Incidence and Characteristics of Humeral Shaft Fractures After Subpectoral Biceps Tenodesis

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Background: Biceps tenodesis is a procedure that can address biceps and labral pathology. While there is an increased risk of humeral fracture after biceps tenodesis, it has been described only in case reports.

Purpose: To identify the incidence, demographics, and characteristics of humeral shaft fractures after biceps tenodesis.

Study Design: Case series; Level of evidence, 4.

Methods: The US Military Health System Data Repository was searched for patients with a Current Procedural Terminology code for biceps tenodesis between January 2013 and December 2016. The cohort of identified patients was then searched for those assigned a code for humeral fracture per the International Classification of Diseases, 9th Revision and 10th Revision. The electronic health records and radiographs of patients who were diagnosed with a humeral fracture were then evaluated to confirm that the fracture was related to the biceps tenodesis. Records were then reviewed for patient demographics, radiographs, operative reports, and clinical notes.

Results: A total of 15,085 biceps tenodeses were performed between January 2013 and December 2016. There were 11 postoperative and 1 intraoperative humeral fractures. The incidence of fracture was <0.1%. All fractures were extra-articular spiral fractures that propagated through the tenodesis site. Eight patients were treated with functional bracing, 3 with open reduction and internal fixation, and 1 with a soft tissue biceps tenodesis revision. Of 8 patients successfully treated nonoperatively, 6 regained full range of shoulder motion. Only 2 of the 4 patients who required operative treatment regained full range of shoulder motion.

Conclusion: Humeral shaft fracture after biceps tenodesis is a rare complication that occurs in 7.9 out of 10,000 cases. Fractures occurred after various methods of fixation, including suture anchor, cortical button, and interference screw. Most patients were initially treated nonoperatively, and those who healed usually achieved full range of motion; however, those who required operative intervention often had restricted range of motion on final follow-up. Future studies should determine risk factors for fracture after biceps tenodesis.

Keywords: fracture; biceps tenodesis; humerus; suture anchor; cortical button

Pathology of the long head of the biceps is a common source of anterior shoulder pain and is often associated with other intra-articular shoulder pathology.[23,25] Two established surgical treatment options are biceps tenotomy and tenodesis. These procedures can address a number of internal derangements associated with the long head of the biceps tendon, including tendinopathy and SLAP (superior labrum anterior to posterior) tears.[14,18,21,26]

Many surgeons advocate for biceps tenodesis because of the decreased risk of cosmetic deformity, loss of strength, muscle cramping, and fatigue that may be associated with tenotomy.[17,19,21,26] While several techniques have proven to be effective, there is no consensus regarding the ideal tenodesis technique.[4,11,20] Several popular fixation methods, including interference screw, suture anchor, and cortical button, require drilling a unicortical hole into the proximal humerus, usually just above the inferior border of the pectoralis major tendon.[12] Biomechanical studies have demonstrated that a drill hole acts as a stress riser and decreases the resistance of the humerus to torsional stress, increasing the risk of a humeral fracture. Furthermore, recent studies have shown that the decreased resistance to torsional stress persists even after the hole has been filled with an implant.[6,12,15,17] While this decreased resistance to stress has been demonstrated in laboratory settings, it has been reported in vivo in only a small number of case reports in the literature to date.[5,7,20,22]

Biceps tenodesis is a procedure commonly performed in isolation and in conjunction with additional arthroscopic procedures. This procedure has a generally favorable

The Orthopaedic Journal of Sports Medicine, 7(3), 2325967119833420
DOI: 10.1177/2325967119833420

functional result in a younger, active population.[10] As such, the high-level activity and physical demands of this population may place these patients at an increased risk of fracture.

The present study was conducted to evaluate the incidence of intra- and postoperative humeral shaft fracture after biceps tenodesis. The secondary outcome was the presentation of the demographics, implants, treatment modalities, and clinical outcomes of a retrospective case series of patients who sustained humeral shaft fractures after a biceps tenodesis. Our hypothesis was that the incidence of humeral shaft fracture after subpectoral biceps tenodesis would be low, given the small number of reported cases in the literature.

METHODS

The United States (US) Department of Defense maintains a central database of clinical encounters for all enrollees in the Military Health System, including active duty servicemembers, dependents, and retirees. After institutional review board approval, the clinical data for all US Department of Defense Military Health System enrollees—including all inpatient and outpatient clinical encounters compiled within the central Military Health System Data Repository—were analyzed with the Management Analysis and Reporting Tool as described by Balazs et al.[3] The database was searched for all patients with a Current Procedural Terminology (CPT) code for biceps tenodesis or tenotomy (29828, 23430, and 23440) between January 2013 and December 2016. The CPT code for biceps tenotomy was included during screening in the event that a biceps tenodesis was miscoded at the time of surgery. The identified patients were then searched for those assigned a code for humeral fracture per the International Classification of Diseases, 9th Revision and 10th Revision (ICD-9 and ICD-10) (see Appendix Table A1).

The electronic health records of all patients identified from the database search were screened to eliminate patients with coding errors, those who sustained a contralateral humeral shaft fracture, and those who sustained a humeral shaft fracture prior to biceps tenodesis. Patients were not excluded on the basis of age, comorbidities, sex, or military status. After screening, we reviewed the radiographs, operative reports, fixation methods, and postoperative clinical notes for each included patient. Details of each patient were recorded, including age, sex, date of surgery, surgical implants, date of the initial diagnosis of a fracture, mechanism of injury, treatment modality, postoperative shoulder range of motion, pain scores, and duty status.

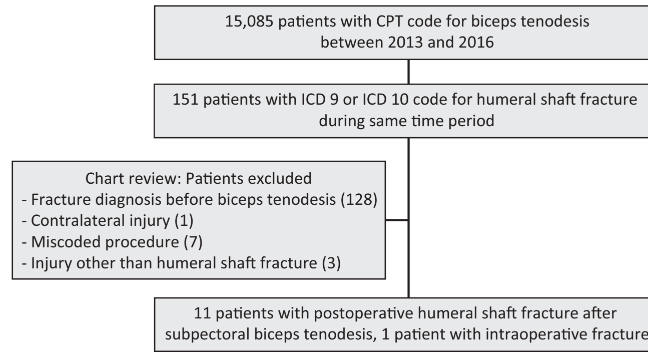

Figure 1. Flow diagram identifying humeral fractures after biceps tenodesis. CPT, Current Procedural Terminology; ICD-9 and ICD-10, International Classification of Diseases, 9th Revision and 10th Revision.

Statistical analysis was conducted with SPSS Statistics (v 24.0; IBM Corp) and manual calculations. The incidence of humeral shaft fracture after biceps tenodesis was calculated by comparing the overall number of fractures with the number of biceps tenodeses performed over the study period.

RESULTS

A total of 15,085 patients in the Military Health System were assigned a CPT code for biceps tenodesis between January 1, 2013, and December 31, 2016. Of these, 9940 patients were coded as open biceps tenodesis (65.9%) and 5145 as arthroscopic biceps tenodesis (34.1%). A total of 151 patients were also assigned an ICD-9 or ICD-10 code for a humeral fracture (Figure 1). After electronic health record cross-referencing, 139 of these patients were excluded owing to miscoding, fractures of the contralateral humerus, or injury prior to the biceps tenodesis. Of the 12 remaining patients, 11 were diagnosed with an ipsilateral humeral shaft fracture postoperatively, and 1 patient was diagnosed with an intraoperative humeral shaft fracture. All 12 patients had at least 2 years of follow-up from the time of the index procedure. The overall incidence of humeral fracture after biceps tenodesis was 0.079% (7.9 per 10,000 cases). All 12 analyzed surgical procedures were subpectoral biceps tenodeses performed with an open technique.

All fractures were extra-articular spiral fractures that propagated through the subpectoral tenodesis site. Six patients (50%) had the tenodesis performed with

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One or more of the authors has declared the following potential conflict of interest or source of funding: W.R.V. has received hospitality payments from Stryker. K.G.K. has received hospitality payments from Smith & Nephew. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from the Walter Reed National Military Medical Center (WRNMMC-2016-0018).

TABLE 1
Patient Demographics and Characteristics[a]

No.	Age, y	Sex	Preoperative Diagnosis	Concomitant Procedures	Biceps Tenodesis Fixation Method	Time to Fracture, d	Mechanism of Injury
1	41	M	SLAP tear, BT		Interference screw	7	Fall down stairs
2	38	M	SLAP tear, AC	DCE	Interference screw	6	Atraumatic while reaching for cup
3	39	M	SLAP tear		Interference screw	120	Fall playing soccer
4	40	M	BT, AC	DCE	Bicortical button	49	Ground-level fall
5	38	M	SLAP tear, PLT	PLR	Suture anchor	158	Ground-level fall
6	44	M	SLAP tear		Unicortical button	220	Fall down stairs
7	27	M	SLAP tear, BT		Suture anchor	78	Fall out of bed
8	25	M	SLAP tear, BT		Interference screw	186	Atraumatic while swinging baseball bat
9	28	M	BT, ALPSA	ALPSA repair	Unicortical button	72	Axial load from large dog
10	23	M	SLAP tear, BT		Interference screw	40	Ground-level fall
11	49	M	BT, AC	DCE	Interference screw	41	Ground-level fall
12	41	F	SLAP tear		Suture anchor	0	Intraoperative

[a]AC, acromioclavicular joint arthritis; ALPSA, anterior labroligamentous periosteal sleeve avulsion; BT, biceps tenodesis; DCE, distal clavicle excision; F, female; M, male; PLR, posterior labrum repair; PLT, posterior labrum tear; SLAP, superior labrum anterior to posterior.

interference screws; 3 (25%) had cortical buttons, 2 of which were placed unicortically and 1 bicortically; and 3 (25%) were fixed with suture anchors, including the patient with an intraoperative fracture.

Patient Demographics

The median age of the 15,085 patients within the biceps tenodesis cohort was 40 years (range, 13-85 years). The male:female distribution of the patients was 84%:16%. The demographics of the 12 patients with intra- and postoperative fractures are summarized in Table 1. Additionally, 3 patients had a preoperative diagnosis of rotator cuff tendinopathy or partial tear. However, none of these patients underwent rotator cuff debridement or repair.

Of the 11 postoperative fractures, 8 (72%) occurred after a fall onto the operative extremity. One fracture occurred after a patient took a dry swing of a baseball bat during a softball game and another in a patient who sustained a collision with a large dog. One patient had an atraumatic mechanism 6 days after his index procedure when he lifted a water glass from a table.

The initial procedures were performed at 9 military treatment facilities across the continental US and by orthopaedic surgeons who were and were not fellowship trained. The time to fracture from index surgery varied within the series (Table 1). The median time from index surgery to the time of fracture was 72 days (range, 0-220 days). Three patients, including the patient with the intraoperative fracture, sustained the injury within 7 days of the index procedure, whereas 2 patients sustained the fracture >6 months after the index procedure. Example radiographs of humeral shaft fractures following subpectoral biceps tenodesis can be seen in Figure 2.

Intraoperative Considerations

Three patients had intraoperative deviations in technique during the index biceps tenodesis procedure, as noted in the operative reports. One patient had 3 attempts at having a pilot hole drilled before a tenodesis screw was placed. In another patient, a cortical button was placed unicortically without an interference screw after 2 attempts to drill bicortically failed. An interference screw was not placed as backup fixation as originally planned because of the multiple drill attempts. A third case was intraoperatively revised from a tenodesis screw to a suture anchor after the surgeon determined that there was inadequate bone stock for screw fixation. The only intraoperative fracture occurred during tapping of a pilot hole in preparation for insertion of a suture anchor.

One patient's biceps tenodesis was complicated by multiple revisions. Initially, the tenodesis fixation failed, resulting in a "Popeye deformity" 12 days after the initial procedure. During the revision, a second suture anchor was placed. Approximately 2 weeks later, the patient developed a wound infection that prompted another return to the operating room for irrigation and debridement. This infection recurred over the course of the next 3 months, requiring multiple debridements and removal of the suture anchors (Figure 2, A and B). The patient then sustained a humeral shaft fracture after he fell approximately 3 weeks after his last surgical procedure. At that time, he was diagnosed with osteomyelitis of the humerus. He was subsequently treated nonoperatively with an aggressive antibiotic course.

Treatment

All 11 postoperative humeral fractures were initially managed nonoperatively with functional bracing, including the patient who underwent multiple debridements for a surgical site infection as described earlier. Two of these patients had persistent pain and were subsequently treated with open reduction and internal fixation (ORIF) (Figure 3). One patient complained of persistent muscle spasm approximately 1 month after the injury and was subsequently treated with revision biceps tenodesis without surgical fixation of the humeral fracture owing to the

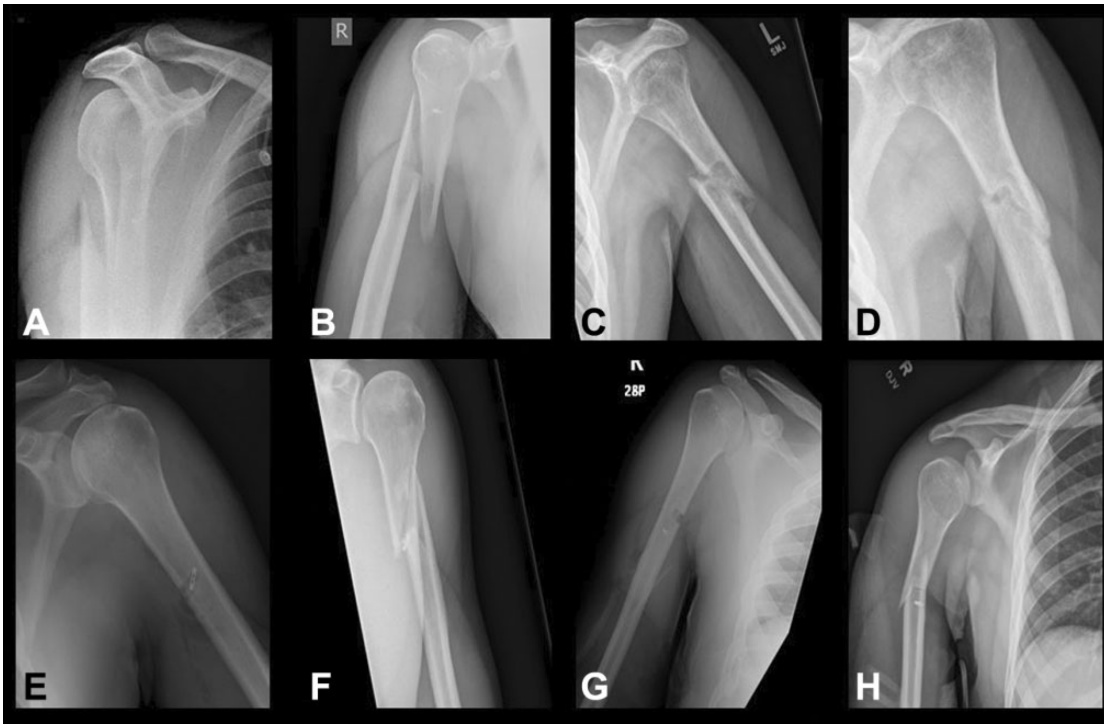

Figure 2. Orthogonal radiographs of fracture (A, B) after surgical site infection treated with removal of suture anchor fixation and (C, D) after biceps tenodesis with interference screw fixation. Postoperative and initial injury radiographs of (E, F) patient with cortical button fixation and (G, H) patient with suture anchor fixation.

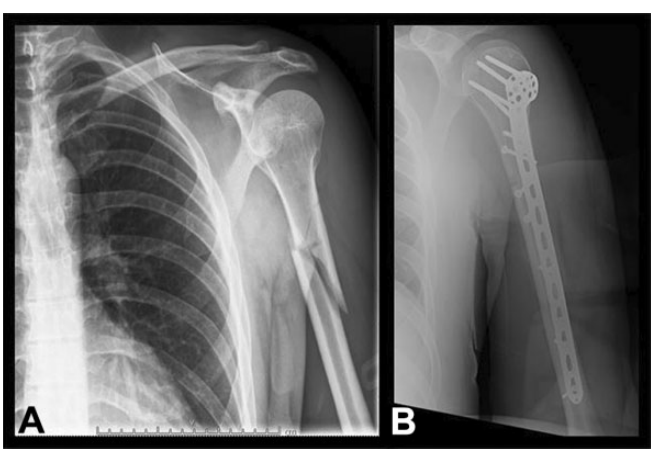

Figure 3. Patient 1: (A) injury radiograph and (B) postoperative radiograph after open reduction and internal fixation.

presence of callus. The patient with the intraoperative fracture was treated with ORIF. All 3 patients who underwent ORIF were treated with proximal humeral locking plates. Biceps tenodesis revisions in these patients were performed through a soft tissue procedure, such as imbricating the biceps tendon to the pectoralis major tendon or incorporating the biceps tendon into the fascial repair. Both patients who received surgical fixation for postoperative fractures did so on an elective basis for persistent pain with functional bracing.

Clinical Outcomes

The details of the final outcomes are reported in Table 2. The mean clinical follow-up time was 9.4 months (range, 4.6-14 months) from the index procedure. Of the 12 patients, 8 (75%) regained symmetric range of motion and strength of the injured shoulder as compared with the contralateral side. Of the patients who did not achieve full range of motion, 3 (25%) were able to achieve shoulder forward flexion and abduction >90°, while 1 (8%) was not. Four patients reported continued pain in the injured shoulder at the time of final follow-up, and 9 patients were released to full activity without restrictions. One patient who underwent ORIF was scheduled to undergo manipulation under anesthesia 6 months postinjury; however, this patient was lost to follow-up.

DISCUSSION

Biceps tenodesis has been shown to be effective in the treatment of intra-articular biceps and SLAP pathology, with an overall complication rate as low as 2% and complications mainly consisting of loss of fixation or persistent biceps pain.[17] This study presents a comparatively large series of humeral fractures after biceps tenodesis surgery and includes instances of humeral fracture after use of suture anchor or cortical button fixation. In this series, the incidence of postoperative fracture after biceps tenodesis was 0.079% (7.9 per 10,000 cases), and fractures occurred

TABLE 2
Fracture Treatment and Results[a]

No.	Fracture Treatment	Time to Final Orthopedic Follow-up, mo	ROM at Final Follow-up	Residual Symptoms
1	ORIF	6	FF, 120°; Abd, 95°; ER, 47°; IR, 20°	Stiffness, scheduled for MUA but lost to follow-up
2	Nonoperative	10.4	Full	Pain with lifting
3	ORIF with BT revision	12.1	Full	None
4	Nonoperative	8	Full	None
5	Nonoperative (multiple I&D for infection)	14	FF, 40°; Abd, 130°; ER, 45°; IR to sacrum	Diffuse tenderness, painful ROM, diminished cuff strength
6	Nonoperative	12	Full	None
7	Nonoperative	12	Full	None
8	Nonoperative	12	FF, 150°; Abd, 150°; ER, 70°; IR, 80°	Persistent numbness in radial and ulnar distributions with normal electrodiagnostic findings, diminished cuff strength, painful ROM
9	Soft tissue BT revision	4.6	FF, 110°; Abd, 65°; ER, 40°; IR to sacrum	Painful ROM
10	Nonoperative	4.6	Full	None
11	Nonoperative	8.7	Full	None
12	ORIF	8.4	Full	None

[a]Abd, abduction; BT, biceps tenodesis; ER, external rotation; FF, forward flexion; I&D, irrigation and debridement; IR, internal rotation; MUA, manipulation under anesthesia; ORIF, open reduction and internal fixation; ROM, range of motion.

among all common types of subpectoral tenodesis fixation methods. Of the 8 patients in this series who were treated nonoperatively, 6 (75%) regained full range of motion.

The inclusion of suture anchor and cortical button fixation implicated in postoperative humeral shaft fracture is novel, as previously reported cases included only screw fixation.[5,7,20,22] Reiff et al[20] reported a case of postoperative humeral fracture after a modified keyhole biceps tenodesis in a 50-year-old woman. This patient sustained a humeral fracture 12 weeks after surgery when she pushed open a revolving door. She was treated with functional bracing and was evaluated for 47 months. She reported no activity limitations or pain at her final follow-up. Sears et al[22] reported on 2 patients who underwent arthroscopically assisted subpectoral biceps tenodesis with interference screw fixation. The first patient was a 47-year-old male laborer who sustained a postoperative humeral fracture 6 months after his index procedure after falling down a hill. This patient was treated by ORIF with plate fixation. The second patient was a 34-year-old male physician who sustained a fracture after picking up a bag 4 months after surgery. This patient was also treated by ORIF with plate fixation. Both patients returned to full activities by 6 months after surgical fixation. Friedel et al[7] reported a humeral fracture 6 weeks after a keyhole biceps tenodesis in a 69-year-old man that occurred after the patient was rolling up a hose. Dein et al[5] reported on a humeral fracture in a baseball pitcher. This patient was a 46-year-old man who underwent open subpectoral biceps tenodesis with an interference screw. The patient went back to pitching 10 months after the index procedure and sustained a humeral fracture while pitching. He was treated with ORIF with an intramedullary rod. He returned to light tossing at 6 months and to full pitching 18 months after surgical fixation. None of these cases reported intraoperative complications or variations in the planned surgical technique, and all fractures occurred through the site of the subpectoral tenodesis.

The cortical defect created by the bone tunnel represents a potential stress riser. A biomechanical study by Edgerton et al[6] demonstrated that a 20% cortical defect results in a 34% decrease in torsional strength of a cadaveric humerus. Other studies have demonstrated a direct relationship between the size of the cortical defect and the reduction in torsional load to failure.[9,13] Alford et al[1] theorized that filling a bone tunnel with a biocomposite screw or soft tissue could restore some of the torsional strength lost from the cortical defect. In their animal model, rabbit femurs had drill holes filled with either PGA (polyglycolide) or metal screws. The authors then compared torsional load to fracture with the unfilled contralateral side. The result was 30% improved peak torque in the PGA group and 17% in the metal screw group as compared with the paired unfilled femurs immediately after the procedure.

A more recent study by Mellano et al[15] tested 3 models: a humerus with an 8-mm reamed unicortical tunnel, a bone tunnel with an 8 × 12–mm PEEK (polyether ether ketone) interference screw alone, and a bone tunnel with an interference screw and cadaveric biceps tendon. An 8-mm unicortical tunnel model demonstrated a 28% decrease in torsional load until fracture as compared with an intact humerus. The “screw alone” group and the “screw with biceps tendon” group each reduced the maximum torsional load to failure by 30% and 20% as compared with the intact humerus, respectively, and there was no significant difference among the 3 groups after fixation.

Cortical buttons and suture anchors have recently become a more popular form of fixation.[16] These implants require a smaller bone tunnel and are theoretically at lower risk of fracture as compared with interference screw.[2] Despite this theoretical risk, no previous biomechanical models have investigated the fracture risk for cortical buttons or suture anchors.[11,24] In this series, the patients who received a cortical button or suture anchor had similar mechanisms of injury and functional recovery as compared with the patients receiving an interference screw.

Most patients in this series had their fracture initially treated nonsurgically. Thus, they were not exposed to the morbidity that can be associated with fixation of the humeral shaft.[8] Most cases of post–biceps tenodesis humeral fracture reported in the literature were treated operatively.[5,7,20,22] In our series, 2 patients who were treated surgically for a postoperative fracture had not regained full range of motion at final follow-up. Both these patients failed 1 month of initial nonoperative treatment, which may have affected their final range of motion. However, 7 of the 8 patients treated with functional bracing were able to regain full active range of motion or were $<20^\circ$ from doing so. The 1 patient who did not regain full motion after functional bracing had undergone multiple surgical procedures, including a revision biceps tenodesis and repeat operations for a surgical site infection, before sustaining the fracture. With the exception of 1 patient, all patients who underwent revision surgery—including the one treated with revision soft tissue biceps tenodesis and those treated with ORIF—did not regain full range of motion. One patient who received surgical fixation for a postoperative fracture did regain full range of motion. This outcome may be due to prolonged postsurgical immobilization as compared with patients treated with functional bracing. There was no uniform decision making for fracture management across the series. The decision to surgically treat a patient with a humeral fracture after a biceps tenodesis should be made on an individual patient basis. The patients in our series who elected to undergo surgical fixation did so because of persistent pain and muscle spasm with functional bracing. Nonsurgical treatment may not be appropriate for all patients.

Limitations

There are several limitations to this study. First, this study is subject to the inherent limitations of a retrospective review based on medical coding, which allows for potential data inaccuracy owing to miscoding of procedures or diagnoses. Furthermore, our database does not allow us to follow the outcomes of patients once they separate from the military, and we would not know if they sustained a humeral shaft fracture. Second, humeral shaft fracture after biceps tenodesis is exceedingly rare. As such, the low incidence of this complication in our study group—despite being based on more than 15,000 cases—may indicate a lack of sufficient power to draw generalizable conclusions about risk factors for fracture after biceps tenodesis. Furthermore, this retrospective review includes patients treated by multiple surgeons at different institutions using differing techniques and following different postoperative protocols and decision algorithms for fracture management. This makes it difficult to directly compare the outcomes of patients who received operative and nonoperative treatment for their humeral fracture. Also, the risk of proximal humeral fracture exists regardless of fixation method; however, we are unable to determine the relative risk of fracture among methods of fixation. Future research matching the patients included in this study with paired controls has potential to elucidate risk factors for humeral shaft fracture after biceps tenodesis.

CONCLUSION

Humeral shaft fracture after subpectoral biceps tenodesis is an extremely rare complication of a commonly performed procedure and can occur regardless of fixation method. In this retrospective study, we identified an incidence of 7.9 fractures per 10,000 cases. The decision to surgically manage a humeral shaft fracture after biceps tenodesis should be based on the individual clinical scenario. Given the small and heterogeneous nature of the study cohort, we are unable to make a recommendation regarding the best treatment of humeral shaft fractures after biceps tenodesis.

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APPENDIX

TABLE A1
ICD-9 and ICD-10 Codes Used in Database Query[a]

	Codes for Humeral Shaft Fracture
ICD-9	81220, 81202, 81212, 81209, 81219, 81203, 81213, 81209, 81219, 81201, 81211, 81221, 812231, 81244, 81254, 81200, 81210, 81209, 81219
ICD-10	
S42.2 fracture upper end of humerus	S422, S4220, S4201, S4201A, S4201B, S4202, S4202A, S4202B, S4209, S4209A, S4209B, S4221, S42211, S42211A, S42211B, S42212, S42212A, S42212B, S42213, S42213A, S42213B, S42214, S42214A, S42214B, S42215, S42215A, S42215B, S42216, S42216A, S42216B, S4222, S42221, S42221A, S42221B, S42222, S42222A, S42222B, S42223, S42223A, S42223B, S42224, S42224A, S42224B, S42225, S42225A, S42225B, S42226, S42226A, S42226B, S4223, S42231, S42231A, S42231B, S42232, S42232A, S42232B, S42239, S42239A, S42239B, S4224, S42241, S42241A, S42241B, S42242, S42242A, S42242B, S42249, S42249A, S42249B, S4225, S42251, S42251A, S42251B, S42252, S42252A, S42252B, S42253, S42253A, S42253B, S42254, S42254A, S42254B, S42255, S42255A, S42255B, S42256, S42256A, S42256B, S4226, S42261, S42261A, S42261B, S42262, S42262A, S42262B, S42263, S42263A, S42263B, S42264, S42264A, S42264B, S42265, S42265A, S42265B, S42266, S42266A, S42266B, S4229, S42291A, S42291B, S42292, S42292A, S42292B, S42293, S42293A, S42293B, S42295, S42295A, S42295B, S42296, S42296A, S42296B
S42.3 Fracture of shaft of humerus	S423, S4230, S42301, S42301A, S42301B, S42302, S42302A, S42302B, S42309, S42309A, S42309B, S4232, S42321, S42321A, S42321B, S42322, S42322A, S42322B, S42323, S42323A, S42323B, S42324, S42324A, S42324B, S42325, S42325A, S42325B, S42326, S42326A, S42326B, S4233, S42331A, S42331B, S42332, S42332A, S42332B, S42333, S42333A, S42333B, S42334, S42334A, S42334B, S42335, S42335A, S42335B, S42336, S42336A, S42336B, S42, S4234, S42341, S42341A, S42341B, S42342, S42342A, S42342B, S42343, S42343A, S42343B, S42344, S42344A, S42344B, S42345, S42345A, S42345B, S42346, S42346A, S42346B, S4235, S42351, S42351A, S42351B, S42352, S42352A, S42352B, S42353, S42353A, S42353B, S42354, S42354A, S42354B, S42355, S42355A, S42355B, S42356, S42356A, S42356B, S4236, S42361, S42361A, S42361B, S42362, S42362A, S42362B, S42363, S42363A, S42363B, S42364, S42364A, S42364B, S42365, S42365A, S42365B, S42366, S42366A, S42366B, S4239, S42391, S42391A, S42391B, S42392, S42392A, S42392B, S42399, S42399A, S42399B
S42.9 Fracture of shoulder girdle, part unspecified	S429, S4290, S4290XA, S4290XB, S4291, S4291XA, S4291XB, S4292, S4292X1, S4292XB

[a]ICD-9, International Classification of Diseases, 9th Revision; ICD-10, International Classification of Diseases, 10th Revision.