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Isolated tears of the sternocostal head of the pectoralis major muscle: surgical technique, clinical outcomes, and a modification of the Tietjen and Bak classification

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Hypothesis: We aimed to describe a modified surgical technique to treat isolated sternocostal head tears using cortical button fixation while preserving the intact clavicular head tendon, to outline a new classification of pectoralis major injuries, and to present the clinical outcomes and return-to-sport data of a cohort of 21 athletes who underwent surgical repair.

Methods: We reviewed prospectively collected data of patients who underwent surgical repair with the described technique for isolated sternocostal head tears from 2008 to 2014. Two-year postoperative clinical outcomes including the Single Assessment Numeric Evaluation score, isokinetic strength, patient satisfaction, and return to sport, as well as preinjury and postoperative bench-press weight, were collected, and descriptive statistics were used for analysis.

Results: Twenty-one patients who underwent repair of isolated sternocostal head tears were included. The majority of the isolated tears of the sternocostal head of the pectoralis major (57%) occurred during the bench press. Of the ruptures, 81% were Tietjen type IIIC and 19% were type IIID. Postoperative Single Assessment Numeric Evaluation scores averaged 90.1 (standard deviation, 8.4), and patient satisfaction was 9.5 of 10 (standard deviation, 0.9). All athletes returned to sport approximately 5.5 months postoperatively. The isokinetic strength deficit averaged 8% compared with the contralateral arm, whereas the average preinjury bench-press weight of 134 kg (range 88-227 kg) was restored to 117 kg (range 61-250 kg) postoperatively.

Conclusion: We propose a new classification of pectoralis major injury. In addition, we present a biomechanically sound repair technique for isolated tears of the sternocostal head of the pectoralis with favorable outcomes. The technique takes the specific anatomy of the sternocostal and clavicular heads into account for the approach.

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

Keywords: Pectoralis major; tendon tear; pec tear; sternocostal head; tendon repair; weightlifting; NFL

Pectoralis major tendon tears have been increasing in frequency as sports participation and recreational activity have expanded within the general population.[6,11,14] These injuries most commonly occur in active men aged 20 to 40 years. Anatomically, the pectoralis major consists of 2

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distinct heads: clavicular and sternocostal (Fig. 1). The clavicular head originates from the medial aspect of the clavicle, and the sternocostal head originates from the sternum and costal cartilage of ribs 1-6. Fibers from the 2 heads rotate 90° on each other, creating a rolled edge along the anterior axillary fold.[8] Both heads share a common tendinous insertion on the proximal humerus just lateral to the bicipital groove. Within the tendon footprint, the inferior sternocostal fibers insert posterosuperiorly to the clavicular head fibers.[8]

The mechanism of pectoralis major injury is either direct trauma, which is often associated with contact sports, or more commonly, indirect trauma, which is associated with weight training.[3,6,17,21,24] The bench press is responsible for the majority of reported pectoralis major tendon tears, and these usually involve isolated tears of the sternocostal head.[6,17,21,24] The injury occurs in the final phase of the eccentric contraction at the point where the arm is in abduction and extension and the inferior fibers of the sternocostal head are maximally stretched and at a mechanical disadvantage.[24]

Nonoperative management is traditionally indicated and well tolerated in patients with intramuscular injuries and strains or in low-demand, sedentary patients. Surgical treatment has been indicated in young, active patients with complete pectoralis major tears. Without repair, athletes are likely to experience disability from a loss of arm adduction, forward flexion, and internal-rotation strength.[2,7,12,18,21,24] A variety of surgical techniques have consistently shown good to excellent postoperative functional outcomes and cosmetic results, although some strength deficits may remain.[1,4-6,9,16,21] Acute repair is generally preferred to chronic repair, although in comparison with nonoperative management, either method consistently yields superior results in active patients.[7,8,12,14,17,19,21]

The specific aims of this study included 3 components. The first aim was to describe a surgical technique modified from the technique described by Kang et al[13] to treat isolated sternocostal head tears using cortical button fixation while preserving the intact clavicular head tendon. The second aim was to describe a new classification of pectoralis major injuries developed by the senior author, which revises the Tietjen classification[23] and Bak modification.[4] The third aim was to report the clinical outcomes and return-to-sport data for a cohort of 21 athletes with isolated sternocostal head repairs.

Methods

We reviewed prospectively collected data of patients with isolated tears of the sternocostal head of the pectoralis major between March 2008 and March 2014. Our inclusion criteria included young, active male patients with acutely treated (<8 weeks) isolated tears of the sternocostal head of the pectoralis major tendon with a minimum of 2 years of follow-up. The exclusion criteria included chronic tears, defined as those treated more than 8 weeks after injury, and revision repairs. We identified 21 patients who met the inclusion criteria.

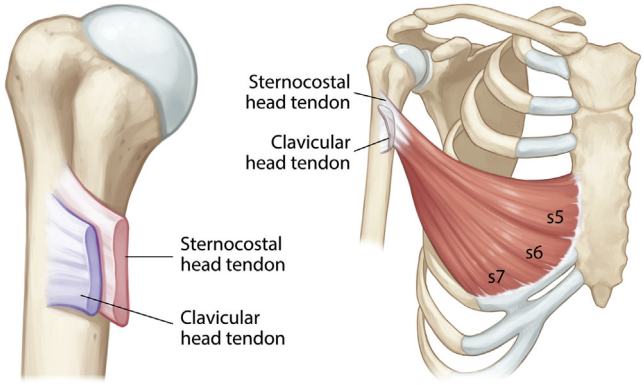

Figure 1 Bilaminar conjoined tendon along lateral lip of bicipital groove. The clavicular head and the superior segments of the sternocostal head constitute the anterior and inferior tendon laminar fibers. The middle portion of the sternocostal head constitutes the inferior U-shaped insertion to the anterior and posterior laminar fibers. The lower portion of the sternocostal head constitutes the more proximal segment of the posterior laminar fibers, inserting more proximal in the humerus than the anterior layer. *S*, sternal segment. (Figure and caption reprinted with permission from Cordasco F. Chapter 73: pectoralis major repair. In: Shoulder surgery: tricks of the trade. Part IV: trauma. New York: Thieme; 2019. p. 445.)

Data including patient demographics, handedness, side of injury, mechanism of injury, primary sport, and preinjury maximum bench-press weight were collected at the initial visit. Patients completed outcome measures including the Single Assessment Numeric Evaluation (SANE) score, postoperative bench press, and patient satisfaction score (on a scale of 0-10); these data were collected at the 2-year follow-up evaluation. At the most recent clinical assessment, isokinetic horizontal adduction strength of the injured side was compared with the contralateral side using the Nicholas Manual Muscle Tester (Lafayette Instrument, Lafayette, IN, USA). Descriptive statistics were reported, with means and standard deviations for continuous outcomes and frequencies for categorical outcomes.

Preoperative evaluation

All athletes underwent preoperative evaluation with a thorough history and physical examination. Athletes typically report a sudden injury during weight training or sports activities, often the bench press, and complain of subsequent pain, bruising (often in the biceps muscle–tendon junction region), weakness, and cosmetic asymmetry. Physical examination often reveals cosmetic deformity at the anterior axillary fold, ecchymosis overlying the chest wall and proximal biceps muscle, and a side-to-side asymmetry with resisted horizontal adduction and internal rotation. Radiographs typically yield negative findings, although the rare bony avulsion (type IIIE in the Bak modification) can be identified. Pectoralis major–specific magnetic resonance imaging (MRI) (not a shoulder MRI scan) is very helpful to differentiate the location and type of injury within the musculotendinous unit (Fig. 2). The history, physical examination, and imaging findings help

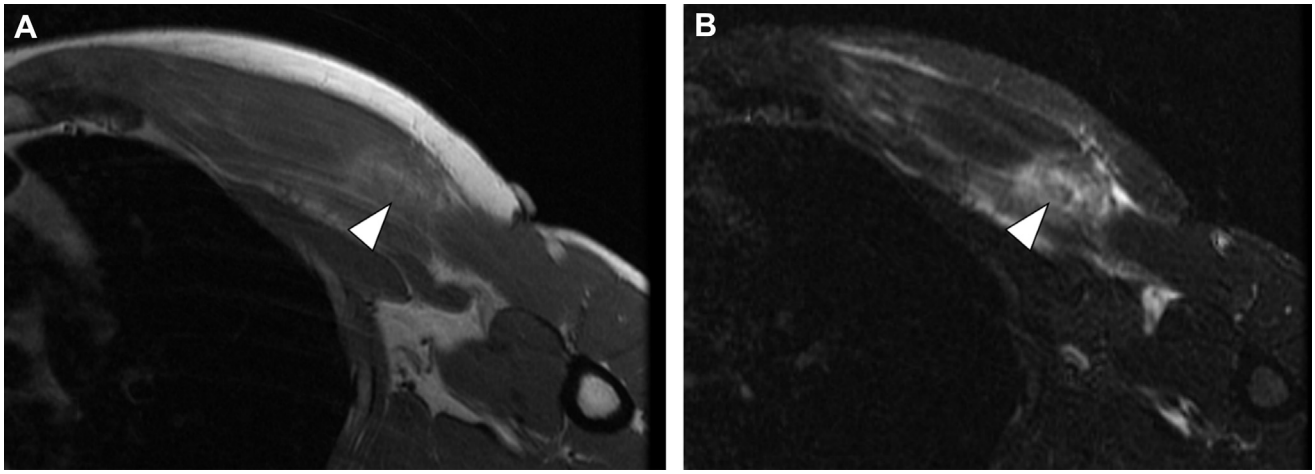

Figure 2 (**A, B**) Left shoulder magnetic resonance imaging showing complete rupture and retraction of sternal head of pectoralis major tendon at humeral insertion (*arrowheads*).

classify the injury to counsel the athlete regarding appropriate treatment options.

Surgical technique

When surgery is indicated, we prefer to operate acutely within 1 to 2 weeks of injury. Surgery is performed with the patient under combined regional and general anesthesia in the beach-chair position and the ipsilateral forearm positioned in a mechanical arm-supporting device. Standard draping of the affected upper extremity is performed, and the surgical field is isolated with an Ioban drape (3M, St Paul, MN, USA). The arm is positioned in slight flexion and abduction, and we prefer a limited, distal, deltopectoral approach.

A modified approach to the isolated sternocostal head injury has been described in brief.[3] What follows is a more detailed description of our preferred surgical technique: We use an approach with a limited deltopectoral skin incision. A key point in the surgical approach is to note that the deltopectoral interval remains visually intact in isolated sternocostal head tears in contrast to complete ruptures of both heads where the clavicular head will retract (Fig. 3). There is no need to develop the deltopectoral interval between the anterior deltoid and clavicular head of the pectoralis major, nor is it necessary to detach the clavicular head for adequate exposure. After dissection through subcutaneous fat, exposure is continued inferomedially via a combination of blunt and sharp dissection to identify the injured sternocostal tendon located in the interval between the intact clavicular head and the subcutaneous tissue (Fig. 4). Similarly to complete injuries, a hematoma is often encountered in this location and helps identify the ruptured tendon.

Once identified, the tendon is mobilized and prepared for repair. We place 2-4 No. 5 FiberWire sutures (Arthrex, Naples, FL, USA) in a modified Krackow configuration, taking care to capture both the superior and inferior surfaces of the muscle-tendon unit (Fig. 5). A retractor displaces the clavicular head superolaterally, exposing the tendon insertion site lateral to the bicipital groove. It is important to remember that the sternocostal head extends posterior and proximal to the clavicular head within the footprint. Residual soft tissue is débrided from the anticipated repair site, and 2 or 3 (depending on the ruptured tendon dimension) longitudinally staggered unicortical drill holes are made using a 3.2-mm drill pin for the Arthrex Proximal Biceps Button. The Arthrex Pec Button has been previously used for this technique,[13,15] but we have transitioned to using the Proximal Biceps Button because we have found that it more reproducibly and predictably deploys into the intramedullary canal.

During drilling, the pin is angled slightly proximally with respect to the long axis of the humerus, which provides an elongated entrance into the intramedullary canal, thereby affording more space in which to flip the button. Two, or occasionally three, Proximal Biceps Buttons are used for isolated sternocostal head ruptures, and each button is paired with one of the previously placed No. 5 FiberWire sutures. A shuttling device is used to thread the suture limbs in opposing directions through their respective buttons. The arm is then brought into an adducted, neutral-rotation position. The buttons are positioned on their inserting devices and deployed within the intramedullary canal of the humerus. Alternating tension is applied to the suture limbs, pulling the sternocostal head tendon for delivery onto its prepared footprint. Each button is then secured with standard knot-tying techniques. Intraoperative fluoroscopy is used to confirm correct button positioning and deployment within the intramedullary canal of the humerus (Fig. 6). Finally, the wound is irrigated and closed in layers, and the extremity is secured in a sling.

Postoperative rehabilitation

Rehabilitation is the same as for complete pectoralis major tendon ruptures. The patient remains in a sling for 4 to 6 weeks. Between weeks 6 and 12, rehabilitation focuses on regaining range of motion and beginning initial strengthening. Patients are allowed to return to unrestricted activity no sooner than 5 months after surgery, pending appropriate progress in their rehabilitation.

Results

Twenty-one athletes with isolated ruptures of the sternocostal head of the pectoralis major were followed up for a

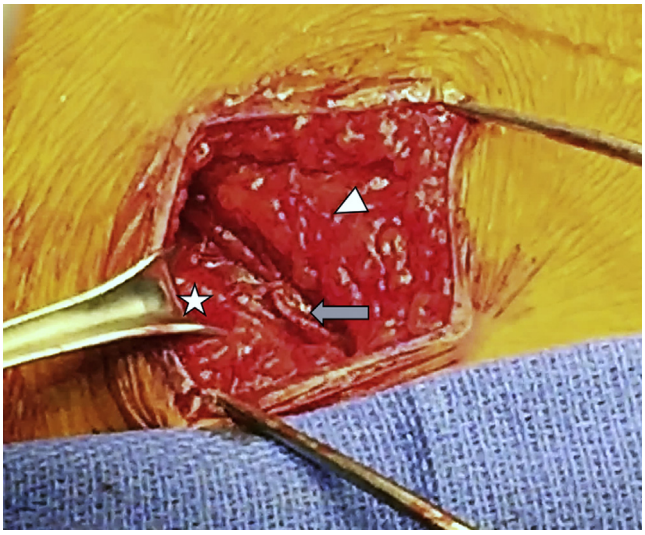

Figure 3 Distal deltopectoral approach in left shoulder and visually intact deltopectoral interval in isolated sternocostal head rupture. The *arrowhead* indicates the deltoid; ⇦, cephalic vein; and *star*, intact clavicular head.

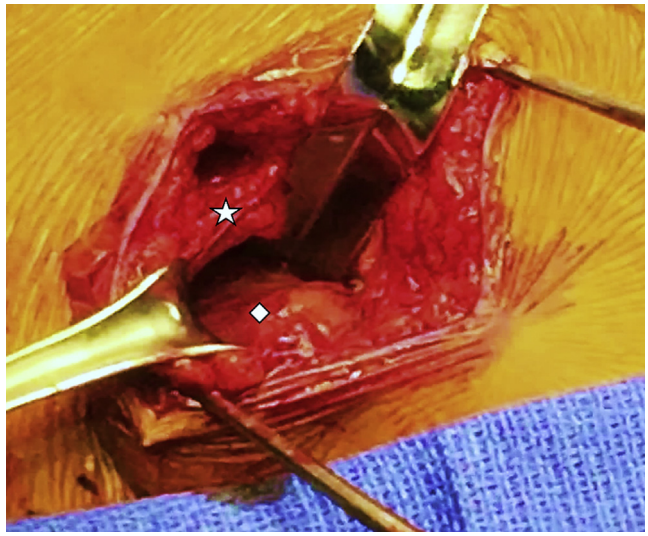

Figure 4 The inferior border of the intact clavicular head in a left shoulder is retracted superiorly to reveal the sternocostal head tear. The sternocostal head (*diamond*) lies in the interval between the inferior border of the clavicular head (*star*) and the subcutaneous tissue.

minimum of 2 years after repair. These 21 athletes were all men and ranged in age from 21 to 59 years (mean age, 35 years). All injuries occurred during athletic activity, with 57% occurring during the bench press. Two of the athletes were football players in the National Football League, and two were high-level Division 1 college athletes. The dominant extremity was affected in 67% of cases. Radiographic findings were negative for an avulsion fracture in all athletes, and MRI revealed complete tears of the isolated sternocostal head in all athletes. Of these athletes with complete sternocostal head tears, 17 (81%) had Tietjen type IIIC (myotendinous junction) tears and 4 (19%) had Tietjen type IIID (tendon) tears.

Postoperative SANE scores averaged 90.1 (standard deviation, 8.4), with patient satisfaction of 9.5 of 10 (standard deviation, 0.9). All athletes returned to sport at approximately 5.5 months postoperatively. Isokinetic strength evaluation revealed an average decrease of 8%. The average preinjury bench-press weight of 134 kg (range 88-227 kg) was restored to 117 kg (range 61-250 kg) postoperatively (Table I). No patient required a second surgical procedure, and no postoperative wound complications or infections occurred within the entire cohort of 21 athletes.

Discussion

The incidence of pectoralis major injuries reported in the medical literature increased significantly over the past few decades.[5,6,8,9,16] A systematic review published in 2012 identified 365 cases of pectoralis major injury, of which only 25 were identified as complete sternocostal head

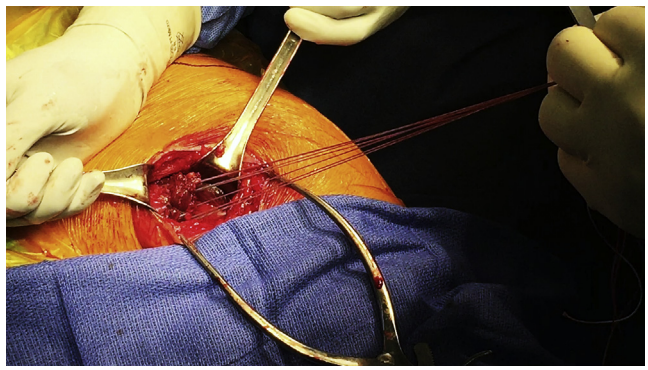

Figure 5 Intraoperative image of modified Krackow configuration with 4 pairs of suture limbs passed through muscle-tendon junction of sternocostal head in left shoulder.

ruptures and 9 were partial injuries involving the sternocostal head.[8] Garrigues et al[9] reported the results of a case series consisting of 19 patients available for follow-up in a cohort of 24 patients with sternocostal head ruptures repaired using a transosseous or suture anchor technique. Subsequent to these 2 publications, over 600 pectoralis major tendon repairs have been added to the medical literature.[5,6,16] Balazs et al[5] reported on a series of 291 active-duty military personnel who had undergone pectoralis major repair. Myotendinous injuries were sustained in 39.9% of these patients, tendinous insertion injuries occurred in 39.9%, and the remainder were listed as multiple-site or unspecified injuries. As this was a large military database study, the authors could not differentiate between 2-tendon tears and isolated sternocostal tears.[5] Nute et al[16] published a series of 257 active-duty military

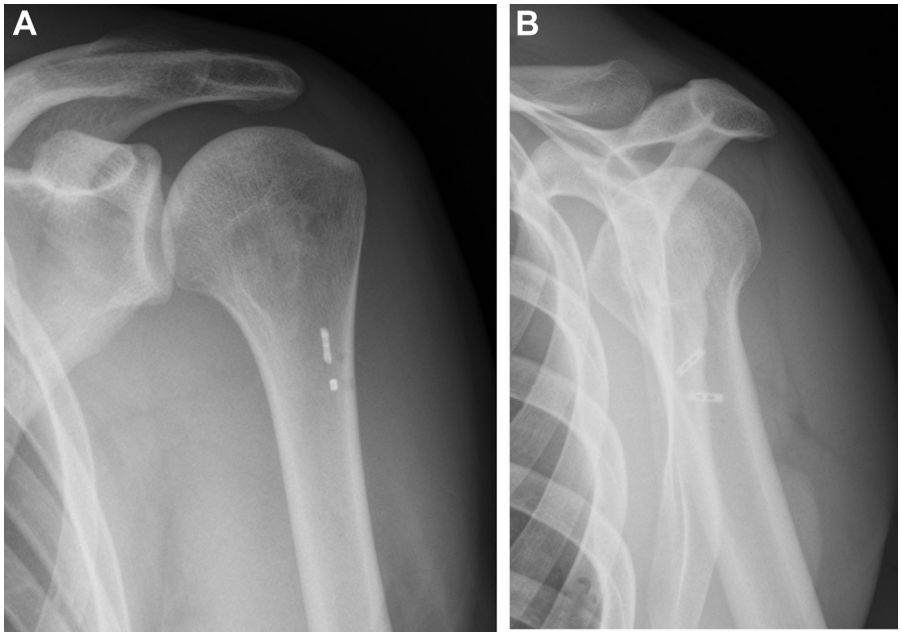

Figure 6 (**A, B**) Radiographic imaging showing buttons deployed within intramedullary canal of left humerus.

personnel after pectoralis major repair and noted that complete tears were present in 120 patients, isolated sternocostal head tears were found in 83, isolated clavicular head tears were present in 3, and the location was unspecified in 28. Cordasco et al[6] reported the largest single-surgeon series to date, comprising 40 consecutive athletes with minimum 2-year follow-up after pectoralis major repair, and noted that 23 of 40 patients had sustained isolated sternocostal head tears, with the remaining 17 having complete tears. From these reports, it appears that isolated sternocostal head tears represent between one-third and one-half of all operatively treated pectoralis major tendon tears. These studies did not describe in detail the surgical approach to the isolated sternocostal head tear or how it may differ from the surgical approach to the complete 2-tendon tear.

The biomechanical strength of various pectoralis major tendon repair techniques has been evaluated in several recent studies. The intact uninjured tendon withstands a significantly higher load to failure than constructs using either cortical button, suture anchor, or transosseous repair techniques.[22] Cortical button fixation was developed as an alternative tendon-to-bone fixation that diminishes stress risers in the proximal humerus. The technique is technically reproducible and allows sequential tightening of the tendon to the footprint.[13,15] Gregory et al[10] evaluated cortical button fixation with different suture configurations including modified Mason-Allen and Krackow locking sutures. Configurations using Krackow sutures were significantly stronger on load-to-failure testing. Rabuck et al[20] compared bone trough, suture anchor, and cortical button fixation techniques using Krackow suture configurations in each. Although a statistically significant difference in construct strength was found favoring the bone trough group over the suture anchor group, no statistically significant difference in strength was found between the bone trough and cortical button groups. The technique used in our series is specific to isolated sternocostal head tears with respect to the surgical approach. The method of fixation is used for both isolated sternocostal head and 2-tendon tears and was selected based on the ease of use and reproducibility of the technique in addition to the supportive biomechanical data previously noted.

The original classification system for pectoralis major injuries was developed by Tietjen[23] in 1980 and included 3 types of injury (Table II): The Tietjen type I injury was defined as a contusion or sprain; type II injury, a partial tear; and type III injury, a complete tear. Type III injuries were further classified into the following subdivisions: IIIA, muscle origin; IIIB, muscle belly; IIIC, musculotendinous junction; and IIID, tendon. Bak et al[4] modified the Tietjen classification by adding type IIIE (bony avulsion) and type IIIF (tendon substance rupture).

As the frequency of pectoralis major injuries reported in the literature has increased, the differentiation between complete tears of both clavicular and sternocostal heads and partial tears involving a single head has been recognized.[6,9] Isolated tears of the sternocostal head are the more frequent of these single-tendon injuries.[6] Unfortunately, the current classification systems do not clearly distinguish between these injury patterns. The isolated sternocostal head tear is most commonly injured at the myotendinous junction.[6] This injury pattern has sometimes been considered unrepairable because of the limited amount of tendon remaining with the sternocostal head

Table I Clinical results

	Age, yr	Mechanism of injury	Primary sport	SANE score (0-100)	Difficulty playing sport	Bench-press weight, kg		Patient satisfaction (0-10)	Isokinetic strength, kg		Isokinetic strength vs. control, %
						Before injury	After injury		Injured	Control	
Patient No.											
1	23	Bench press	Exercising	80	Mild	111	—	7	51	54	94
2	32	Basketball	Basketball	70	None	102	82	9	50	59	86
3	36	Bench press	Weightlifting	90	Mild	—	—	—	—	—	—
4	42	Bench press	Weightlifting	85	Mild	143	93	8	56	60	93
5	33	Bench press	Tennis/ racquetball	95	None	96	95	10	65	59	110
6	48	Bench press	Exercising	96	None	100	82	10	44	46	96
7	36	Bench press	Fitness	95	None	143	111	9.5	61	56	109
8	23	Bench press	Weightlifting	80	None	161	—	10	54	61	88
9	27	Football	Football	100	None	—	—	10	—	—	—
10	25	Bench press	Weightlifting	95	None	95	—	10	—	—	—
11	59	Skiing	Weightlifting	80	Mild	113	—	10	—	—	—
12	34	Arm wrestling	Weightlifting	85	None	—	—	8	67	65	103
13	36	Brazilian jiu-jitsu	Mixed martial arts	95	None	—	—	9	44	49	89
14	26	Bench press	Football	100	None	227	249	10	—	—	—
15	28	Weightlifting	Boxing, Olympic lifting	80	Mild	188	143	10	75	89	84
16	46	Bailing out of window (fireman)	Cycling, weightlifting	90	Mild	88	63	9	33	42	80
17	49	Skiing	Running, fly fishing	100	None	125	—	10	71	67	107
18	42	Bench press	Weightlifting, handball	90	None	143	—	10	65	82	80
19	25	Bench press	Rugby	100	None	166	172	10	72	87	83
20	35	Bench press	Volleyball, weightlifting	92	Mild	111	86	9.5	42	53	79
21	21	Weightlifting	Football	95	Mild	159	—	10	43	48	91
Average				90		134	117	9	56	61	92
SD				8		38	57	1	13	14.	0

SANE, Single Assessment Numeric Evaluation; *SD*, standard deviation.

Table II Tietjen classification of pectoralis major tears

Type I: contusion or sprain
Type II: partial tear
Type III: complete tear
A: muscle origin
B: muscle belly
C: myotendinous junction
D: tendon
E: bony avulsion (Bak modification)
F: Tendon substance rupture (Bak modification)

Table III Cordasco classification of pectoralis major tears

Type I: Contusion or strain
Type II: tear of isolated single head
A: muscle origin
B: muscle belly
C: myotendinous junction
D: tendon
Type III: tear of combined heads
A: muscle origin
B: muscle belly
C: myotendinous junction
D: tendon
E: bony avulsion

noted on imaging. This is an important point given that 17 of the 21 athletes (81%) in this series had myotendinous tear patterns. Confusion as to whether a single-tendon injury should be classified as a partial or complete injury can contribute to similar confusion in treatment decision making given the reported division between nonoperative and operative management for these classifications. Furthermore, the described surgical repairs often neglect the subtleties between 2-tendon and single-tendon repair techniques.

Proposed classification of pectoralis major injury

As a result of the inadequacies of the Tietjen classification and Bak modification, we propose a new classification of pectoralis major injury, developed by the senior author, based on the improved understanding of the clinical relevance of these injuries (Tables II and III). The original Tietjen type I injury was described as a contusion or sprain; we reclassify this as a muscle contusion or strain because the term ''sprain'' refers to ligamentous injury. The original Tietjen type II injury was described as a partial tear, which has led to some confusion in the literature, as noted earlier. We reclassify this as a complete tear of an isolated single tendon. We reclassify the Tietjen type III injury as a complete tear of 2 tendons (sternocostal and clavicular heads). We maintain Tietjen subcategories A, B, C, and D for both type II and type III injuries, and we add Bak type IIIE (bony avulsion) as an additional although rare subcategory within the cohort comprising a complete tear of 2 tendons. We do not believe Bak type IIIF (tendon substance rupture) is clinically useful because the treatment recommendation is the same for any injury within the tendon. For the clinical decision regarding treatment, types IIC and IID and types IIIC, IIID, and IIIE are indicated for surgery in young active athletes whereas types I, IIA and IIB, and IIIA and IIIB would be managed nonoperatively. We believe that this new pectoralis injury classification provides a more accurate description of the spectrum of pectoralis major injuries, facilitates clinical decisions regarding treatment, and improves the communication about this injury within the medical community.

The reports in the literature with respect to postoperative return to function have shown satisfactory findings.[5,6,9,16] Nute et al[16] reported that 94% of the 257 patients in their series returned to full function. Similarly, 95.3% of the 214 patients in the study of Balazs et al[5] returned to full duty. Garrigues et al[9] reported an average SANE score of 93 in 19 patients available for follow-up. The average preoperative bench-press weight of 144 kg was restored to 120 kg at follow-up. Cordasco et al[6] reported on a consecutive series of 40 athletes with pectoralis major repair at minimum 2-year follow-up. Postoperative SANE scores averaged 93.6.

Complications and second surgery rates after pectoralis major repair have also been reported in the literature, with differences noted between large multicenter database studies and single-surgeon series.[5,6,9,16] Balazs et al[5] used a large military database to obtain postoperative complications and outcomes in a large series of pectoralis repairs. Of the 214 patients with a minimum 12-month follow-up, 29 (13.5%) had complications, 12 (5.6%) had infections, and 7 (3.3%) required reoperations. Nute et al,[16] in a similar study, noted significant surgical-site morbidity, with an overall complication rate of 23%. A total of 41 major complications occurred in 31 patients (12%). The authors reported a 5.8% rate of rerupture after repair and a 4.7% rate of wound complications requiring a return to the operating room. Altogether, 21 patients (8.1%) required a second surgical procedure.[16]

Garrigues et al[9] reported no incidences of second surgery or postoperative wound complications. In a similar single-surgeon series, excluding 2 reinjuries in the early postoperative period due to noncompliance, Cordasco et al[6] reported a second surgery rate of 2.5% (1 athlete required tenodesis of the long head of the biceps 5 months after repair). No postoperative wound complications or infections occurred within the entire cohort of 82 athletes.

Our findings in this series of 21 athletes with isolated sternocostal head repairs—a mean SANE score of 90.1, a mean patient satisfaction score of 9.5 of 10, an 8% strength deficit compared with the contralateral side,

and the preoperative and postoperative bench-press metrics—compare favorably with the data available in the published literature. In addition, no infections, hematomas, or wound complications occurred, and none of the patients required a second operation.

The limitations of this study are multiple. Although SANE scores were available for all patients, the bench-press and isokinetic strength data were incomplete. This study represents a single-surgeon series and therefore may not be generalizable. The repairs were not routinely imaged postoperatively; therefore, quantification of repair integrity is not possible.

Conclusion

In our experience, isolated sternocostal head tears are a common injury within the spectrum of pectoralis major injuries. In addition, the majority of tears within this group are of the myotendinous variety. However, these injuries have not been sufficiently delineated in the current classification schemes or published repair techniques. We believe the new classification of pectoralis major injury that we have been using is a more accurate description of the spectrum of pectoralis major injuries, facilitates clinical decisions regarding treatment, and improves the communication about this injury within the medical community. With the modifications we have described regarding the surgical approach, repair options for isolated sternocostal head ruptures are similar to those for complete ruptures of both the sternocostal and clavicular heads in our experience. We present a biomechanically sound repair technique that takes the specific anatomy of the sternocostal head into account during the surgical approach. Using this technique in this series of athletes, we found predictable, reproducible and favorable clinical results. No patient required a second surgical procedure, and no postoperative wound complications or infections occurred within the entire cohort of 21 athletes.

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