complications.

To identify potential risk factors for nonunion, the demographic and clinical variables of the nonunion study population (n = 25) were subsequently compared with tabulated data from a large population of adolescent diaphyseal clavicle fractures (n = 545) from the Function after Adolescent Clavicle Trauma and Surgery (FACTS) prospective, multicenter cohort study with similar patient ages represented. Meta-analytic statistical methodology was used to compare variables from both study populations (current cohort of nonunions vs. the FACTS database). Analysis of variance from summary data was used for the continuous variables, and χ^2 test was employed with the categorical variables. The α was set at $P < .05$ to declare significance.

Results

Twenty-five patients with clavicle fracture nonunions were identified, with a mean age of 14.5 years (range, 10.0-18.9 years) (Table I). No records of patients with a clavicle fracture