Surgical Treatment for Avulsion Injuries of the Humeral Lesser Tuberosity Apophysis in Adolescents

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Background: There is little published information regarding avulsion fractures of the humeral lesser tuberosity in adolescents, and no consensus exists on optimal treatment. The purpose of this study was to investigate the demographics, injury mechanisms, and results of operative treatment of lesser tuberosity avulsion fractures in skeletally immature patients.

Methods: Eight patients were treated with open reduction and internal fixation (ORIF) for lesser tuberosity avulsion fractures from 2000 through 2010. Data were collected regarding patient demographics, mechanisms of injury, operative findings, and early clinical results. Preoperative radiographic studies were evaluated, and patient-derived functional outcome scores were obtained. The mean age of the patients was 13.3 years. All patients were male and sustained sports-related injuries, typically from forceful shoulder abduction and external rotation with eccentric subscapularis load. The dominant extremity was injured in six patients. Six patients had initial radiographs that were interpreted as normal. Time from injury to surgery ranged from two weeks to five months. Surgical treatment consisted of ORIF with use of suture anchors (in six patients) or transosseous sutures (in two patients).

Results: All patients achieved pain relief, and there were no neurovascular complications. All patients had full return of internal rotation strength, negative lift-off tests, and negative belly-press tests postoperatively. Average time to return to sports was 4.4 months postoperatively. Return of full external rotation occurred in five patients at an average of 4.9 months postoperatively. There were no refractures. Patient-derived functional outcome scores at an average of 24.6 months after surgery demonstrated excellent shoulder function and high patient satisfaction.

Conclusions: Humeral lesser tuberosity avulsion fractures do occur in adolescents, typically from high-energy sports injuries. Careful physical examination and magnetic resonance imaging (MRI) evaluation aid in achieving a timely diagnosis. Surgical reduction and suture fixation is safe and effective in restoring subscapularis function and return to sports, even in cases of delayed treatment. Full recovery of shoulder external rotation may not be seen until six months postoperatively.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Avulsion fractures of the humeral lesser tuberosity in adolescents are uncommon. Hartigan first described a lesser tuberosity avulsion in 1895 in a seventeen-year-old boy with an ipsilateral humeral shaft fracture. However, few reports of this rare injury exist. It was not until 1985 that the first case report of an isolated pediatric lesser tuberosity avulsion fracture was published. A recent literature review identified only twenty-one reported cases of subscapularis avulsion in patients younger than twenty years of age.

Diagnosis of this injury is often challenging, leading to delays in treatment. One previous report described two adolescents who were diagnosed with an avulsion fracture of the humeral lesser tuberosity more than one year after injury. A recent study found that more than half of these fractures were chronic.

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(defined as existing more than six months after initial injury). Failure to diagnose these injuries promptly may lead to non-union and chronic shoulder pain. Currently, there is no published information comparing nonoperative to surgical treatment of humeral lesser tuberosity avulsion fractures, and no consensus. In addition, although these injuries may be treated nonoperatively, the results of nonoperative management may not be acceptable to all patients.

Previous reports of operative fixation have been limited to three or fewer patients. Only two previous case series have reported patient-derived functional outcome scores following surgical treatment of humeral lesser tuberosity fractures in adolescents. One study included three adolescents treated with screw and washer fixation, while the other series of three adolescents treated with arthroscopic repair reported American Shoulder and Elbow Surgeons (ASES) scores. To the best of our knowledge, no studies have reported patient-derived functional outcome scores following open surgical treatment of humeral lesser tuberosity avulsion fractures in adolescents with use of suture anchors or transosseous sutures.

The purpose of this study was to investigate the demographics, mechanisms of injury, and short-term results of operative fixation of lesser tuberosity avulsion fractures in skeletally immature patients. We hypothesized that surgical treatment of humeral lesser tuberosity avulsion fractures results in excellent function and successful return to a pre-injury level of sports participation.

**Materials and Methods**

**Study Design**

This study is a retrospective case series of patients treated surgically for displaced humeral lesser tuberosity avulsion fractures at a single institution. Patients were identified by means of a computer database query of all operative reports, admission notes, discharge summaries, and clinic notes from 2000 through 2010. Inclusion criteria were an age of eighteen years or younger at the time of injury, the presence of a lesser tuberosity avulsion fracture with or without a subscapularis tear, and radiographic and/or intraoperative confirmation of a lesser tuberosity avulsion fracture. The exclusion criterion was an age older than eighteen years at time of injury.

Medical records were reviewed for age, sex, laterality, mechanism of injury, time from injury to surgery, and intraoperative findings. Preoperative imaging was evaluated for diagnosis and associated pathology. Preoperative and final postoperative range of motion and strength were noted, as were the presence or absence of weakness or discomfort during the lift-off test or belly-press test. Postoperative complications, if any, were noted.

Primary outcomes examined included presence of pain, presence or absence of weakness or discomfort during the lift-off test or belly-press test, shoulder range of motion, and shoulder strength. Secondary outcomes assessed included time to return to unrestricted sports and patient-derived functional outcomes scores. These scores were obtained at a minimum of six months postoperatively. Administered outcomes instruments consisted of the visual analog scale (VAS) for pain, VAS for satisfaction with treatment,
subjective shoulder value (SSV) of the involved and contralateral shoulder\textsuperscript{19}, ASES score\textsuperscript{20}, simple shoulder test (SST)\textsuperscript{21}, Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) score\textsuperscript{22}, and QuickDASH sports module score. The institutional review board of our hospital’s Committee on Clinical Investigation approved this investigation.

\textbf{Patient Demographics}

A computer database query of all operative reports, admission notes, discharge summaries, and clinic notes from 2000 through 2010 identified thirty-four patients treated at our institution for a lesser tuberosity and/or subscapularis injury. Of these, twenty patients were excluded from the study because of age greater than eighteen years at time of injury. Thorough chart review of the remaining fourteen patients was conducted to identify those patients who sustained humeral lesser tuberosity fractures. Of these fourteen patients, eight patients were confirmed as having sustained a humeral lesser tuberosity fracture.

The mean age at the time of injury was 13.3 years (range, twelve to fifteen years). All patients were male and sustained sports-related injuries, typically from forceful shoulder abduction and external rotation with apparent eccentric subscapularis load (see Appendix). Sports participation at the time of injury included ice hockey (two patients), lacrosse, football, baseball, basketball, dodge ball, and skateboarding. The dominant extremity was injured in six of eight patients. Five patients had injured the right shoulder, and three patients had injured the left. Six patients had initial radiographs that were interpreted as normal, and all patients subsequently underwent magnetic resonance imaging (MRI) that was diagnostic for the injury. All patients were seen by at least one outside orthopaedic surgeon prior to referral to our institution. Time from initial injury to surgery ranged from two weeks to five months, and the average time from injury to surgery was 6.5 weeks.

All patients presented to our institution with activity-related anterior shoulder pain. While all patients had pain with sports activities that required shoulder motion, some patients also had pain with activities of daily living. Four patients had weakness and/or limitations in internal rotation of the shoulder. Physical examination on presentation was notable for weakness during internal rotation and weakness or discomfort during lift-off test and/or belly-press test in all patients. In two patients who presented late, passive shoulder external rotation was increased in the injured shoulder as compared with that seen in the contralateral shoulder. Six patients had isolated lesser tuberosity avulsion fractures. Two patients had anterior glenohumeral capsular injuries, and one of these patients had a concomitant biceps tendon dislocation. All eight patients elected surgical treatment, which consisted of open reduction and internal fixation (ORIF) with use of suture anchors (in six patients) or transosseous sutures (in two patients). The patient with biceps tendon instability underwent concomitant biceps tenodesis.

\textbf{Surgical Technique}

In all cases, the surgical procedure was performed under general anesthesia. Routine preoperative antibiotics were utilized. The patient was positioned in the modified beach-chair position. A standard deltopectoral approach was used. The injury pattern and size of the lesser tuberosity were confirmed through intraoperative visualization.

Repair was performed with use of suture anchors (Lupine BR anchors [DePuy Mitek, Norwood, Massachusetts] and/or Bio-Corkscrew FT Suture Anchors [Arthrex, Naples, Florida]) or transosseous sutures (number-5 FiberWire suture [Arthrex, Naples, Florida] or number-5 Ethibond suture [Ethicon, Somerville, New Jersey]) at the discretion of the surgeon (Figs. 3-A and 3-B). For cases in which transosseous sutures were utilized, these sutures were passed through the lesser tuberosity and then through the humeral shaft. Although excision of the lesser tuberosity can be considered if the fragment is too small for internal fixation, fragment excision was not necessary in any patient in the current case series.

Postoperatively, patients were immobilized in a sling-and-swathe arm sling for four to six weeks, followed by initiation of supervised shoulder range-of-motion exercises. Formal physical therapy beginning at six weeks postoperatively was utilized at the discretion of the surgeon.

\textbf{Source of Funding}

There was no external funding source for this study.
Results

All patients achieved near-complete pain relief, and there were no neurovascular complications. All patients had full return of internal rotation strength, a negative lift-off test, and a negative belly-press test. Average time to return to sports was 4.4 months postoperatively (range, 3.7 to 5.0 months). There were no refractures. Return of full external rotation occurred in five of eight patients at average of 4.9 months postoperatively. Three patients had not recovered external rotation symmetric to the contralateral, uninjured shoulder at the latest follow-up of six, ten, and thirteen months, respectively. Average loss of external rotation in these patients was 13° (range, 5° to 20°).

**Figs. 3-A and 3-B** Intraoperative photographs depicting a humeral lesser tuberosity avulsion fracture in a right shoulder. **Fig. 3-A** A traction suture has been placed in the lesser tuberosity and subscapularis muscle, and the cartilaginous undersurface of the tuberosity fragment is seen (arrow). The lesser tuberosity footprint of the proximal part of the humerus is visualized to the left (arrowhead). **Fig. 3-B** Clinical photograph on completion of the repair. Note the nonabsorbable sutures (arrow) seen superficial to the reduced lesser tuberosity.
Functional outcomes scores were obtained at an average of 24.6 months (range, 5.8 to 72.3 months) after surgery (Table I). At the most recent follow-up, patients reported an average VAS pain score of 0.44 (range, 0 to 2) on a scale of 0 to 10, with 0 representing no pain. The mean VAS satisfaction score was 9.63 (range, 8 to 10) on a scale of 0 to 10, with 10 representing complete satisfaction. Mean SSV of the involved shoulder was 93.4 points (range, 85 to 100 points), with 100 representing a perfect shoulder. The average ASES score was 95.7 of 100 points (range, 85 to 100 points), with 100 representing a perfect shoulder. The average SST score was 11.9 of 12 points (range, 10 to 12 points), with 12 representing perfect function. Patients reported an average QuickDASH score of 7.8 of 25 points (range, 0 to 25 points), with 0 representing perfect function for both the QuickDASH and the QuickDASH sports module.

**Discussion**

In the present study, we report the early clinical results and patient-derived outcomes of the surgical treatment of avulsion fractures of the humeral lesser tuberosity in skeletally immature patients. The current investigation identifies several important findings with regard to this fracture pattern.

Although historically, lesser tuberosity avulsions have been rarely reported in skeletally immature patients, the prevalence may be increasing. Indeed, while our search criteria included the years 2000 through 2010, all patients in our series were treated in the years 2005 through 2010, and seven out of eight patients were treated after 2008. This may reflect a change in athletic participation patterns, as younger patients are involved in increasingly high-energy activities. Like other apophyseal avulsion fractures, humeral lesser tuberosity fractures may become more prevalent due to the higher demands being placed on the growing athlete’s shoulder. In addition, the increasing surgical treatment of this injury may reflect improved surgical techniques; for example, the improved design and increasing utility of suture anchors have made it much easier to achieve a secure, anatomic reduction with minimal morbidity. The increased prevalence of humeral lesser tuberosity fractures may also reflect the more widespread utilization of MRI, as six of the eight patients had negative findings on radiographs and the specific fracture pattern was only diagnosed with use of MRI.

All of our patients were between twelve and fifteen years of age at the time of surgical intervention, and the majority of patients were between thirteen and fourteen years of age. This age group may correlate with the ossification and physeal closure of the proximal part of the humerus. The lesser tuberosity ossification center develops at four to five years of age, and the lesser and greater tuberosities fuse with each other between five and seven years of age and fuse with the humeral head between seven and thirteen years of age. The narrow range of twelve to fifteen years of age found in our study may reflect a relative weakness of the lesser tuberosity during this period of skeletal growth and maturation. Thus, humeral lesser tuberosity avulsion fractures may represent another “transitional” fracture of adolescence, similar to medial humeral epicondyle, tibial tubercle, and juvenile Tillaux fractures.

The results of this investigation also highlight the possibility that these injuries may be initially missed, resulting in potential delays in diagnosis and treatment. In the current study, the majority of patients presented acutely or subacutely at an average of 3.4 weeks from the time of injury. This finding is consistent with the findings of prior published studies. Improved accessibility to and resolution of MRI has likely contributed to a decrease in this delay. It is important to recognize that these injuries occur in adolescents, and a high index of suspicion is needed for timely diagnosis and expedited care.

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**TABLE I Patient-Derived Functional Outcomes Scores Following Surgical Intervention**

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Weeks from Injury to Surgery</th>
<th>Follow-up (mo)</th>
<th>VAS Score</th>
<th>SSV</th>
<th>ASES Score</th>
<th>SST</th>
<th>QuickDASH</th>
<th>QuickDASH Sports Module</th>
</tr>
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<td>13</td>
<td>4</td>
<td>20.8</td>
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<td>10</td>
<td>99</td>
<td>98.33</td>
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<td>0</td>
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<td>0.5</td>
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<td>13</td>
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<td>72.3</td>
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<td>9</td>
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<td>95</td>
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<td>0.44</td>
<td>9.63</td>
<td>93.38</td>
<td>95.73</td>
<td>11.88</td>
<td>2.27</td>
</tr>
</tbody>
</table>

**Notes:**

- VAS = visual analog scale (with 0 representing no pain, and with 10 representing complete satisfaction).
- SSV = subjective shoulder value.
- ASES = American Shoulder and Elbow Surgeons scale.
- SST = simple shoulder test.
- QuickDASH = Quick Disabilities of the Arm, Shoulder and Hand.
- QuickDASH Sports Module = Quick Disabilities of the Arm, Shoulder and Hand sports module.

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*VAS score was 0.44 (range, 0 to 2) on a scale of 0 to 10, with 0 representing no pain and with 10 representing complete satisfaction. The mean VAS satisfaction score was 9.63 (range, 8 to 10) on a scale of 0 to 10, with 10 representing complete satisfaction. Mean SSV of the involved shoulder was 93.4 points (range, 85 to 100 points), with 100 representing a perfect shoulder. The average ASES score was 95.7 of 100 points (range, 85 to 100 points), with 100 representing a perfect shoulder. The average SST score was 11.9 of 12 points (range, 10 to 12 points), with 12 representing perfect function. The average QuickDASH score was 7.8 of 25 points (range, 0 to 25 points), with 0 representing perfect function for both the QuickDASH and the QuickDASH sports module.*
Examination of passive shoulder external rotation and performance of a lift-off test and a belly-press test should be a part of the routine shoulder examination, even in younger patients. Fortunately, even with considerable delays in diagnosis, fracture fragment and subscapularis mobilization and primary repair may be successfully achieved in younger adolescents.

A number of imaging modalities have been utilized to aid in diagnosis, including radiographs, ultrasonography, and MRI. Radiographs do not reliably show the avulsed fracture fragment—which may be predominantly cartilaginous—and the radiographic views are often inadequate. While ultrasonography has many theoretical advantages, including its ability to identify cartilaginous structures and avoidance of radiation, its use is not widespread and its diagnostic potential is dependent upon the skill of the operator. Consistent with the finding that all patients in our series required MRI for diagnosis of the injury, MRI remains the imaging modality of choice. Still, a high index of suspicion is required, particularly in male patients between the ages of twelve and fifteen years who have sustained an abduction-external rotation sports injury. Providers must be aware of the potential for the presence of a lesser tuberosity avulsion fracture, and careful, systematic assessment of the axial magnetic resonance images must be performed to reach the appropriate diagnosis. Even when the signal intensity suggests a purely tendinous avulsion, surgeons must be aware of the possibility of finding an apophyseal avulsion fragment at the time of surgical exploration.

This injury pattern is an osseous avulsion of the lesser tuberosity as opposed to a rupture of the subscapularis tendon, as demonstrated in all eight patients in our series. Although this avulsion injury most often occurs in isolation, glenohumeral dislocation and/or damage to the long head of the biceps may occur. Favorable early results were seen in our series of lesser tuberosity avulsion fractures treated with surgical repair. Motion and internal rotation strength returned, with pain relief and return to sporting activities four to five months postoperatively. There were no cases of neurovascular complications in this series, and subscapularis mobilization and direct repair of the lesser tuberosity to the humerus was possible in all patients, even when there was a considerable delay before surgery. As with adult subscapularis avulsions, patients should be counseled regarding the limitations in passive external rotation in the early postoperative period. Even though three patients in our series had a limitation in external rotation, this did not affect the clinical outcome. These three patients had excellent ASES scores of 93 to 100, SST scores of 11 to 12 (optimal score is 12), and a QuickDASH score of 0 in two patients and 7 in one patient.

A number of technical points bear mention. First, a cartilaginous or osseous lesser tuberosity avulsion should be suspected in younger adolescents with a presumed subscapularis tear. At the time of surgical exposure, care should be taken to identify and mobilize the subscapularis musculotendinous unit without stripping the osteocartilaginous fragment from its soft-tissue attachments. With larger lesser tuberosity fragments with adequate bone attached, direct repair is recommended. Transosseous suture or screw fixation may be used, allowing for bone-to-bone healing and reconstituting the anatomy of the bicipital groove. When the avulsed lesser tuberosity fragment is too small for fixation, the lesser tuberosity may be excised and the tendon may be repaired directly to the lesser tuberosity footprint. It has been our experience that the anatomic footprint of the lesser tuberosity is cancellous and often lacks the cortical shell needed for small-diameter suture anchors. In these situations, the surgeon should be prepared to use larger threaded suture anchors or to utilize transosseous suture repair techniques. Finally, care must be taken during the transosseous repair so as not to injure the biceps tendon. If utilizing transosseous sutures, the sutures typically enter medial to the bicipital groove and are tied over an osseous bridge lateral to the biceps.

This investigation has several limitations. First, this was a retrospective case series of a limited number of patients and thus was inherently subject to selection and performance bias. Despite this, however, the current study represents, to our knowledge, the largest surgical series to date of this relatively rare pediatric injury. Second, although the clinical follow-up among patients in the series presented here was short, all had restoration of subscapularis function and returned to sports participation without limitation at the most recent clinical evaluation, thus supporting the assertion that the proposed surgical treatment is effective. Longer follow-up is needed to address questions regarding the potential for refracture, growth disturbance, and ultimate functional limitations.

Third, while the VAS has been validated in children who were eight years of age and older, the remaining outcomes scores have not been validated in an adolescent population. Validated, shoulder-specific outcomes instruments for the pediatric and adolescent patient population are currently unavailable, and the future development of such instruments will aid in our assessment of these types of avulsion fractures and other similar injuries. Finally, given the study design, no definitive conclusions can be made regarding the comparative outcomes of surgical versus nonoperative treatment for these injuries. However, considering the excellent results associated with surgical treatment in our study as well as the risk of a patient developing chronic shoulder pain should a non-union develop after nonoperative treatment, it appears beneficial to treat these avulsion fractures surgically. In conclusion, humeral lesser tuberosity avulsion fractures do occur in adolescents, typically as a result of high-energy sports injuries. Conducting a careful physical examination that is supplemented with MRI can prevent delays in diagnosis in most patients. ORIF provides reliable restoration of subscapularis function and return to sports.

Appendix

A table showing the patient demographics and the surgical technique utilized for repair as well as a figure showing an incidental proximal humeral cyst is available with the online version of this article as a data supplement at jbjs.org.
References