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Systematic review on the incidence, operative treatments, and outcomes of deltoid ruptures

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Background: A deltoid rupture can result in significant losses of shoulder function, and in the setting of a rotator cuff tear, the deltoid serves as the sole abductor of the shoulder. Deltoid ruptures can be secondary to trauma, a consequence of massive rotator cuff tears, or a result of postoperative complications. There is a paucity of literature on the management of deltoid ruptures. In this systematic review, we aim to report on the incidence of deltoid ruptures, the surgical treatment options, and the outcomes following operative treatment.

Methods: A literature search was conducted on February 1, 2023 on MEDLINE and Google Scholar. Titles and abstracts were screened and the full text versions of articles that met criteria were reviewed. Criteria for inclusion included peer-reviewed studies evaluating the outcomes following surgical treatment of deltoid ruptures (direct repair, mobilization, reconstruction, and pedicled pectoralis transfer, with or without a reverse total shoulder arthroplasty). Secondary outcomes included incidence and causes of deltoid ruptures.

Results: A total of 101 studies were retrieved. After review and additional studies identified from reference lists, a total of 14 studies were included in the review. The incidence of deltoid ruptures ranged from 0.3% to 7%, and large, full-thickness rotator cuff tears were found to be a significant risk factor. Surgical treatment options for deltoid ruptures include direct repair, rotationplasty, and pedicelled muscle-tendon transfers; and when indicated, these procedures can be paired with a reverse total shoulder replacement. Postoperatively, the operative extremity should be immobilized in the position of least tension (forward flexion and abduction, 30°-70°) for 4-8 weeks. Most patients in this systematic review who underwent surgical treatment of their deltoid rupture had significant improvements in pain and mean postoperative forward elevation and abduction above 90°.

Discussion: The current available literature demonstrates that direct deltoid repair, rotationplasty, or reconstruction (muscle tendon transfer) with or without a concomitant reverse total shoulder arthroplasty can be an acceptable treatment option in patients with deltoid defects and massive rotator cuff tear. The average shoulder flexion and abduction increased postoperatively with improvements in pain.

The deltoid is the primary force generator of the shoulder, which contributes up to 75% of maximal shoulder strength; therefore, a deltoid rupture can result in a significant loss shoulder function.[12] In the setting of a rotator cuff tear, the deltoid can serve as the sole abductor of the shoulder.

Deltoid ruptures can be secondary to trauma, a consequence of massive rotator cuff tears, or a result of a postoperative complication. In the absence of a functioning rotator cuff, increased forces are placed on the deltoid due to the altered biomechanics of the glenohumeral articulation in a rotator cuff deficient shoulder. The activation of the deltoid in a rotator cuff deficient shoulder can lead to proximal migration of the humeral head leading to impingement

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.
The Department of Clinical Investigations Institutional Review Board at Tripler Army Medical Center approved this study as Institutional Review Board exempt.
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of the deltoid origin against the acromion. This can cause deltoid muscle fiber degeneration that can result in a proximal deltoid origin rupture.[1,6,17] Moreover, muscle weakness associated with aging and injuries to the axillary nerve have been found to result in atraumatic deltoid ruptures. There has been reported association between rotator cuff tears and deltoid ruptures.[2]

The incidence of spontaneous or traumatic deltoid ruptures and tears is unknown. There is a paucity of literature on the management of deltoid ruptures, operative options, and expected outcomes following operative treatment. In this systematic review, we aim to report on the incidence of deltoid ruptures, the surgical treatment options, and the outcomes of operative treatment.

Materials and methods

Search strategy

A systematic review on the incidence of deltoid ruptures, the surgical treatment options, and the outcomes of operative treatment was performed. A literature search was performed in accordance with the Preferred reporting Items for Systematic Reviews and Meta-Analysis guidelines.[16] We searched MEDLINE and Google Scholar on February 1, 2023. Medical Subject Headings terms and keywords used for the search included various combinations of the following: "Deltoid Tear", "Deltoid Rupture", and "Deltoid Avulsion". The MEDLINE search used was as follows: deltoid tear [Title/Abstract] OR "deltoid rupture" [Title/Abstract] OR "deltoid avulsion" [Title/Abstract]. A Google Scholar search was conducted and used as follows: allintitle: deltoid tear OR rupture OR avulsion OR loss -ankle -foot -tibia -talus. For each of the searches, the titles and abstracts were screened and the full-text versions of articles that met criteria were downloaded. Full texts were reviewed and any referenced articles that were not already obtained were obtained. "Related citations" were reviewed during the searches, and the "cited by" function on Google Scholar was used to identify any additional studies.

Study selection

Criteria for inclusion included peer-reviewed studies (published articles or abstracts) evaluating the outcomes following surgical treatment of deltoid ruptures (direct repair, mobilization, reconstruction, and pedicled pectoralis transfer, with or without a reverse total shoulder arthroplasty). Secondary outcomes included incidence and causes of deltoid ruptures. Only English language studies were included. Exclusion criteria included deltoid ruptures with a pathologic source and nonoperative management of the deltoid rupture.

Data abstraction and study quality assessment

Authors K.M. and S.K. independently performed a search of the literature and screened titles and abstracts. Full articles were reviewed and selected per the inclusion/exclusion criteria. For the selected articles, author B.C. extracted data from each article. The decision to include the articles was made by consensus.

The methodological index for nonrandomized studies (MINORS) criteria were used to evaluate the quality of the included studies. The instrument consists of 12 items that are assessed for each individual study. Items are scored 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate). The global ideal score is 16 for noncomparative studies and 24 for comparative studies.[21]

Results

After the initial search query, a total of 101 titles were screened for relevance. Twenty-five studies were resulted on PubMed and 76 on Google. Titles were screened and studies not in English language reported on pathologic causes of deltoid ruptures, and duplicate studies were excluded. Of the abstracts reviewed, 76 abstracts were excluded, and 25 potential studies were identified for full manuscript review. Upon full manuscript review, 14 studies met final criteria and were included in this review (Fig. 1).

Incidence of deltoid ruptures

Four articles discussed the rates and incidence of deltoid ruptures. The average MINORS score for the articles was 7. The incidence of deltoid ruptures ranged from 0.3% to 7% among study participants, and most patients had concomitant rotator cuff tears.[2,3,10,13] Most of the patients in the study presented with pain in shoulder and decreased range of motion in flexion and external rotation. Postoperative deltoid ruptures generally have poor outcomes.

Large, full-thickness rotator cuff tears were found to be a significant risk factor for deltoid ruptures. Alharbi et al conducted a cross-sectional study of 271 shoulders and found the incidence of deltoid tears at 7% with a mean age of 65 years in patients with rotator cuff tears.[2] However, the incidence may be lower as Ilaslan et al conducted a retrospective analysis of 24 patients of 8562 total shoulders scanned on magnetic resonance imaging with an incidence of deltoid ruptures reported 0.3% with an average patient age of 73 years.[13] All patients in this cohort also had a full-thickness rotator cuff tear.

With respect to the cause of deltoid rupture, several studies reported direct trauma without prior surgical treatment. Blazar et al encountered 3 patients with 4 affected shoulders that had proximal deltoid muscle detachments. All patients had sudden weakness and a decrease in shoulder function; risk factors included older age, female sex, and an associated rotator cuff tear.[3] Morisawa et al presented on 2 patients with spontaneous deltoid ruptures with an associated massive rotator cuff tear. One patient was a farmer who had an atraumatic rupture and underwent anterior acromioplasty, rotator cuff, and deltoid repair. The second patient had multiple steroid injections and was treated nonoperatively with continued impaired shoulder function.[17]

Postoperative deltoid ruptures were found to have poorer results. In a study by Groh et al, 36 patients had loss of deltoid function following open shoulder surgery and were referred to a single surgeon. Three of the patients had injuries to the axillary nerve, while 33 had damage to the muscle origin. Twenty-two of the 33 patients who suffered loss of the deltoid secondary to detachment of the anterior or anterior and lateral deltoid had poor shoulder function. Surgical correction was performed in 20 of the patients, which yielded generally poor outcomes.[10]

Direct deltoid repair

Four articles reported on direct deltoid repairs. The average MINORS score was 7.75 and all 4 studies were case reports. Patients in these studies all had improved pain, and reported satisfaction. From the available case reports, all patients demonstrated improved outcomes following a primary direct deltoid repair. The patient's age may impact outcomes; younger patients who underwent a direct repair were able to regain near-normal motion and strength. Therefore, a direct repair may be a viable option in patients based on chronicity and acuity of tear[1,4,5,11,20] (Table I).

There is 1 case report describing an isolated middle head of the deltoid tear. Calcei et al reported on a 27-year-old male with an isolated middle head of deltoid tear after a motor vehicle accident, who presented 4 months after the initial injury. He subsequently underwent a transosseous open deltoid repair. The patient had full painless range of motion and strength at 1 year postoperatively.[4]

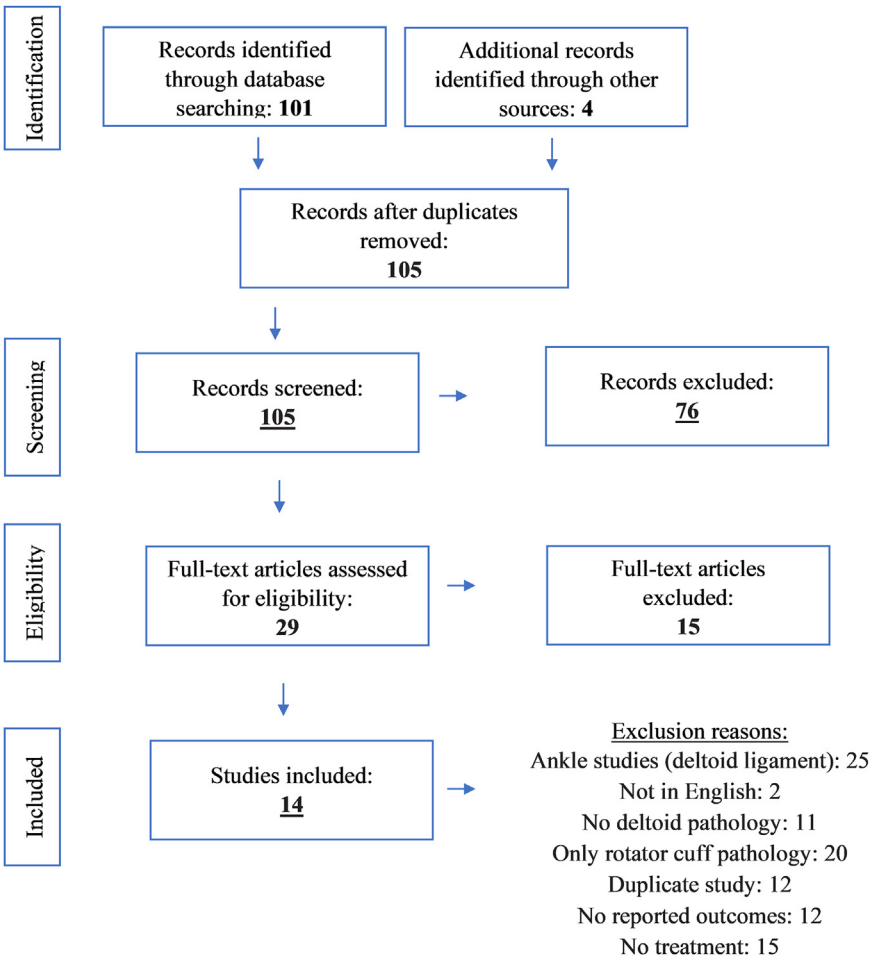

Figure 1 Search criteria for deltoid ruptures incidence and treatment.

Table I
Outcomes on deltoid repairs.

Study	N	ER		Flexion		CONSTANT		Recurrence/Failure
		Preop	Postop	Preop	Postop	Preop	Postop	N
Calcei et al, 2021[4]	1	-	-	-	-	-	27	-
Alben et al, 2022[1]	1	-	-	-	-	-	-	-
Han et al, 2012[11]	1	-	-	90	-	-	-	-
Sanderson et al, 2021[19]	1	-	-	-	170	-	-	-

ER, external rotation.

Patient age may play a role in outcome as Alben et al reported on a 73-year-old female with an atraumatic rupture of the anterior and middle deltoid with a concomitant massive rotator cuff tear. The patient refused a reverse total shoulder arthroplasty and 9 days post injury underwent a direct suture transosseous acromion repair of the anterior and middle deltoid using with sutures fixation and a plate serving as a washer without rotator cuff repair. At 1 year postoperatively, she reported overall shoulder function was grossly unchanged with a Single Assessment Numeric Evaluation score 30%; however, pain had improved.[1]

Conversely, Han et al reported on a 21-year-old active-duty trainee with a deltoid rupture who had failed 3 months of nonoperative management. At the time of surgery, he was found to have a 2-cm anterior deltoid defect with 2 cm of retraction that was addressed with a direct repair using transosseous technique. He was able to return to duty; his strength and function had fully recovered at 6 months.[11]

Direct repair of deltoid and concomitant rotator cuff tear may show favorable outcomes. Chiba et al reported on a 53-year-old male with an anterior deltoid detachment and supraspinatus tear who underwent surgical repair of the torn anterior deltoid and supraspinatus tendon 2 months out from injury. Intraoperatively, there was a 6-cm anterior deltoid defect, with 5 cm of retraction. Both the deltoid and supraspinatus were directly repaired, and the patient's shoulder function returned to near baseline at 12 months. The patient's final follow-up demonstrated full strength with 150° of active forward elevation and 150° of active abduction. His Japanese Orthopaedic Association score increased from 81 to 97.[5]

Table II
Outcomes on deltoid repair and reverse total shoulder replacement.

Study	N	ER		Flexion		CONSTANT		Recurrence/Failure
		Preop	Postop	Preop	Postop	Preop	Postop	N
Garafolo et al, 2016[8]	18	22.4 ± 3.6	33.7 ± 4.7	53 ± 9.1	132.7 ± 11.6	42 ± 6.1	73.3 ± 8.2	-
Marinello et al, 2016[14]	5	12 ± 16	22 ± 13	48 ± 39	120 ± 41	-	-	-
Martin et al, 2021[15]	1	15	30	30	130	-	-	-

ER, external rotation.

Deltoid repair and reverse total shoulder replacement

Three articles were selected and reviewed for direct deltoid repairs and reverse total shoulder replacement[8,14,15] (Table II). The average MINORS score for the 3 articles was 10.3; there were 2 case series and 1 case report. Favorable results were shown with direct deltoid repairs and concomitant reverse total shoulder arthroplasty; and when direct repairs were not possible, deltoid rotationplasty can be performed with favorable results.

Garofalo et al conducted a case series of 18 patients who underwent a reverse total shoulder replacement with direct repair of the deltoid using transosseous tunnels. In all cases, the deltoid was mobilized to perform direct repair. All patients had improvements in Constant scores from 42 to 72.3. Mean postoperative active forward flexion increased from 53° to 132°, and external rotation improved from 22.4° to 33.7°.[8]

In cases with larger deltoid defects, deltoid rotationplasty may be a viable option. Marinello et al reported on 6 shoulders in 5 patients who underwent a concomitant reverse total shoulder replacement and deltoid repair or rotationplasty. In all patients, the anterior and/or middle deltoids were ruptured, and the posterior deltoid was intact. When a direct deltoid repair was not possible, the middle and/or posterior deltoid was mobilized and rotated to fill the defect. The average age of the patients was 69 years, and the follow-up period was 76.8 months. Three of the shoulders had direct repair of the ruptured deltoid through transosseous tunnels and 3 required rotationplasty. One of the shoulders sustained a partial retear of the deltoid; only the anterior deltoid repair had a recurring defect. It was not repaired as the patient was satisfied as she had excellent pain relief and 100° of forward elevation. Postoperatively, average forward elevation increased from 48° to 120°, external rotation increased from 12° to 22°, and pain was improved.[14]

Finally, in the setting of rheumatoid arthritis, Martin et al reported a 58-year-old female with rheumatoid arthritis and rotator cuff arthropathy with a synovial cyst that underwent reverse total shoulder replacement and direct side-to-side middle deltoid repair. Two years postoperatively, the patient's forward elevation increased from 30° to 130°, and external rotation increased from 15° to 30°.[15]

Muscle tendon transfer and reverse total shoulder replacement

Three articles were included describing muscle tendon transfer for deltoid deficiency and reverse total shoulder replacement[7,9,22] (Table III). The average MINORS score was 9.67. In situations where the deltoid is irreparable or nonfunctional, a muscle tendon transfer can be performed to recreate deltoid function. A pedicled pectoralis or pedicled latissimus dorsi transfer are possible muscle tendon transfer options.

Elhassan et al reported on 31 patients with an average age of 51 years who underwent a reverse total shoulder arthroplasty with a pedicled pectoralis muscle transfer for deltoid paralysis and shoulder arthritis. Eight of these patients underwent an additional tendon transfer to restore external rotation (5 latissimus and 3 lower trapezius). After an average follow-up of 37 months, the 29 patients had no or mild pain. The postoperative range active elevation increased from 15° to 83° and abduction increased from 12° to 20°. The Subjective Shoulder Value increased from 7% to 53%, and Disabilities of the Arm, Shoulder and Hand scores improved from 54 to 33.[7]

Pectoralis tendon transfer was also described in case report by Wheelwright et al who described a 70-year-old male with a history of anatomic total shoulder replacement and Parsonage Turner neuropathy involving the anterior head of the deltoid, who previously failed a nerve transfer to restore the anterior deltoid. In addition to his neuropathic anterior deltoid, the patient had an irreparable rupture of the supraspinatus and subscapularis; subsequently, he underwent a revision total shoulder arthroplasty with a concomitant pectoralis major transfer. Preoperatively, he had pseudoparalysis with no ability to forward flex. At 1 year postoperatively, he was able to actively forward flex to 130°, externally rotate to 60°, and internally rotate to the lumbosacral spine.[22]

Pedicled latissimus dorsi transfer was reported by Goel et al who described a 68-year-old male treated with a reverse total shoulder replacement with concomitant pedicled latissimus dorsi transfer for deltoid deficiency secondary to failed previous open rotator cuff repair. The patient had an intact anterior and posterior deltoid; therefore, a pedicled latissimus dorsi transfer was used to fill the middle deltoid defect. Preoperatively, the patient was pseudoparalytic. At 1 year postoperatively, his forward elevation improved from 20° to 135°, and external rotation increased from 15° to 20°.[9]

Discussion

The anterior and middle heads of the deltoid, particularly the middle head, contribute to most of the shoulder's abduction strength.[18] In conjunction with the rotator cuff musculature, the deltoid also contributes to the stability of the shoulder. Damage to the rotator cuff musculature can cause impingement and arthropathy leading to degradation of the deltoid muscle. Large, full-thickness rotator cuff tears were found to be a significant risk factor for deltoid ruptures. Without the stabilizing forces of the rotator cuff muscles, deltoid activation leads to proximal humeral translation causing impingement of the deltoid origin against the edge of the acromion leading to muscle fiber degeneration with an increased risk of rupture.[1]

Deltoid ruptures are rare with limited reported literature as a result. The etiology of ruptures can be separated into either traumatic or atraumatic causes.[3,4] The atraumatic causes can be caused iatrogenic secondary to previous surgery, degeneration, or recurrent corticosteroid injections.[13,19] There are different advocated treatments by authors to include arthroplasty, muscle transfer, and arthrodesis, but overall no consensus on treatment. The studies available however do support repair or reconstruction of the deltoid in addition to a reverse total shoulder arthroplasty with low rates of failure.

Author recommendations

In reviewing the literature, proximal deltoid ruptures commonly involve the anterior and/or middle deltoid. The authors of this

Table III
Outcomes on muscle tendon transfers and reverse total shoulder replacement.

Study	N	ER		Flexion		DASH		Recurrence/Failure
		Preop	Postop	Preop	Postop	Preop	Postop	N
Elhassan et al, 2018[7]	31	20	16	15	83	54	33	2
Wheelwright et al, 2022[21]	1	0	30	0	130	-	-	-
Goel et al, 2012[9]	1	15	20	20	135	-	-	-

DASH, Disabilities of the Arm, Shoulder and Hand; *ER*, external rotation.

study recommend the following approach in the treatment of proximal deltoid ruptures. Regardless of chronicity and retraction, a direct transosseous repair to the clavicle and acromion can be successful. In situations where the torn deltoid cannot be mobilized sufficiently for repair, a rotationplasty may be an option. A rotationplasty involves mobilizing the intact anterior and/or posterior deltoid to cover the defect. Finally, if a rotationplasty is not possible, there is insufficient functional muscle or deltoid paralysis, a pedicelled muscle tendon transfer of the pectoralis major or latissimus dorsi can be performed.

Postoperatively, the operative extremity should be immobilized in the position of least tension (forward flexion and abduction, 30°-70°) for 4-8 weeks. In circumstances in which the patient has a concomitant irreparable rotator cuff tear or glenohumeral arthritis, a reverse shoulder replacement can be successfully performed. Most patients in this systematic review who underwent surgical treatment of their deltoid rupture had significant improvements in pain and mean postoperative forward elevation (>90 degrees) and abduction (>90 degrees).

Strengths and limitations

The strengths of this study include robust search terminology with a wide retrieval of available literature and a systematic and comprehensive literature search with a predetermined search strategy. All studies were reviewed by each author and data extraction was done independently. While there was no uniform measure of patient outcome measures, overall trends in improvement were noted.

The limitations of this study include the wide heterogeneity of available research. While reported studies show promising function and outcomes in patients, the studies use different outcome measures which made it difficult to provide objective conclusions. The results were limited to retrospective case reports and case series (Level IV) with no control or prospective research design. Further prospective and case control studies could help further elucidate the preferred treatment options.

Conclusion

The current available literature demonstrates that direct deltoid repair, rotationplasty, or reconstruction (muscle tendon transfer) with or without a concomitant reverse total shoulder arthroplasty can be an acceptable treatment option in patients with deltoid defects and massive rotator cuff tear. The average shoulder flexion and abduction increased postoperatively with improvements in pain.

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