



Terrible triad injuries are no longer terrible! Functional outcomes of terrible triad injuries: a scoping review



Thomas Stambulic^{a,1}, Veeral Desai, BHSc^{a,1}, Ryan Bicknell, MD^b, Parham Daneshvar, MD^{b,*}

^aSchool of Medicine, Queen's University, Kingston, ON, Canada

^bDepartment of Orthopaedic Surgery, Queen's University, Kingston, ON, Canada

ARTICLE INFO

Keywords:

Terrible triad
Radial head fracture
Coronoid process fracture
Elbow fracture-dislocation
Mayo Elbow Performance Score
Disabilities of the Arm
Shoulder and Hand (DASH)

Level of evidence: Level III

Background: The terrible triad injury (TTI) of the elbow is a combination of a posterolateral dislocation of the elbow joint combined with fractures of the radial head and coronoid process most often caused by a fall on an outstretched hand. The injury pattern was named for its poor outcomes and high complication rates following surgical repair, but increased understanding of elbow anatomy and biomechanics has led to the development of standardized surgical protocols in an attempt to improve outcomes. Most existing literature on terrible triad injuries is from small retrospective cohort studies and surgical techniques to improve outcomes. Therefore, the purpose of this scoping review is to provide an overview of the functional outcomes, prognosis, and complications following current surgical treatment of TTIs.

Methods: A scoping review was performed to evaluate the literature. In total, 617 studies were identified and screened by 2 reviewers, with 43 studies included for qualitative analysis. These 43 studies underwent data extraction for functional outcomes using the Mayo Elbow Performance Score (MEPS) and Disabilities of the Arm, Shoulder, and Hand score (DASH) and were stratified accordingly. Secondary outcome measures assessed in the study were a range of motion (ROM) and complication rate.

Results: The average MEPS was 90 (excellent) from a total of 37 studies with 1609 patients, and the average DASH score was 16 from 16 studies with 441 patients. Another 6 studies with a total of 127 patients reported a mean Q-DASH score of 13. A total of 39 studies consisting of 1637 patients had a mean forearm rotation of 135 degrees, and 36 studies consisting of 1606 patients had a mean flexion-extension arc of 113 degrees. Among the studies, there was a 30% complication rate with a need for revision surgery in 7.8% of cases. The most common complications were radiographic evidence of heterotopic ossification (11%) and ulnar nerve neuropathy (2.6%).

Discussion/Conclusions: This study shows that current surgical treatment for terrible triad injuries has resulted in improved outcomes. Based on primary outcome measures using MEPS and DASH scores, almost all of the studies have highlighted good or excellent functional outcomes. This highlighted the marked improvement in outcome scores since the term was coined, suggesting that terrible triad injuries may no longer be so terrible.

© 2022 The Authors. Published by Elsevier Inc. on behalf of American Shoulder & Elbow Surgeons. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

The terrible triad injury (TTI) of the elbow is a combination of a posterolateral dislocation of the elbow joint combined with fractures of the radial head and coronoid process.¹ Terrible triad injuries are most often caused by a fall on an outstretched hand resulting in a posterolateral load on the elbow joint.¹ This pattern of loading leads to rupture of the lateral ulnar collateral ligament from

its origin, radial head fracture and dislocation, and coronoid fracture.⁸ The medial collateral ligament may also be injured in some cases but is not required as a definition of the injury. Terrible triad injuries account for 10% of all radial head fractures,¹⁰ although minimal epidemiological evidence in the literature exists for the general prevalence of TTIs. Although most injuries can be diagnosed with plain radiographs, a computed tomography (CT) scan is routinely employed in patients with TTIs to identify fracture patterns, comminution, and displacement, which may not be evident on plain radiographs.⁷

First described in 1996 by Hotchkiss, the injury pattern was named for its poor outcomes and high complication rates following surgical repair, including heterotopic ossification,

Institutional review board approval was not required for this review article.

*Corresponding author: Parham Daneshvar, MD, Division of Orthopaedic Surgery – Victory 3, Department of Surgery, Kingston Health Sciences Centre, 76 Stuart St, Kingston, Ontario, K7L2V7, Canada.

E-mail address: pdane@vbjc.ca (P. Daneshvar).

¹ These authors share co-first authorship.

<https://doi.org/10.1016/j.xrrt.2022.01.002>

2666-6391/© 2022 The Authors. Published by Elsevier Inc. on behalf of American Shoulder & Elbow Surgeons. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

stiffness, nerve injury, instability, pain, posttraumatic arthritis, and recurrent subluxation or dislocation of the elbow.^{1,7} However, increased understanding of elbow anatomy and biomechanics has led to the development of standardized surgical protocols and novel approaches and techniques to attempt to improve outcomes for TTI patients.¹²

Currently, most of the literature on terrible triad injuries is from small retrospective cohort studies investigating specific approaches or protocols to improve surgical outcomes. Additionally, studies report different outcome measures, which make comparisons difficult. To our knowledge, there have been no other scoping reviews or systematic reviews assessing how current approaches and surgical protocols have changed outcomes. Over the years, surgeons have noted improved outcomes after these previously known terrible injuries; however, we continue to call these terrible triad injuries of the elbow. Therefore, the purpose of this scoping review is to provide an overview of the functional outcomes, prognosis, and complications following the current surgical treatment of TTIs. Our hypothesis is that with our improved understanding and treatment of these injuries, the outcomes are not as 'terrible'.

Materials and methods

Study design

A scoping review was performed to evaluate the literature based on established guidelines.⁵ This review was designed to assess the literature and identify knowledge gaps. This review combines both qualitative and quantitative properties through a systematic approach via a comprehensive search strategy and standardized study selection and evaluation. Due to heterogeneity in the articles reviewed, no meta-analyses were performed in this study.

Selection criteria

Studies were included if the following inclusion criteria were met: 1. publication after the year 2000; 2. use of human subjects; 3. Met the accepted criteria of a Terrible Triad Injury; and 4. Utilized the Mayo Elbow Performance Score (MEPS), Disabilities of the Arm, Shoulder, and Hand (DASH), or the Quick-DASH (Q-DASH) as one of the primary outcome measures. Exclusion criteria included (1) non-English language, (2) use of cadaveric subjects, and (3) publication in the form of an abstract, letter, editorial, or review article. It should be noted that all studies included exclusively contained terrible triad injuries. Studies that included a heterogeneous group of elbow fracture-dislocations were excluded during the full-text review.

Search strategies

MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, and Google Scholar were searched from January 2000 until December 2020. A search algorithm is outlined in [Supplementary Appendix S2](#).

Study selection

The article selection was performed over 2 rounds by 2 reviewers (VD and TS) using the Covidence platform in accordance with the PRISMA-ScR (Preferred Reporting Items for Systematic reviews and Meta-analyses extension for Scoping Reviews). During the first round, selection was based on the review of titles and abstracts. An article, to be as inclusive as possible, was carried forward to the next stage if either reviewer thought that the study was appropriate. In the second round, the final study selection was based on a full-text review using the aforementioned inclusion and exclusion criteria.

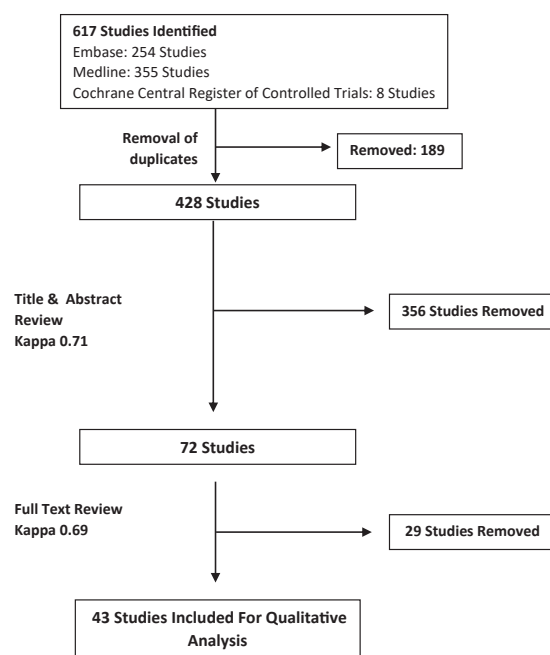


Figure 1 Outline of systematic search strategy used.

Duplicate studies were eliminated at the beginning of the process, using the Covidence software. The consensus was reached for final article inclusion through discussion among the investigators. The visual outline of this process can be viewed in [Fig. 1](#).

Data extraction

Both reviewers (VD and TS) extracted the study design, number of patients enrolled, the functional outcomes, range of motion metrics, and complication rates from each study. Once the data were confirmed, all data were transferred to the results section as viewed in [Tables I–IV](#).

Results

Article selection

Using the Medline, Embase, Cochrane Library, and Google Scholar databases, we identified 420 articles from our predefined search strategy. After the abstract screening, 72 remained for full-text evaluation, with 43 studies ultimately included in our literature review. The 43 studies meeting inclusion and exclusion criteria encompassed 1749 elbows and reported postoperative functional outcomes with the Mayo Elbow Performance Score (MEPS) or The Disabilities of the Arm, Shoulder, and Hand (DASH) or Quick-DASH metrics. Across all included studies, the mean age of patients was 45.14 years, with a mean follow-up of 31.9 months following surgery.

Functional outcomes

The 2 primary outcomes used in this study were the MEPS and DASH scoring systems. The Mayo Elbow Performance Score (MEPS) comprises 4 subscales on pain, range of motion, stability, and function of the elbow joint. The final score ranges from 5 to 100 points, and this is often summarized into 4 outcome classifications. A score of 90 or above denotes an excellent function, 75–89 a good function, 60–74 a fair outcome, and less than 60 denotes a poor outcome. The second outcome measure used is the Disabilities of

Table I
Functional outcomes and range of motion scores across all terrible triad injuries.

Outcome	Mean (range)	# Studies reporting	# Elbows
MEPS	90 (78-95)	37	1609
DASH	16 (7-22)	16	441
Q-DASH	13 (4-21)	6	127
ROM – flexion/extension	113 degrees (80-172)	36	1606
ROM- flexion	128 degrees (114-145)	28	756
ROM - extension	15 degrees (4-24)	26	707
ROM – pronation-supination	135 degrees (99-140)	39	1637
ROM - pronation	72 degrees (47-98)	30	789
ROM - supination	70 degrees (34-85)	30	789
Complications	30%	35	1499
Reoperations	7.8%	38	1061

MEPS, Mayo Elbow Performance Score; DASH, Disabilities of the Arm Shoulder and Hand; Q-DASH, Quick-DASH; ROM, range of motion.

Table II
Total complication rates across all studies.

Complication	Percentage
Heterotopic Ossification (radiographic)	11.2
Revision surgery/reoperation	7.9
Erosion (capitellar)	0.1
Infection	1.0
Neurological lesions	1.4
Stiffness	1.7
Ulnar impaction syndrome	0.1
Intra-articular fragment postoperatively	0.1
Osteolysis around radial head prosthesis	0.1
Instability	0.2
Ulnar nerve neuropathy	2.6
Delayed fracture unions or non-unions	1.0
Radio-ulnar synostosis	0.1
Soft tissue injury	1.0
Post traumatic arthritis or osteoarthritis	2.1
Dislocation	0.3
Subluxation	0.6

Table III
Functional outcomes and distribution of radial head fractures.

Mason fracture type	Mean MEPS (range)	# Studies reporting	# Elbows
I	93 (88-100)	12	36 (9%)
II	89 (70-96)	15	150 (37%)
III	87 (55-99)	16	217 (54%)

MEPS, Mayo Elbow Performance Score.

the Arm, Shoulder, and Hand Questionnaire (DASH). This is a 30-question survey on activities of daily living and specific symptoms, such as pain or paraesthesia of the upper limb. The degree of impairment is calculated via a score. The final DASH score ranges from 0 points (no impairment) to 100 points (the greatest possible functional impairment of the limb).

From a total of 37 studies with 1609 patients that included MEPS scores, an overall average MEPS of 90 (range: 78-95) was calculated, indicating an excellent return to function (Table I). Sixteen studies containing 441 patients reported a mean DASH score of 16 (range: 7-22) indicative of good outcomes. Another 6 studies with a total of 127 patients reported the shortened version of the DASH score (Quick-DASH or Q-DASH) with a mean Q-DASH of 13 (range: 4-21). (Table I)

Range of motion

Almost all studies included in our analysis included range of motion (ROM) outcomes for forearm rotation (pronation/supination) and flexion-extension arcs; 39 studies consisting of 1637 patients

had a mean forearm rotation of 135 (range: 99-140) degrees, 36 studies consisting of 1606 patients had a mean flexion-extension arc of 113 degrees (range: 80-172) (Table I), 28 studies consisting of 756 elbows had a mean flexion of 128 (range: 114-145), 26 studies containing 707 elbows had a mean extension of 15 short of full (range: 4-24), 30 studies encompassing 789 elbows had a mean pronation of 72 (range: 47-98) and mean supination of 70 (range: 34-85).

Other outcome measures

A number of the studies used additional outcome measures, including but not limited to the Oxford Elbow score, Broberg-Morrey, Visual Analog Scale (VAS), and the American Shoulder and Elbow Surgeons score (ASES). However, these outcome measures were not utilized often enough among the studies that were selected to warrant any significant analysis.

Complications and reoperations

A number of studies reported the complications associated with surgical treatment of the terrible triad. From the 42 studies encompassing 1734 elbows, which reported data for complications, the overall reoperation rate was 7.8%, and the overall complication rate (including radiographic heterotopic ossification) was 30%. Frequently identified complications are provided in Table II.

Radial head fracture type

For studies, including MEPS as a functional outcome, we identified 16 studies that differentiated outcomes based on the type of radial head fracture according to the Mason classification. Out of a total of 418 elbows: 36 (9%) were Mason Type 1, 150 (37%) were Mason Type 2, and 217 (54%) were Mason Type 3. The details regarding the type of radial head fractures and corresponding MEPS are demonstrated in Table III.

Coronoid process fracture type

We analyzed studies that classified fractures of the coronoid process according to the Regan-Morrey classifications. Functional outcomes stratified by the Regan-Morrey classification for coronoid process fractures are provided in Table IV.

Radial head fixation/excision compared with radial head arthroplasty

We identified results from studies that compared radial head arthroplasty to no arthroplasty. For patients treated with radial head arthroplasty, the mean MEPS was 88 (range: 55-98) from 226

Table IV
Functional outcomes and distribution of coronoid process fractures.

Regan-Morrey fracture type	Mean MEPS (range)	# Studies reporting	# Elbows
I	87 (68-88)	11	125 (50%)
II	89 (75-96)	11	103 (41%)
III	88 (68-100)	7	23 (9%)

MEPS, Mayo Elbow Performance Score.

Table V
Functional outcomes comparing radial head fixation/excision and radial head arthroplasty.

Fixation technique	Mean MEPS (range)	# Studies reporting	# Elbows
Non-arthroplasty	89 (78-96)	16	275
Radial head arthroplasty	88 (55-98)	17	226

MEPS, Mayo Elbow Performance Score.

Table VI
Functional outcomes comparing radial head fixation and excision.

Fixation technique	Mean MEPS (range)	# Studies reporting	# Elbows
Radial head fixation	88	9	149
Radial head excision	91	6	38

MEPS, Mayo Elbow Performance Score.

patients across 17 studies and a mean DASH score of 18 (range: 11-72) from 115 patients across 8 studies (Table V). For patients treated with no arthroplasty (which included fixation and excision) of the radial head, the mean MEPS was 89 (range: 78-96) from 275 patients across 16 studies and a mean DASH of 14 (range: 7-25) from 153 patients across 8 studies (Table V).

Among studies that included no arthroplasty of the radial head, they were divided into fixation versus excision. These outcomes are reported in Table VI.

Discussion

The purpose of this study was to evaluate the current outcomes and complications of terrible triad injuries. All studies included for analysis were published after the year 2000, with limited reports in the literature reporting on the injury prior to this time point. To our knowledge, the 43 studies with 1749 elbows included in our literature review comprise the most data cumulatively analyzed for terrible triad injuries. Although the ‘Terrible Triad’, first described by Hotchkiss in 1996, was originally named for its poor outcomes, the results we found suggest substantial improvement in outcomes since the injury’s original description. Most of the studies in our analysis were published within the last 10 years. We identified 2 studies^{3,10} published before 2010 with an average MEPS of 85 from 65 elbows, which was similar to the more recent studies. For functional outcomes, we found an average MEPS score of 90 from 1609 patients, indicating an excellent result with the score encompassing metrics of pain, range of motion, stability, and function of the elbow joint. Across the 37 studies, including MEPS scores, all had average scores reported as good to excellent (MEPS > 75). Similarly, the average DASH score of 16 from 441 elbows suggests good functional outcomes in daily activities following repair. The average range of motion scores identified (mean forearm rotation: 135/mean flexion-extension arc: 113) are also consistent with these findings. These findings demonstrate that the loss motion is mild, including minimal loss of extension and

supination for most patients. This information can help guide patients and treating physicians.

Radial head fractures range in severity from nondisplaced fractures to fractures with severe displacement and comminution. The Mason classification separates radial head fractures based on the location of the fracture and the amount of comminution and displacement involved, with Mason I fractures being the least severe and Mason III being the most.^{2,4} In most cases, type I fractures are treated conservatively, with brief immobilization followed by early motion, while Mason II and III fractures are often treated surgically.¹³ Naturally, stratification along Mason fracture types reflects MEPS scores correlating with the severity of the injury. It should be noted that MEPS scores were very high for all 3 categories. Mason I fractures received an excellent functional outcome status with a mean score of 93 over 12 studies. While both Mason II and III fractures fall into the good category, it should be noted that they both had scores approaching the excellent category (threshold of 90), with mean MEPS of 89 and 87, respectively. Additionally, both had sample sizes of greater than 150 elbows. This indicates strong recoveries of terrible triad injuries across all Mason fracture types. We were unable to separate the type IIIs into fixation versus arthroplasty and subsequently analyze how that affected the outcome. This is congruent with the literature, which highlighted the strongest range of motion recovery in Mason I fractures, followed by Mason II and Mason III fractures.⁶

The Regan-Morrey classification stratifies coronoid fractures in 3 groups based on the proportion of the coronoid involved as delineated on the lateral radiographic views of the elbow. From studies reporting outcomes using this classification, all 3 types landed in the good category with mean MEPS of 87 (Type I), 89 (Type II), and 88 (Type III). Of all the fractures using the Regan-Morrey classification, only 9% fell into the type III category, with the majority falling under type I (50%) and type II (41%). These findings are consistent with a meta-analysis by Schindelar et al¹¹ where no differences in functional outcomes were found comparing coronoid fixation to non-fixation, as well as coronoid ORIF to coronoid suture repair.

Complications

Complications were commonly found in patients who did not achieve good or excellent outcomes (MEPS score > 75). We found an overall reoperation rate of 7.9% and an overall complication rate of 30%. However, there was considerable variation between studies in terms of definitions and the reporting of complications, and whether these were described clinically or radiographically. The most common complication radiologically was heterotopic ossification (11%). The most frequent clinical complications were ulnar neuropathy (2.6%), post-traumatic osteoarthritis (2.1%), and stiffness (1.7%). The incidence of infection was 1.0%. In mild-moderate cases of heterotopic ossification found radiologically without symptoms, conservative management was generally adequate. Repeat surgeries were mostly identified in relation to infection, nonunion or malunion, hardware loosening, recurrent elbow instability, and/or posttraumatic arthritis.

With regards to surgical treatment for radial head fractures within terrible triad injuries, options include radial head arthroplasty, fixation, or excision. When surgery is indicated, open reduction and internal fixation (ORIF) is usually considered the most appropriate choice, if possible, unless the patient has a displaced fracture with greater than 3 fragments, at which point then a radial head arthroplasty is recommended.⁹ Both non-arthroplasty and arthroplasty approaches resulted in good outcomes with mean MEPS outcome scores of 89 and 88,

respectively. This indicates good patient outcomes following this injury regardless of whether fixation or excision is used, compared to radial head arthroplasty. Among studies that included nonarthroplasty repair of the radial head, outcomes comparing fixation to excision both had high average MEPS scores of 88 and 91, respectively.

Strengths

The main strength of our study was the number of studies (43) and elbows (1749) included for analysis. To our knowledge, our review encompasses the largest collection of terrible triad injury outcomes to date. Our review was able to subclassify outcomes based on the Mason classification for radial head fractures and the Regan-Morrey classification for coronoid process fractures. In terms of nonarthroplasty repair of the radial head, our study also broke down fixation and excision outcomes, which is seldom reported in reviews on this topic.

Limitations

The main limitations of our study have resulted from the heterogeneity between studies included in our analysis. The use of different outcome scores (MEPS, DASH, Q-DASH, Broberg-Morrey) and variation in the definitions and reporting of complications across studies led us to include only select studies on given outcomes/complication variables, resulting in different population subsets for the average outcomes we reported. Additionally, data we retrieved to subclassify injuries into Mason, Regan-Morrey, and radial head arthroplasty/repair classifications was insufficient to compare between subgroups to determine if statistically significant differences were present.

Conclusions

This study shows that current surgical treatment for terrible triad injuries has resulted in improved outcomes. Based on primary outcome measures using MEPS and DASH scores, almost all of the studies have highlighted good or excellent functional outcomes. This was consistent when we stratified the studies along with different fracture types (Mason classification system and Regan-Morrey classification system), as well as different surgical treatments (Radial head arthroplasty vs. fixation). Furthermore, the average MEPS outcome measures from all included studies resulted in 'good' or 'excellent' outcomes. The overall reoperation rate of 7.8% remains a key limitation for the overall success of treating terrible triad injuries surgically. This reinforces the idea that

terrible triad injuries of the elbow may no longer deserve the moniker of 'terrible', at least in regard to the functional post-operative outcome but continue to have nonsignificant rates of reoperations and complications from surgical techniques.

Disclaimers:

Funding: No funding was disclosed by the authors.

Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.xrrt.2022.01.002>.

References

- Chen NC, Ring D. Terrible triad injuries of the elbow. *J Hand Surg Am* 2015;40:2297–303. <https://10.1016/j.jhsa.2015.04.039>.
- Dillon MT, Getz CL, Beredjickian PK, Wiesel BB, Carolan GF, Ramsey ML. Evaluation of reliability of the Mason classification for radial head fractures. *Am J Orthop (Belle Mead NJ)* 2010;39:430–2.
- Egol KA, Immerman I, Paksima N, Tejwani N, Koval KJ. Fracture dislocation of the elbow. *Bull NYU Hosp Jt Dis* 2007;65:263–70.
- Iannuzzi NP, Leopold SS. In brief: the Mason classification of radial head fractures. *Clin Orthop Relat Res* 2012;470:1799–802. <https://doi.org/10.1007/s11999-012-2319-2>.
- Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. *Implementation Sci* 2010;5:1–9. <https://10.1186/1748-5908-5-69>.
- Mason ML. Some observations on fractures of the head of the radius with a review of one hundred cases. *Br J Surg* 1954;42:123–32.
- Mathew PK, Athwal GS, King GJ. Terrible triad injury of the elbow: current concepts. *J Am Acad Orthop Surg* 2009;17:137–51. <https://10.5435/00124635-200903000-00003>.
- O'Driscoll SW. Elbow instability. *Acta Orthop Belg* 1999;65:404–15.
- Pike JM, Athwal GS, Faber KJ, King GJ. Radial head fractures—an update. *J Hand Surg Am* 2009;34:557–65. <https://10.1016/j.jhsa.2008.12.024>.
- Pugh DM, Wild LM, Schemitsch EH, King GJ, McKee MD. Standard surgical protocol to treat elbow dislocations with radial head and coronoid fractures. *J Bone Joint Surg Am* 2004;86:1122–30. <https://10.2106/00004623-200406000-00002>.
- Schindelar LE, Sherman M, Ilyas AM. Comparison of surgical techniques for fixation of terrible triad injuries of the elbow: a meta-analysis. *Orthopedics* 2020;43:328–32. <https://10.3928/01477447-20200923-04>.
- Van Riet RP, Morrey BF. Documentation of associated injuries occurring with radial head fracture. *Clin Orthop Relat Res* 2008;466:130–4. <https://10.1007/s11999-007-0064-8>.
- Zaidenberg EE, Abrego MO, Donndorff AG, Boretto JG, De Carli P, Gallucci GL. Treatment of terrible triad injuries at a mean follow-up of nine years. *Shoulder Elbow* 2019;11:450–8. <https://10.1177/1758573218809375>.