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Periprosthetic fractures after shoulder arthroplasty: a systematic review

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- *Purpose:* The goal of this study was to review available literature on periprosthetic shoulder fractures to evaluate epidemiology, risk factors and support clinical decision-making regarding diagnostics, preoperative planning, and treatment options.
- *Methods:* Two authors cross-checked the PubMed and Web of Science medical databases. The inclusion criteria were as follows: original human studies published in English, with the timeframe not limited, and the following keywords were used: 'periprosthetic shoulder fracture,' 'total shoulder arthroplasty periprosthetic fractures,' 'total shoulder arthroplasty fracture,' and 'total shoulder replacement periprosthetic fracture.' Seventy articles were included in the review. All articles were retrieved using the aforementioned criteria.
- *Results:* The fracture rate associated with total shoulder arthroplasty varied between 0 and 47.6%. Risk factors for periprosthetic fractures were female gender, body mass index < 25 kg/m^2, smoking, rheumatoid arthritis, and Parkinson's disease. The most commonly used classification is the Wright and Coefield classification. Periprosthetic fractures can be treated both, conservatively and operatively.
- *Conclusion:* Periprosthetic fracture frequency after shoulder arthroplasty ranges from 0 to 47.6%. The most common location of the fracture is the humerus and most commonly occurs intraoperatively. The most important factor influencing treatment is stem stability. Fractures with stem instability require revision arthroplasty with stem replacement. Fractures with a stable stem depending on the location, displacement and bone stock quality can be treated both conservatively and operatively. For internal fixation plates with cables and screws are most commonly used.

Keywords
- periprosthetic fracture
- shoulder arthroplasty
- humerus fracture

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Introduction

First results of total shoulder arthroplasty (TSA) were published in the 1970s by Near *et al.* (1). Later, in the 1980s, Garmont presented reverse shoulder arthroplasty (RSA) (2, 3, 4, 5). Currently, shoulder replacement is the third most commonly performed type of arthroplasty. It has been increasingly popular in the last 40 years, showing exponential growth (6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19).

Degenerative changes related to osteoarthritis (OA) remain the most common reason for performing arthroplasty, but there is a growing number of procedures being performed due to other indications (11, 20). Many reports have shown good functional results and high satisfaction rates comparable to total hip and knee replacements (2, 11, 13, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32).

Despite satisfactory implant survival rate (at 88.13% in 10 years of observation), shoulder replacement is associated with some complications: aseptic loosening, secondary rotator cuff damage, infection, neural injury, and finally, periprosthetic fracture (33). A significantly higher complication rate (four times higher) is being observed after reverse total shoulder replacements (2, 19, 32, 34, 35).

Periprosthetic fracture is a universal complication for all kinds of arthroplasties. In shoulder arthroplasties they are less common, but, nevertheless, they pose a complex challenge for clinicians (4, 15, 21, 36, 37, 38, 39, 40).

Such complications could potentially sabotage surgical outcomes. In the literature, there is a limited amount of reports discussing the treatment and risk factors of periprosthetic shoulder fractures (21, 33, 36).

The goal of this study was to review available literature on periprosthetic shoulder fractures to evaluate epidemiology, risk factors and support clinical decision-making regarding diagnostics, preoperative planning, and treatment options.

Methodology

Methodology of this systematic review was designed according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations (41).

Two authors cross-checked the PubMed and Web of Science medical databases. The timeframe was not limited. The language was limited to English, and studies' subject was limited to human. The key words used were 'periprosthetic shoulder fracture,' 'total shoulder arthroplasty periprosthetic fractures,' 'total shoulder arthroplasty fracture,' 'total shoulder replacement periprosthetic fracture.' The initially selected articles were screened for eligibility criteria by reading abstracts. Bibliography of the selected articles were reviewed for further articles that could be potentially included in the review.

The included studies must have evaluated the complications following shoulder arthroplasty. We included original retrospective and randomized studies and case series. Letters to the editor, expert consensuses, case reports, and review papers were excluded.

Quality assessment was undertaken by two independent investigators. The Cochrane Collaboration's 'Risk of bias' tool as reported in the Cochrane Handbook for Systematic Reviews of Interventions was utilized to evaluate the risk of bias in randomized controlled trials and the Newcastle–Ottawa Scale and Modified Newcastle–Ottawa Scale were used to assess the methodological rigor in observational studies (Supplementary Tables 1 and 2; see section on supplementary materials given at the end of this article) (42, 43, 44).

Results

We identified 4362 studies in the primary search. Overall, 212 papers met the inclusion criteria. One hundred sixty-six were selected based on their title, 82 after abstract review. Twenty were rejected as these were duplicates. From quotations of the searched works, 30 works were initially selected of which 13 were rejected. In the end, 70 articles were included in the review (Fig. 1).

Two researchers extracted data from the eligible studies: first author's or authors' names, type of procedure that resulted in periprosthetic fracture (TSA, RTSA, HA, revision arthroplasty), duration of follow-up, prevalence of periprosthetic fractures, classification of periprosthetic fractures, risk factors, treatment, outcome measures, and results.

Epidemiology

In the analysis of the National Joint Registry, intraoperative fractures of the humerus were the 14th most common complication (1.3%), postoperative fractures were 17th (1%), and glenoid fractures were 19th (6).

The general rate of periprosthetic fracture in the studies included in this review was as follows: 0–10% in TSA, 0–11% in HA, 0.4–29% in RTSA, and 3.4–40% in revision procedures. Individual data from all of the studies are presented in Tables 1, 2, 3, and 4. The most common location was the humerus. The rate of scapular fractures was between 0 and 15.6%.

The prevalence of intraoperative fractures varied between 0 and 47.6%, postoperative between 0 and 16.1%.

In studies describing periprosthetic fracture mechanism intraoperative fractures occurred most commonly during the final or test stem impaction. Less frequently, they were associated with stem removal or medullary canal reaming. Rarely, they occurred during glenoid exposition, retractor positioning, or shoulder dislocation/reposition (15, 22, 40). Postoperative fractures occurred as often due to aseptic loosening as during injuries (14, 21, 40, 45). The average time from arthroplasty to postoperative fracture diagnosis was between 1 and 5.8 years after primary procedure and 3.2 years after revision (4, 21, 23, 28).

In TSA periprosthetic fractures were more common when cemented stems were used (2%) compared to uncemented (1.63%), in revisions when the uncemented stem was used (relative ratio = 2.9) (15, 46).

Risk factors

All the described risk factors in the analyzed studies and their influence on the periprosthetic fracture occurrence are presented in Table 6 (11, 15, 22, 23, 36, 47, 48, 49, 50, 51).

Factors most strongly associated with a periprosthetic fracture were female sex, previous shoulder operations (including arthroplasties), long operative time (>174 min), history of solid organ transplantation, posttraumatic arthritis, inflammatory arthritis, and implant instability. Hatta *et al.* demonstrated a statistically

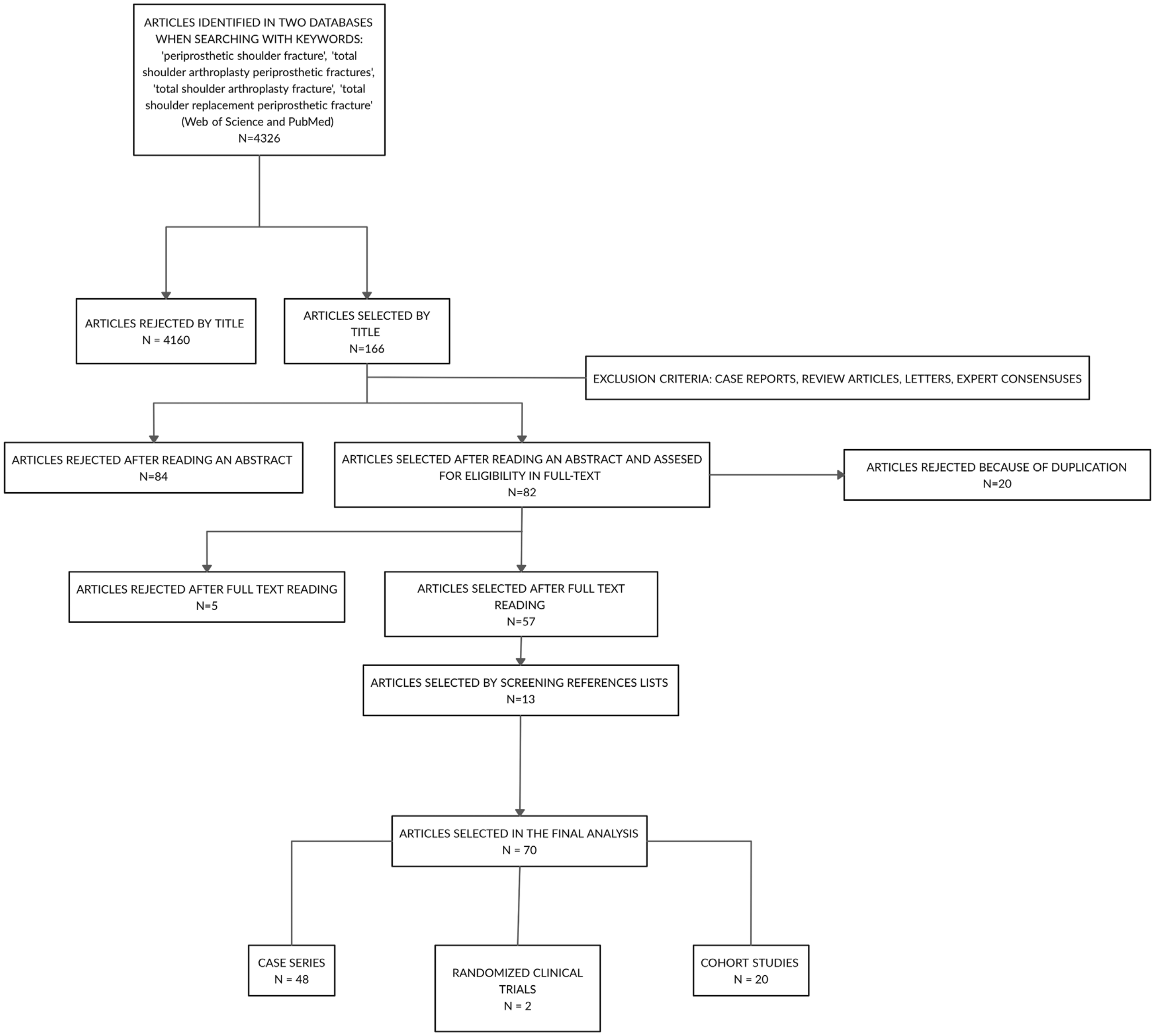

Figure 1
Flowchart summarizing our search methodology and results.

significant correlation between a history of smoking and periprosthetic fractures. Also, there was a higher prevalence of fracture occurrence in the actively smoking group comparing to patients who quit smoking at least 1 month before the procedure (52). In Testa *et al.* joint registry analysis, the authors found that periprosthetic fractures in 1 year postoperatively are more common in patients younger than 80 years of age compared to older patients (odds ratio = 0.35) (53).

In Walters *et al.* study, the authors compared the results of bilateral shoulder arthroplasty based on the interval between two procedures. They found that having the second arthroplasty before 3 months from the initial procedure increased the likelihood of periprosthetic fracture compared to interval of more than a year (54).

Classifications

We found five classifications describing periprosthetic shoulder fractures (Fig. 2, 3, 4, and 5).

Wright–Cofield (W-C) classification was the most commonly used in the analyzed studies (Table 5) (4, 15, 21, 33, 38). Along with two other classifications – Groh and Campbell – it divides the fracture based on its pattern either in relation to the tip of the stem or humerus region

Table 1 Epidemiology of periprosthetic fractures associated with TSA.

Study	Prevalence of fractures			Comments
	General	Intraoperative	Postoperative	
Mansat *et al.* (68)	0%	–	–	In all patients, the indication for surgery was AVN. All were cemented.
Gartsman *et al.* (29)	0%	–	–	In all patients, the indication for surgery was OA. All were cemented.
Kiet *et al.* (14)	0%	–	–	In all patients, the indication for surgery was OA. All stems were cemented.
Schoch *et al.* (7)	0.6%	–	0.6%	The prevalence of fractures requiring revision procedure.
Cowling *et al.* (8)	1.6%	1.6%	–	NJR analysis
Desmkuh *et al.* (23)	2.8%	0.3%	2.5%	In the majority of patients, the indication for surgery was rheumatoid arthritis (69%). Components were cemented. Glenoid fracture: 0.3%
Singh *et al.* (36)	2.8%	1.8%	1%	Glenoid fracture: 0.3%
Somerson *et al.* (6)	3%	–	–	Analysis of the FDA MAUDE database for reporting side effects during therapy. Intraoperative fractures of the humerus constituted 1.3% of all complications, postoperative fractures of the humerus 1%
Chin *et al.* (69)	3%	2.8%	0.2%	Different indications. Uncemented. Glenoid fracture: 0%
Lo *et al.* (13)	10%	10%	–	In all patients, the indication for surgery was OA. Cemented and uncemented. Glenoid fracture: 5%
Waterman *et al.* (11)	0.05%	–	–	Analysis of national database. Complications within 30-days after TSA.
Uribe *et al.* (70)	2.8%	–	2.8%	Inlay prosthesis. In all patients, the indication for surgery was OA. Glenoid fracture: 2.8%
Aibinder *et al.* (18)	0%	–	–	Analysis of the results of short stem implantation.

(32, 37). Worland classification is the only classification that assess the stability of the stem (55).

There is only one described classification of periprosthetic scapular fractures. It was proposed by Levy *et al.* and classifies acromion fractures (Fig. 6) (56). It was reproduced by one study (47). In the rest of the article the classification used for further descriptions will be W-C.

Treatment

Conservative

According to most authors, periprosthetic fractures, regardless of whether they occur during or after surgery, can be treated conservatively or surgically (4, 16, 23, 32, 34, 37, 38, 45, 57, 58).

In Hasler *et al.* study, the authors did not introduce any treatment or modified rehabilitation protocol after incidentally diagnosed intraoperative fractures that occurred during RTSA. All fractures healed (59).

Type A and C fractures (W-C) were treated conservatively if there was no loosening of the implant and the fracture did not extend to the cement mantle (4, 32, 37, 58, 60). Type B fractures were treated conservatively for up to 3 months if the implant was stable (38, 60, 61). For nonoperative treatment, the authors used different types of immobilization: hanging cast, sugar tong splints, and orthosis. After failed conservative treatment they performed surgical interventions (37, 38).The average time to achieve bone union was 3.5 months (37).

Scapular fractures were treated conservatively only (16, 32, 34, 57).

Open reduction and internal fixation

Metaphyseal fractures were treated with wires or cerclage (4, 15, 32, 62, 63). Wagner *et al.* additionally used cortical strut allografts in displaced fractures (15).

In type B humeral shaft fractures with stable stem and markedly displaced type C fractures, the most commonly used treatment was plate (either locking compression plate or dynamic compression plate) with screws and wires (4, 16, 32, 38, 60, 64, 65, 66, 67). Schoch *et al.* used matching lengthening plates designed specifically for treating periprosthetic fractures of the humerus (76). In four studies fixation was reinforced with allografts (38, 64, 66, 67). The bone union was achieved in 91.67–100% of the cases. The mean time to achieve union was between 3.7 and 12 months (38, 60, 64, 65, 66).

Table 2 Epidemiology of periprosthetic fractures associated with HA.

Study	Prevalence of fractures			Comments
	General	Intraoperative	Postoperative	
Feeley *et al.* (71)	0%	–	–	In all patients, the indication for surgery was AVN.
Gartsman *et al.* (29)	0%	–	–	In all patients, the indication for surgery was OA. All stems were uncemented.
Rispoli *et al.* (30)	0%	–	–	In all patients, the indication for surgery was OA. Cemented and uncemented.
Gadea *et al.* (27)	1.1%	–	–	Different indications. Cemented; No differentiation between intra- and postoperative fractures.
Singh *et al.* (36)	2.3%	1%	1.3%	Different indications. Analysis of periprosthetic fractures. Glenoid fracture: 0.6%
Lo *et al.* (13)	9.5%	9.5%	–	In all patients, the indication for surgery was OA. Cemented and uncemented. Glenoid fracture: 0%
Boileau *et al.* (26)	11%	4.4%	6.6%	

Table 3 Epidemiology of periprosthetic fractures associated with RTSA.

Study	Prevalence of fractures			Comments
	General	Intraoperative	Postoperative	
Lindbloom *et al.* (72)	0.4%	–	0.4%	Different indications. Cemented and uncemented. Acromion fracture: 0.1%
Cuff *et al.* (73)	2%	–	2%	In all patients. the indication for surgery was rotator cuff tear. Cemented stem. Scapular spine fracture: 2%
Ascione *et al.* (60)	1.6%	–	1.6%	Different indications. Cemented and uncemented stems.
Saltzman *et al.* (24)	2.7%	2.7%	–	Different indications. Scapular fracture: 1.8%; Glenoid fracture: 0.9%
Choi *et al.* (2)	7.5%	–	7.5%	In all of the patients. the indication for surgery was rotator cuff tear. ncemented stems were used. Glenoid fracture: 2.6%
Garcia-Fernandez *et al.* (4)	1.96%	0.98%	0.98%	Only humeral fractures analyzed. Different indications. Cemented and uncemented.
Cho *et al.* (19)	7.5%	2.5%	5%	Irreparable rotator cuff tears. Only postoperative acromial fractures
Ji *et al.* (34)	14%	9.5%	5%	Different indications. Cemented stem. Glenoid fracture: 2.5%
Hasler (59)	5%	5%	–	Only intraoperative fractures diagnosed incidentally
Rangarajan *et al.* (74)	5.6%	5.6%	–	Custom-made glenoid component
Kiet *et al.* (14)	7.5%	7.5%	–	Rotator cuff arthroplasty. All of the stems were cemented. Scapular fracture: 7.5%; Glenoid fracture: 3.75%
Kriechling *et al.* (75)	7.8%	7.8%	–	Scapular fracture: 5.3%
Mangano *et al.* (76)	9.6%	3.2%	6.4%	Over 79 years of age population. Different indications. Cemented and uncemented. Scapular fracture: 3.2%
Holcom *et al.* (17)	12%	4%	8%	In all patients. the indication for surgery was rheumatoid arthritis with rotator cuff insufficiency. Cemented stems. Scapular fracture: 12%; Glenoid fracture: 8%
Jeong *et al.* (80)	8.9%	8.9%	–	Treatment of complex proximal humeral fractures. Cemented stems. All of the fractures in non-fracture stem (16%).
Atoun *et al.* (5)	29%	9.7%	19.3%	Analysis of short stem implantation. Different indications. Scapular fracture: 9.7%; Glenoid fracture: 6.5%

Revision

In majority of the studies, the authors decided whether to perform open reduction and internal fixation (ORIF) or make a revision arthroplasty based on the presence of stem loosening (60). The method of choice was a revision procedure with the use of a long stem (12, 23, 28, 37, 38, 58, 67). Campbell *et al.* proposed the appropriate length of the stem. The tip of the stem should be implanted at least three times the cortical diameter from the most distal part of the fracture. When complying to this rule, the average time to achieve bone union was 2.3 months compared to 8.7 months without it (37). If supplementary fixation was needed, the authors employed plates and wires (12, 37, 38, 32, 58, 64). Andersen *et al.* used strut allografts when the bone stock was assessed to be poor intraoperatively (67).

In two B3 fractures (W) Wolf *et al.* performed revision arthroplasty (one with a long stem implantation and other with a resection prosthesis) (61).

Swell *et al.* in their study described the treatment of complex periprosthetic fractures with a custom-made prosthesis. Seven prostheses were used, nine stems in total; in three cases, a custom-made implant of the elbow and shoulder was used. In two cases, the bridging prosthesis was used. In one case, the standard revision stem was used. The radiological and clinical union was achieved in 12 patients after an average time of 27 weeks (33).

Table 4 Epidemiology of periprosthetic fractures associated with revision shoulder arthroplasties.

Study	Prevalence of fractures			Comments
	General	Intraoperative	Postoperative	
Ingoe *et al.* (77)	3.4%	3.4%	–	NJR analysis.
Owens *et al.* (58)	7.5%	6.25%	1.25%	Only long and medium-long stems. Cemented and uncemented. No information on the primary procedures. Scapular fracture: 0%
Saltzman *et al.* (24)	15.3%	3.8%	11.5%	Conversion of HA or TSA to RSA due to glenoid failure and/or rotator cuff insufficiency. Scapular fracture: 0%
Melis *et al.* (59)	13.5%	10.8%	2.7%	TSA to RSA due to aseptic loosening of the acetabulum. Cemented and uncemented. Scapular fracture: 0%
Wagner *et al.* (15)	15.7%	15.7%	1.7%	Conversion of HA or TSA to RSA.
Levy *et al.* (28)	15.8%	–	15.8%	Conversion of HA to RSA. All stems were cemented. Scapular fracture: 10%; Acromion fracture: 10%
Flury *et al.* (25)	22%	22%	–	Conversion of TSA to RSA due to cuff insufficiency. All stems were cemented. Scapular fracture: 0%
Wieser *et al.* (40)	40%	27%	13%	Conversion of HA or TSA to RSA due to rotator cuff failure. Cemented and uncemented. Scapular fracture: 15.6%; Acromion fracture: 11%; Glenoid fracture: 4.4%
Austin *et al.* (78)	30%	30%	–	Revision reverse shoulder arthroplasties. Both. conversions and reverse to reverse. Different indications. All stems were cemented. No description of fractures.
Antoni *et al.* (9)	27.1%	24.3%	2.7%	All types of revisions. Different indications. All stems were cemented. Scapular fracture: 0%
Bartels *et al.* (79)	24.8%	24%	0.8%	Conversion of TSA to RSA due to glenoid component loosening.

Table 5 The distribution of types of fractures in evaluated studies using Wright and Cofield classification.

Study	A	B	C	Other
Wutzler *et al.* (21)	3	1	–	B+C 1
Kumar *et al.* (38)	6	6a	3	–
Carlos *et al.* (4)	1	3	–	–
Wagner *et al.* (15)	36	–	–	–
Sewell *et al.* (33)	11	6	4	–

Complications

Kumar *et al.* and Novi *et al.* described complications of periprosthetic fractures treatment. The most common was acromial fracture followed by implant instability, infection, and nonunion (38, 64). Novi *et al.* reported high prevalence of neurological complications (12.5%) and infections (6.25%).

Discussion

Periprosthetic fracture frequency depends mainly on the type of surgery. Revision procedures are much more commonly associated with periprosthetic fractures than primary procedures. For primary surgeries, the lowest risk of periprosthetic fracture is associated with an anatomical shoulder replacement and hemiarthroplasty. Significantly higher periprosthetic fracture occurrence was associated with RTSA. The additional risk factors increasing risk of fracture by the most are female gender, smoking history, and conditions associated with steroid intake.

The most common location of the fracture was the humerus, although scapular fractures are given more consideration in recent times.

Periprosthetic fractures of the humerus most often occur intraoperatively. Special attention and care must be taken during the preparation of the medullary canal and inserting both trial and final implants. Postoperative fractures most commonly occur after one up to 5 years after the surgery. Therefore, it is necessary to pay special attention for periprosthetic fractures in all patients with shoulder prosthesis who present in the emergency department after injury.

Limited use of fracture classification was noticed – in only 10 out of 70 studies. The most commonly used

Table 6 Risk factors presented in the analyzed studies along with the calculated odds ratio, relative ratio, or hazard ratio.

Risk factor	OR	RR	HR
Female sex	2.41–4.39	3.3	
Low mineral bone density		1.6	
Osteoporosis	1.49–1.86		
BMI <25 kg/m^2			1.12
Long operative time (>174 min)	4.05		
History of solid organ transplantation			8.18
Parkinson's disease	1.5		
Smoking			4.56–7.27
RA		1.9	
Post-traumatic arthritis	2.17	1.9	
AVN	1.1		
Revision surgery	2.8		
Implant instability	2.65		
Excessive deltoid lengthening	1.04		
Previous shoulder operations	2.91	2.8	
Early bilateral shoulder arthroplasty	4.18		
Inflammatory arthritis	2.57		
Previous HA	2.34		

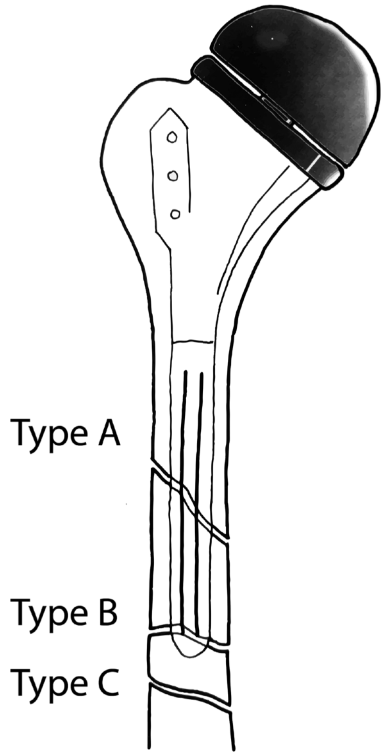

Figure 2
Wright and Cofield classification. It divides periprosthetic fractures into three types. Type A – fracture located near the tip of the stem. Extending proximally. Type B – fracture located near the tip of the stem. Extending distally. Type C – fracture located distally to the stem.

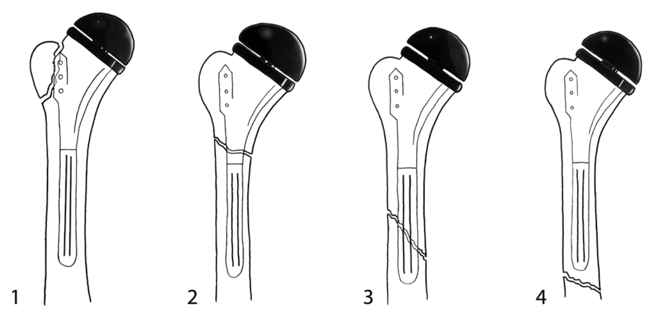

Figure 3
Campbell classification. Region 1 – tuberosity fracture. Region 2 – proximal metaphysis. Region 3 – proximal part of the diaphysis. Region 4 – middle and distal part of the diaphysis.

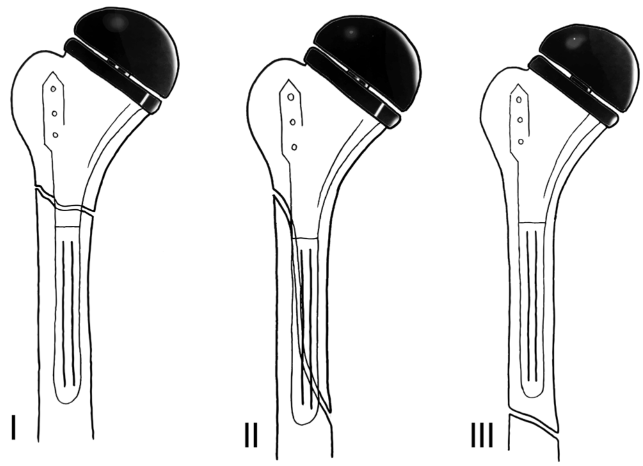

Figure 4
Groh classification. I – fracture occurs proximally to the tip of the stem. II – fracture occurs proximally to the tip of the stem and extends distally. III – fracture originates distally to the tip of the stem.

classification is the Wright and Cofield's one. Comparing the fracture types among these studies, we noticed that most fractures are classified as distal from the tip of the stem. That may suggest the need to extend these classifications with subtypes, which could be helpful in preoperative planning. Given the factors influencing the therapeutic decisions stability of the stem in all of the fracture types should be assessed and bone stock also.

Fractures located distally from the tip of the stem or around metaphysis with a stable stem can be initially treated conservatively.

Fractures around the stem usually require revision surgery. In most cases, it might be necessary to replace the stem. During this procedure, the Campbell's rule

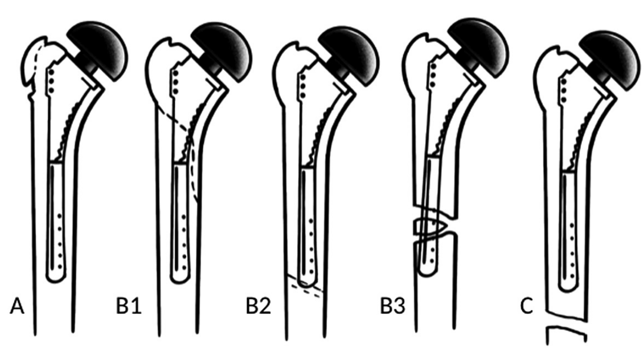

Figure 5
Worland classification. It divides fractures into three types: A, B, C and type B further into three subtypes: B1, B2, B3. Type A and C are similar to regions 1 and 4 of Campbell classification (fracture around tuberosity and fracture distal to the tip of the stem, respectively). Type B fractures are located around the stem: B1 – spiral pattern of fracture, B2 – transverse or short oblique pattern of fracture, B3 – fracture with stem instability.

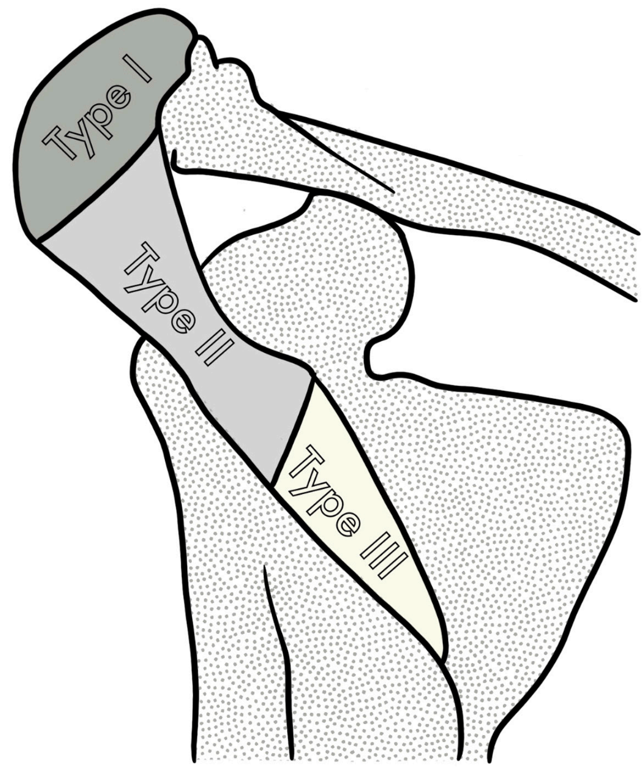

Figure 6
Levy classification. Type I – anterior and middle deltoid origin; type II – involvement of at least the entire middle deltoid origin; type III – entire middle and posterior deltoid origin.

should be applied – the tip of the new stem should be implanted at least three times the cortical diameter from the most distal part of the fracture. In metaphyseal fractures without stem instability, a bone suture or wires may be considered. For diaphysis fractures without the implant instability, plates systems with screws and/or wires could be used. The use of matching lengthening plates for the treatment of periprosthetic fractures of the humerus seems especially promising.

Bone union after both nonoperative and surgical treatment should be obtained after about 3 months.

The promising method for particularly complicated humerus fractures could be custom-made prostheses, as the initial results are encouraging.

Conclusion

Periprosthetic fracture frequency after shoulder arthroplasty ranges from 0 to 47.6%. The most common location of the fracture is the humerus and most commonly occurs intraoperatively. risk factors increasing risk of fracture by the most are female gender, smoking history, and conditions associated with steroid intake. The most popular classification of periprosthetic humeral fractures is W-C classification and for acromial fractures Levy classification. The most important factor influencing treatment is stem stability. Fractures with stem instability require revision arthroplasty with longer stem replacement or custom-made implant. Fractures with a stable stem depending on the location, displacement, and bone stock quality can be treated both conservatively and operatively. Nondisplaced fractures can usually be treated without surgical intervention with plaster cast or orthosis. Displaced fractures require ORIF; plates with cables and screws are most commonly used.

Supplementary materials
This is linked to the online version of the paper at https://doi.org/10.1530/EOR-22-0097.

ICMJE Conflict of Interest Statement
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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