J Shoulder Elbow Surg (2021) 30, e185–e198

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

ONLINE ARTICLES

The elbow plica: a systematic review of terminology and characteristics

Erica Kholinne, MD, PhD[a,b], Akriti Nanda[c], Hua Liu, MD[d], Jae-Man Kwak, MD[b], Hyojune Kim, MD[b], Kyoung-Hwan Koh, MD, PhD[b], In-Ho Jeon, MD, PhD[b,*]

[a]*Department of Orthopedic Surgery, St. Carolus Hospital, Faculty of Medicine, Trisakti University, Jakarta, Indonesia*
[b]*Department of Orthopedic Surgery, University of Ulsan, Asan Medical Center, Seoul, Republic of Korea*
[c]*Medical Sciences Division, John Radcliffe Hospital, Oxford, UK*
[d]*Department of Hand Surgery, Affiliated Hospital of Nantong University, Nantong University, Nantong, China*

Background: There has been a lack of evidence regarding the structure of the elbow plica, or synovial fold. Inconsistency remains regarding the correct terminology, prevalence, and investigation used to understand this anatomic structure.
Methods: For this systematic review, we searched the PubMed, Ovid-MEDLINE, Cochrane, Google Scholar, and Embase databases using keywords as well as medical subject headings for English-language studies. We conducted a systematic review using the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines.
Results: We included 27 articles in this review. ''Plica'' was the most commonly used terminology (33%). The prevalence of plicae in asymptomatic and symptomatic patients was 77% and 97%, respectively. Provocative factors were sporting activities (57%), including those performed by professional athletes, and heavy labor (43%). Lateral elbow pain represented the most common symptom (49%). Magnetic resonance imaging was the most commonly used diagnostic modality (64%). On the magnetic resonance imaging scans of symptomatic patients, the most common location of the plica was the posterolateral region (54%) and its thickness was a minimum of 3 mm. In 2 studies that included symptomatic patients, the plica was found to cover more than one-third of the radial head.
Conclusion: Plicae are prevalent in both asymptomatic and symptomatic patients. Consideration of the pathologies associated with an elbow plica helped identify the following: (1) its thickness is >3 mm and (2) its location is in the posterolateral aspect and/or it covers more than one-third of the radial head quadrant.
Level of evidence: Level V; Systematic Review

Keywords: Elbow plica; synovial plica; systematic review; terminology; prevalence; investigation

A plica is a normal anatomic structure that appears as a synovial tissue fold found in the lining of a joint.[13] It represents the remnants of synovial membranes from embryologic development, and the associated pathologies are generally asymptomatic.[17,24] There does not appear to be a function for plicae within the knee joint,[30] and the pathologies are generally asymptomatic.[17] Plica pathologies become symptomatic if a person has chronic inflammation secondary to repetitive athletic activities; these pathologies later become thickened fibrotic tissue folds that can cause impingement.[17,29] Radiocapitellar snapping, which is associated with plica pathologies, is not a common condition, and owing to its rarity, it is frequently underappreciated.[2,3,20,33,34] Furthermore, the

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

*Reprint requests: In-Ho Jeon, MD, PhD, Department of Orthopedic Surgery, University of Ulsan, Asan Medical Center, 86 Asanbyeongwon-gil, Songpa-gu, Seoul, Republic of Korea, 138-736.
E-mail address: jeonchoi@gmail.com (I.-H. Jeon).

1058-2746/$ - see front matter
https://doi.org/10.1016/j.jse.2020.09.011

under-recognition of elbow plicae is worsened by heterogeneity in the terminology used in the literature. Terms such as "plica,"[2,23,34] "plica syndrome,"[7] "synovial fold,"[11,20] "synovial fringe,"[8] and "elbow synovial fold syndrome"[3,31] are all interchangeably used. This leads to confusion on how to determine the prevalence and investigation of elbow plicae needed to establish a proper diagnosis when the pathologies occur.

The aims of this systematic review were as follows: (1) to establish a consensus on the terminology for elbow plicae, (2) to understand their prevalence in asymptomatic and symptomatic populations, and (3) to determine how plicae can be investigated and diagnosed clinically.

Materials and methods

Search strategy and study selection

This systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines.[27] The PubMed, Embase, Cochrane Library, Scopus, and Google Scholar databases were electronically searched using keywords conforming to medical subject headings to find relevant articles. The following keywords were chosen to increase sensitivity: ([(elbow OR humeroradial joint OR radiohumeral joint) AND (meniscus OR plica)] OR snapping elbow OR snapping triceps OR synovial fold syndrome OR synovial fringe). The number of studies was limited; thus, there were no restrictions on publication status or study period. After eliminating duplicate documents, 2 independent reviewers who were shoulder and elbow fellowship–trained orthopedic surgeons (E.K. and H.K.) examined the titles and abstracts to select the articles; subsequently, they selected the final articles through a full-text review. We also conducted citation tracking in the bibliographies of the retrieved studies to find additional related articles. Any disagreement that arose in the selection process was resolved by group discussion or intervention by a third reviewer who was a professor of elbow surgery (I.-H.J.). Figure 1 summarizes the study-selection flow diagram.

Inclusion and exclusion criteria

All included studies contained the following: original data published in the English language and human or cadaveric studies involving the synovial plicae. Studies on diagnosis, treatment, or even the prevalence of plica pathologies in the general population were also included.

Quality appraisal

Four reviewers (E.K., A.N., H.L., and H.K.) independently reviewed each article and then decided whether to include each study based on discussion and consensus. The level of evidence of each study was determined according to the criteria set by the Oxford Centre for Evidence-Based Medicine.[14] The decision regarding whether to include studies was also discussed with 2 expert orthopedic surgeons specializing in elbow surgery (K.-H.K. and I.-H.J.).

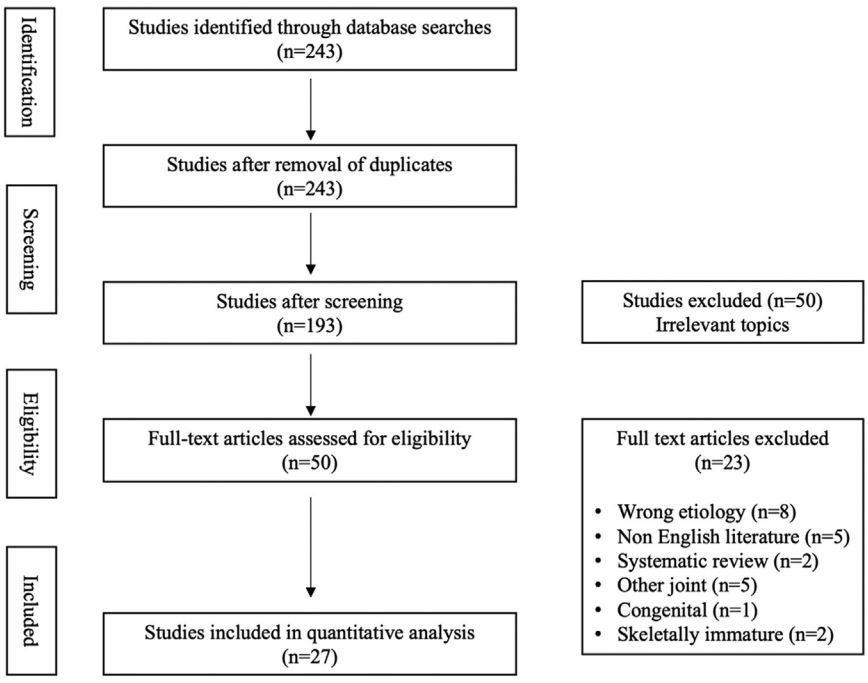

Figure 1 Flowchart of article selection according to Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines.

Table I Article characteristics of included studies and terminology used

Study No.	Article (year)	Journal	Country of study	Type of study	Level of evidence	Terminology used
1	Akagi and Nakamura[1] (1998)	*Journal of Shoulder and Elbow Surgery*	Japan	Clinical	V	Synovial fold
2	Antuna and O'Driscoll[2] (2001)	*Arthroscopy*	USA	Clinical	IV	Plica
3	Awaya et al[3] (2001)	*American Journal of Roentgenology*	USA	Radiologic	IV	Plica, synovial fold
4	Brahe Pedersen et al[5] (2017)	*SICOT J*	Denmark	Clinical	IV	Plica, synovial fold
5	Celikyay et al[6] (2015)	*Medical Ultrasonography*	Turkey	Radiologic	IV	Plica
6	Choi et al[7] (2017)	*PloS One*	Republic of Korea	Radiologic	IV	Plica syndrome, synovial fold
7	Clarke[8] (1988)	*Arthroscopy*	USA	Clinical	IV	Synovial fringe, plica, synovial band
8	Del Grande et al[9] (2015)	*Skeletal Radiology*	USA	Radiologic	IV	Plica
9	Duparc et al[10] (2002)	*Surgical and Radiologic Anatomy*	France	Radiologic	IV	Synovial fold
10	Feller et al[11] (2018)	*JB&JS Case Connector*	USA	Clinical	V	Synovial fold
11	Fukase et al[12] (2005)	*Skeletal Radiology*	Japan	Clinical	V	Synovial fold
12	Husarik et al[16] (2010)	*Radiology*	Switzerland	Radiologic	IV	Plica, synovial fold
13	Isogai et al[17] (2001)	*Journal of Shoulder and Elbow Surgery*	Japan	Clinical	IV	Synovial fold
14	Kim et al[20] (2006)	*American Journal of Sports Medicine*	USA	Clinical	IV	Plica, synovial fold
15	Koh et al[21] (2007)	*Journal of Shoulder and Elbow Surgery*	USA	Radiologic	IV	Synovial fold
16	Kongmalai et al[22] (2016)	*Journal of the Medical Association of Thailand*	Thailand	Clinical	IV	Plica
17	Lee et al[23] (2018)	*Journal of Shoulder and Elbow Surgery*	Republic of Korea	Clinical	IV	Plica
18	Mete et al[25] (2014)	*JBR-BTR*	Turkey	Radiologic	V	Plica
19	Meyers et al[26] (2012)	*Pediatric Radiology*	USA	Clinical	IV	Plica
20	Natwa et al[31] (2018)	*BMJ Case Reports*	USA	Clinical	V	Synovial fold, plica
21	Phorkhar et al[32] (2015)	*Journal of the Medical Association of Thailand*	Thailand	Clinical	IV	Plica, synovial fold
22	Rajeev and Pooley[33] (2015)	*Journal of Orthopaedic Surgery*	UK	Clinical	IV	Plica
23	Ruch et al[34] (2006)	*Journal of Shoulder and Elbow Surgery*	USA	Clinical	IV	Plica
24	Ruiz De Luzuriaga et al[35] (2013)	*Skeletal Radiology*	USA	Radiologic	III	Synovial fringe, plica
25	Sanghi et al[36] (2007)	*Military Medicine Radiology Corner*	USA	Radiologic	V	Synovial fold, plica
26	Steinert et al[37] (2010)	*Archives of Orthopaedic and Trauma Surgery*	Germany	Clinical	IV	Plica, synovial fold
27	Tateishi et al[38] (2006)	*Knee Surgery, Sports Traumatology, Arthroscopy*	Japan	Clinical	V	Synovial fold, plica

Table II Demographic and clinical characteristics of included articles

Study No.	Article (year)	No. of patients (elbows)	Age, average ± SD (range), yr	Sex	Associated history or initial diagnosis	Sports activity or heavy labor	Trauma history	Dominant extremity affected	Clinical presentation
1	Akagi and Nakamura[1] (1998)	1	27	1 M	Painless snapping	Heavy lifting	—	No	Pain and mechanical symptoms: locking, clicking, catching, and popping
2	Antuna and O' Driscoll[2] (2001)	14	36 (27-48)	8 M and 6 F	Intra-articular loose bodies were initially diagnosed in 5 of 14 (35.7%)	None	Nondisplaced radial head fracture in 2 of 14 (35.7%)	10 of 14 (71.4%)	Pain and mechanical symptoms (7 of 14)
3	Awaya et al[3] (2001)	Cadavers: 5	74.4 (57-89)	5 M	NA	NA	—	Not mentioned	
		Asymptomatic: 164	39.6 (8-86)	105 M and 59 F	None	None	—	Not mentioned	
		Symptomatic: 8	28.3 (17-37)	8 M	6 of 8 (75%) presented with symptoms mimicking loose bodies	2 of 8 (25%) were professional athletes	—	Not mentioned	Mechanical symptoms
4	Brahe Pedersen et al[5] (2017)	60 (64)	44 (18-66)	17 M and 43 F	Not mentioned	25 of 60 (41.6%) were manual workers	—	Not mentioned	Pain and mechanical symptoms
5	Celikyay et al[6] (2015)	Asymptomatic: 51 (100)	44.12 ± 13.08	26 M and 25 F	None	None	—	Not mentioned	
		Symptomatic: 15	52.6 ± 9.58	10 M and 5 F	All presented with elbowosteoarthritis (studygroup)	None	—	Not mentioned	Pain, swelling, and limited ROM
6	Choi et al[7] (2017)	Asymptomatic: 25 (50)	22 (20-24)	25 M	None	None	—	Not mentioned	
		Symptomatic: 14	32 (16-55)	12 M and 2 F	Not mentioned	None	—	Not mentioned	No details on symptoms
7	Clarke[8] (1988)	3	31.6 (18-48)	2 M and 1 F	None	Basketball, tennis, and vigorous housework	Olecranon contusion 2 mo prior	2 of 3 (66.7%)	Pain and mechanical symptoms
8	Del Grande et al[9] (2015)	Asymptomatic: 21	23 (18-34)	21 M	1 of 21 (4.7%) with mild laxity	Professional baseball pitchers	—	Not mentioned	—
9	Duparc et al[10] (2002)	Cadavers: 50	Not mentioned	Not mentioned	NA	NA	—	NA	—
10	Feller et al[11] (2018)	1	59	1 M	None	Heavy labor (shipyard welder)	—	Not mentioned	Pain and mechanical symptoms

11	Fukase et al[12] (2005)	1	12	1 M	None	None	—	Yes	Pain and mechanical symptoms
12	Husarik et al[16] (2010)	Asymptomatic: 60	32.8 (22-51)	30 M and 30 F	None	None	—	NA (because all were asymptomatic)	—
13	Isogai et al[17] (2001)	Cadavers: 100 (179)	77.7 (42-101)	41 M and 59 F	Not mentioned	NA	—	NA	—
14	Kim et al[20] (2006)	12	21.6 (17-33)	9 M and 3 F	All athletes; LE was initially diagnosed in 6 of 12 (50%)	7 baseball pitchers, 2 softball pitchers, and 3 golfers	—	11 of 12 (91.6%)	Pain and mechanical symptoms
15	Koh et al[21] (2007)	Cadavers: 43 (49)	67 (35-86)	18 M and 25 F	None	NA	—	NA	—
16	Kongmalai et al[22] (2016)	29	40 (15-59)	10 M and 19 F	LE was initial diagnosis in all patients	Not mentioned	—	17 of 29 (58.6%)	Pain
17	Lee et al[23] (2018)	20	42 (18-63)	11 M and 9 F	None	None	Nonspecific trauma in 5 of 20 (25%)	13 of 20 (65%)	Pain and mechanical symptoms
18	Mete et al[25] (2014)	1	17	1 F	None	Swimmer	—	Not mentioned	Pain and mechanical symptoms
19	Meyers et al[26] (2012)	1	14.5 (13-16)	1 M and 1 F	None	None	Nonspecific trauma in 1 of 2 (50%)	Not mentioned	Pain and mechanical symptoms
20	Natwa et al[31] (2018)	1	Not specified	1 M	None	Baseball pitcher	—	Yes	Pain
21	Phorkhar et al[32] (2015)	20	38 (14-53)	7 M and 13 F	Not mentioned	Not mentioned	NA	Not mentioned	Pain
22	Rajeev and Pooley[33] (2015)	121	38 (24-56)	92 M and 29 F	LE was initial diagnosis in all patients	Not mentioned	—	Not mentioned	Pain
23	Ruch et al[34] (2006)	10	40 (18-60)	4 M and 6 F	LE was initial diagnosis in all patients	Not mentioned	—	Not mentioned	Pain and mechanical symptoms
24	Ruiz De Luzuriaga et al[35] (2013)	Symptomatic: 9	Symptomatic: 35.7 (18-63)	5 M and 4 F	Loose body initially diagnosed in 2 of 9 (22.2%)	Not mentioned	—	Not mentioned	Pain and mechanical symptoms
		Control: 15	Control: 13.3 (15-58)	13 M and 2 F	NA		—	Not mentioned	—
25	Sanghi et al[36] (2007)	1	17	1 F	None	Cheerleader	—	No	Pain and mechanical symptoms

(*continued on next page*)

Table II Demographic and clinical characteristics of included articles (*continued*)

Study No.	Article (year)	No. of patients (elbows)	Age, average ± SD (range), yr	Sex	Associated history or initial diagnosis	Sports activity or heavy labor	Trauma history	Dominant extremity affected	Clinical presentation
26	Steinert et al[37] (2010)	3	48.6 (27-65)	3 M	None	Not mentioned	Nonspecific trauma in 1 of 3 (33.3%)	Not mentioned	Pain and mechanical symptoms
27	Tateishi et al[38] (2006)	1 (2)	64	1 F	None	Left: dumbbell exercise Right: farming	—	Yes	Pain and mechanical symptoms

SD, standard deviation; *M*, male; *F*, female; *NA*, not applicable; *ROM*, range of motion; *LE*, lateral epicondylitis.

Data extraction and analysis

Data were extracted from the text, figures, tables, and supplementary material of each included study. These data included (1) article characteristics and terminology, (2) demographic and clinical characteristics, and (3) plica characteristics and investigations. We conducted a qualitative assessment of all studies and created a narrative report. When possible, data were combined, although this was not always possible because of the low level of evidence and heterogeneity of the studies. These data were summarized in tables using Microsoft Office Excel 2013 (Microsoft, Redmond, WA, USA).

Results

In the first step, 243 articles were retrieved for initial screening; the titles and abstracts of these articles were then examined for duplication. Conference abstracts were excluded from the review. Full-text reviews of 50 articles helped to identify 27 articles (ie, 7 level V studies, 19 level IV studies, and 1 level III study) for the systematic review.

Article characteristics and terminology

Studies were mostly performed in the United States (44%), followed by Asia (30%) and Europe (26%). There were 17 clinical studies (63%) and 10 radiologic studies (37%). Overall, 4 of 27 studies included specimens from cadavers. ‘‘Plica’’ was the most commonly used terminology in 9 studies (33%); ‘‘synovial fold’’ and ‘‘plica’’ were interchangeably used as identical terms in 10 studies (37%). ‘‘Synovial fold’’ was the solely used terminology in 6 studies (22%) (Table I).

Demographic and clinical characteristics

The 27 chosen studies included 683 patients (762 elbows) and 198 cadavers (283 elbow specimens). The patients included 423 male patients (62%) and 260 female patients (38%) (Table II). The initial diagnoses were lateral epicondylitis (166 patients, 53%)[20,33,34] and loose bodies (13 patients, 4%).[2,3] The provocative factors before the symptoms were documented in 68 of 109 patients (62%). These factors were sporting activities (including those performed by professional athletes) in 39 of 68 patients (57%) and heavy labor in 29 of 68 patients (43%). The dominant extremity was affected in 68% of all patients reported (56 of 83). Trauma events preceded the plica pathology in 12 of 42 patients (29%). Figure 2 describes the distribution of clinical symptoms in symptomatic patients. Among all 333 symptomatic patients, pain was the most common symptom (171 patients, 49%), followed by pain with mechanical symptoms (139 patients, 40%), pain with motion limitation (15 patients, 4%), and mechanical symptoms (8 patients,

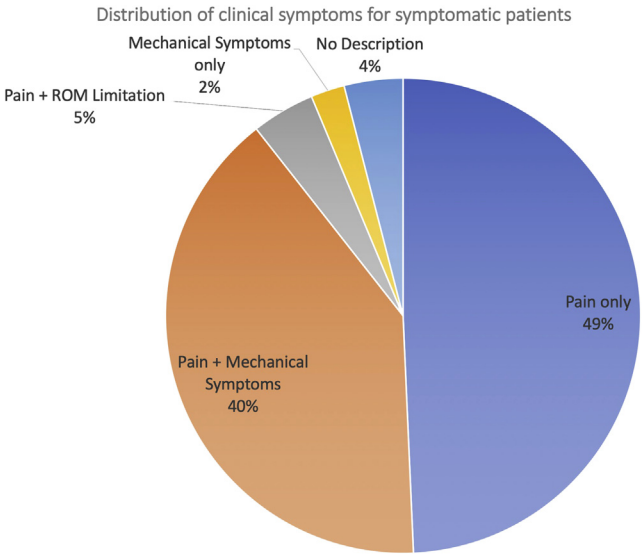

Figure 2 Distribution of clinical symptoms in patients with symptomatic plicae. *ROM*, range of motion.

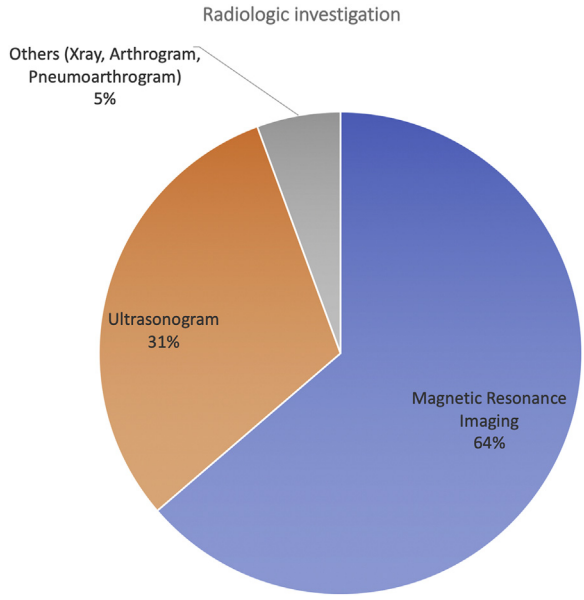

Figure 3 Distribution of tools used for radiologic investigation of plicae.

2%). The symptoms in 14 patients (4%) were not described in detail.

Plica characteristics and investigations

Among all the studies that described radiologic investigations, magnetic resonance imaging (MRI) was the most commonly used diagnostic modality (351 patients, 64%), followed by ultrasonography (169 patients, 31%) (Fig. 3, Table III). The prevalence of plicae in asymptomatic patients was reported to be 77% (349 of 454 patients).[3,6,7,9,16,21,35] However, in symptomatic patients, it was reported to be 97% (280 of 288 patients).[5-7,11,20,23,25,26,33,34,36-38] In the asymptomatic patient group, the radiologic modalities (MRI and ultrasonography) could detect plica structures in 311 of 384 patients (81%). In the symptomatic patient group, the radiologic modalities used included MRI to detect plica structures in 94 of 105 patients (90%). In the symptomatic group, plicae were predominantly located in the posterolateral region (95 patients, 54%), followed by the posterior region (42 patients, 24%). In the asymptomatic group and in cadaveric studies, the location of the plicae was similarly distributed among the posterior, posterolateral, and anterior regions (29%, 37%, and 22%, respectively). Pathologic findings on radiologic examinations were identified in 91 of 94 patients (97%). A thickened plica was the most common MRI finding in symptomatic patients (94%). Among the 42 MRI scans that provided diagnostic details in symptomatic patients, the plica was consistently determined to be >3 mm in thickness (craniocaudal length).[3,20,23,26] Among the 5 studies that described the thickness of plicae in asymptomatic patients, measurements ranged from 1.7 to 2.2 mm in craniocaudal thickness.[3,6,9,10,16] Choi et al[7] and Mete et al[25] suggested that the plica covers one-fifth to more than one-third of the radial head in asymptomatic patients.

Discussion

This systematic review reported 3 major components associated with the plica: terminology, prevalence, and investigations. "Plica" was the most commonly used term, followed by "synovial fold." Moreover, our study showed that the terms "plica" and "synovial fold" may be confused with the meniscus or meniscocapsular complex and annular or orbicular ligament, which produces similar symptoms with pathology (pain and mechanical symptoms). The meniscus of the radiohumeral joint[15,18] and the meniscocapsular complex[28] were not easy to distinguish from a thickened plica in the elbow joint on MRI investigations. However, the histologic findings of a meniscus in the radiohumeral joint showed fibrocartilaginous tissue without collagen fiber bundles and a synovial layer on the tissue surface that correlated with those found in the knee joint.[18] The annular or orbicular ligament, which contains the nociceptive receptors,[19] can become hypertrophic and stenotic.[4] Despite the symptoms (pain and mechanical symptoms) that can arise from a hypertrophic annular ligamentous pathology, the structure is not overly similar to that of a plica. Furthermore, an anatomic study has revealed that a synovial plica protrudes as a distinct structure from the proximal edge of the inner surface of the annular ligament, which also merges with the common extensor tendon to form a composite structure together with the capsule and bone.[17]

Table III Plica characteristics and investigations

Study No.	Article (year)	Location		Radiologic investigation	Incidence and radiologic findings		Plica dimensions	
		Asymptomatic	Symptomatic		Asymptomatic	Symptomatic	Asymptomatic	Symptomatic
1	Akagi and Nakamura[1] (1998)		Anterolateral	Radiography Pneumo-arthrogram		Radiography: normal Pneumo-arthrogram: intra-articular cord in radiohumeral joint		Dimension: 27 mm (long) × 6 mm (wide)
2	Antuna and O'Driscoll[2] (2001)		Lateral	Radiography in all patients MRI in 6 of 14		MRI: thickened		No detail
3	Awaya et al[3] (2001)	Anterior in 2 of 5 Posterior in 3 of 5	Posterior	MRA in 11 of 177 MRI in 166 of 177	Radiography: normal Incidence (by MRI) of 4 of 5	Synovial plicae with projecting focal fat pad from superior-posterior region to olecranon recess	2 mm	Thickness: 3.1 mm (range, 2-5 mm)
		Posterior in 126 of 164 Anterior in 113 of 164			Incidence (by MRI) of 74 of 164			
4	Brahe Pedersen et al[5] (2017)		Posterolateral	US		Hypoechoic rims between radial head and capitellum		NA
5	Celikyay et al[6] (2015)	Posterolateral	Posterolateral	US	Incidence of 100%	Incidence of 15 of 22	Thickness in osteoarthritis group of 1.420 ± 0.462 mm Thickness in asymptomatic group of 2.127 ± 0.485 mm	NA
6	Choi et al[7] (2017)	Posterolateral in 46 of 50	Posterolateral	MRI	Incidence of 46 of 50	Incidence of 100% 2 of 50: chondromalacia of radial head	Mediolateral measurement: 3.8 mm Sagittal measurement: 4.7 mm	Median dimension: 7.0 mm (mediolateral) × 7.4 mm (sagittal) Radial head coverage: 21%

7	Clarke[8] (1988)		Lateral	Radiography		1 of 3: loose body at anterior compartment	Radial head coverage: 16% mediolateral and 21% sagittal	No detail
8	Del Grande et al[9] (2015)	Posterolateral		MRI	Incidence of 100%		Dimension: 5.3 mm (3.8-7.1 mm) (anteroposterior) × 2.2 mm (1.5-4.3 mm) (craniocaudal) × 2.7 mm (1.6-4.7 mm) (mediolateral)	
9	Duparc et al[10] (2002)	Posterolateral in 15 of 43 Posterior in 11 of 43 Lateral in 9 of 43 Anterolateral in 2 of 43 Circular in 4 of 43 Anterior and posterior in 2 of 43		None (anatomic study)	Incidence of 43 of 50		Mean length: 21.4 mm (range, 9-51 mm) Mean width: 2.9 mm (range, 1-10 mm) Mean maximal thickness: 1.7 mm (range, 1-4 mm)	
10	Feller et al[11] (2018)		Lateral	MRI US		MRI: common extensor tendinopathy and thickened radial collateral ligament US: entrapment of synovial fold to radiohumeral joint during elbow flexion		NA

(*continued on next page*)

Table III Plica characteristics and investigations (*continued*)

Study No.	Article (year)	Location		Radiologic investigation	Incidence and radiologic findings		Plica dimensions	
		Asymptomatic	Symptomatic		Asymptomatic	Symptomatic	Asymptomatic	Symptomatic
11	Fukase et al[12] (2005)		Posterolateral	MRI		Nodular lesion in humeroradial joint		NA
12	Husarik et al[16] (2010)	Posterolateral in 59 of 60		MRI	Incidence of 59 of 60		Median dimension: 4.3 mm (sagittal) × 1.9 mm (craniocaudal) × 3.9 mm (mediolateral)	
13	Isogai et al[17] (2001)	Lateral in 68 of 100		None (anatomic study)	NA		No detail	
14	Kim et al[20] (2006)		Lateral	Radiography MRI MRA in 5 of 12		MRI: 9 of 12 with abnormal plica (thickened, irregular, and nodular appearance)		Thickness: >3 mm
15	Koh et al[21] (2007)	Anteroposterior in 43 elbows Lateral in 10 elbows Circular in 6 elbows		US	Incidence of 40 of 43 (triangular structure bordered by hypoechoic rims)			—
16	Kongmalai et al[22] (2016)		Not mentioned	None		—		No detail
17	Lee et al[23] (2018)		Posterior in 15 of 20 Anterior in 1 of 20 Both in 4 of 20	Radiography MRI		MRI: meniscus-like synovial plica		Mean thickness: 3.7 ± 1.0 mm Mean dimension: 9.4 ± 1.6 mm (mediolateral) × 8.2 mm ± 1.7 mm (anteroposterior)
18	Mete et al[25] (2014)		Posterolateral	MRI		Thickened radiohumeral plica		Radial head coverage: more than one-third

19	Meyers et al[26] (2012)		Posterolateral	Radiography MRI		MRI: thickened synovial plica	Dimension: 3.1 and 3.5 mm (craniocaudal)
20	Natwa et al[31] (2018)		Not mentioned	Radiography MRI MRA		MRA: posterolateral joint capsular tear and adjacent synovial hypertrophy	No detail
21	Phorkhar et al[32] (2015)		Not mentioned	None		—	—
22	Rajeev and Pooley[33] (2015)		Not mentioned	MRI (No. of patients not specified)		Thickened plica	No detail
23	Ruch et al[34] (2006)		Posterior	NA		Large plica in radiocapitellar articulation	No detail
24	Ruiz De Luzuriaga et al[35] (2013)	Posterior	Posterior	MRI in 16 of 24 MRA in 8 of 24	Incidence of 100%	Thickened plica	No detail
25	Sanghi et al[36] (2007)		Posterolateral	MRI		Thickened plica	No detail
26	Steinert et al[37] (2010)		Posterolateral	MRI		Thickened plica	No detail
27	Tateishi et al[38] (2006)		Anterior	Arthrogram MRI		Arthrogram: protruding shadow in location that resembled MRI findings MRI: triangular tissue extruding from articular capsule at anterior portion of radiohumeral joint	NA

MRI, magnetic resonance imaging; *MRA*, magnetic resonance arthrography; *US*, ultrasonography; *NA*, not available.

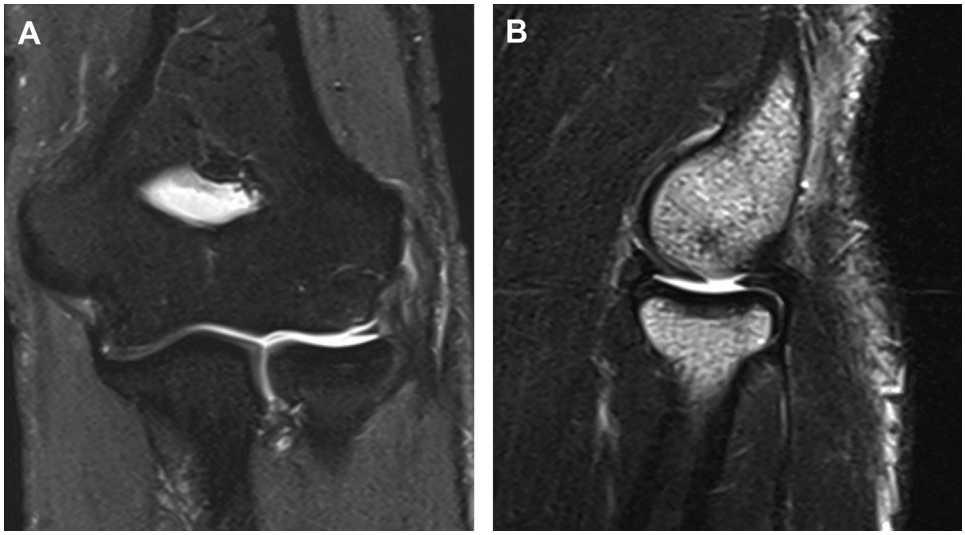

Figure 4 Magnetic resonance imaging investigation showing elbow plica observed on coronal T2 (**A**) and sagittal T1 (**B**) sequences.

Our systematic review has established that plicae are prevalent and are found in a large proportion of individuals, even those who are asymptomatic. A thickened plica has been linked with overuse injuries, trauma, and associated lateral elbow pain.[20,23,31,38] This systematic review showed that sports activities involving throwing, which require repetitive flexion and extension, may serve as a provocative factor.[8,20,31] Heavy manual labor may also contribute as a provocative factor, as indicated by several studies.[1,5,8,11] Many nonspecific previous studies have also shown that traumatic events[2,3,23,37] and repetitive microtrauma from overuse injury[20,31,38] may be associated with symptomatic plicae. Repetitive microtrauma may result in inflammation, which explains the subsequent thickening of the structure and the eventual impingement and compression to the surrounding articular surface (capitellum and radial head). Consequently, pain and mechanical symptoms such as snapping of the radiocapitellar joint were often experienced by patients. Our systematic review also showed that the dominant extremity was most commonly affected in symptomatic patients, which supports an overuse-injury background. Therefore, it is not advisable to underestimate the history of overuse injury in this pathologic condition.

A snapping synovial plica can be misdiagnosed as lateral epicondylitis, intra-articular loose bodies, and snapping of the triceps tendon.[31] This review showed that 3 main symptoms are associated with snapping synovial plicae, namely (1) lateral elbow pain, (2) mechanical symptoms, and (3) loss of motion, particularly extension. The lateral elbow pain present in all cases can be explained by the presence of nerve fibers in the folds,[10] as well as the release of cytokines and other inflammatory mediators.[8]

Lateral epicondylitis may also coexist with symptomatic synovial plicae, which also presents as lateral elbow pain; however, tenderness at the posterolateral soft spot may indicate the need to differentiate plica syndrome from lateral epicondylitis.[20] On the basis of this systematic review, we suggest the use of the term ''plica'' to describe the anatomic structure and the term ''plica syndrome'' to describe the pathology owing to the existence of a large symptom spectrum.[3,31]

Preoperative imaging investigations have shown that plain radiographs are not helpful in diagnosing symptomatic plicae and for excluding intra-articular loose bodies.[1,2,8,20,23,31,37,38] Symptomatic plicae can be reckoned as internal derangement of the elbow joint; therefore, an MRI examination will be essential as a diagnostic tool (Fig. 4).[2,3,11,20,23,31,33,37,38] Our systematic review showed that a thickened plica is the most common finding in symptomatic patients. However, the included studies did not allow a conclusion to be reached regarding which MRI sequence. MRI is an excellent tool for the initial diagnosis; however, there is no established cutoff point regarding the thickness of the plica to be considered pathologic. Many studies have reported that the plica is thicker in symptomatic persons and therefore more likely to become caught in surrounding structures, causing impingement symptoms. In a study performed to determine the value of MRI in establishing symptomatic plicae, Lee et al[23] found that the mean thickness of a pathologic plica was 3.7 mm. However, Ruiz de Luzuriaga et al[35] reported that a plica would be considered pathologic when it was thicker than 2.6 mm, which was compared with a control group with an average thickness of 1.8 mm. Among the studies that described the thickness of the plica, it was found that the symptomatic plica had a thickness >3 mm. Despite the lack of definitive cutoff measurements for thickness, we suggest that plicae should be considered pathologic if they measure >3 mm in thickness in conjunction with clinical symptoms. We

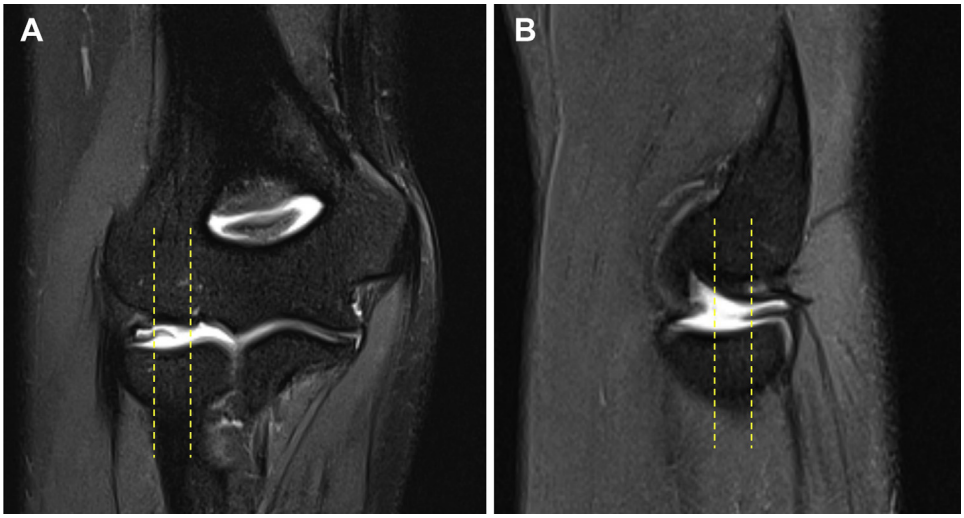

Figure 5 Magnetic resonance imaging investigation showing plica coverage of more than one-third of radial head quadrant on T2 sequence of coronal (**A**) and sagittal (**B**) projections.

suggest that MRI examinations be used to determine the pathology using a minimum 3-mm slice thickness in continuous slice increments so that the plica is not missed on imaging.

MRI is also valuable in determining the position of the plica in correspondence with the radial head quadrant. Although no consensus exists on the location of the plicae and whether they can be considered symptomatic, our systematic review showed that plicae present in the posterolateral quadrant may be symptomatic. It is also important to note that plica coverage of more than one-third of the radial head quadrant indicates a risk of being pathologic (Fig. 5).[7,25] In this systematic review, we conclude that the diagnostic measurement of a plica is only relevant if it is diagnosed noninvasively. Arthroscopy is the gold standard because it is the best method for diagnosis; however, it is invasive and expensive. Hence, considering its noninvasive nature, MRI is helpful as an initial examination.

Study limitations

This review has some limitations. First, none of the studies had a control group (healthy contralateral elbow joint) to allow for a comparison of the radiologic findings of the pathologic plicae. Second, data from the included studies were retrospectively collected. Third, the studies' radiologic investigation tools were heterogeneously reported, preventing direct comparison of radiologic findings and therefore indicating the need for standardized methods.

Conclusion

On the basis of this systematic review, we suggest using the term "plica" for the elbow synovial fold structure and "plica syndrome" to indicate its pathology. Plicae are prevalent and found in a large proportion of individuals, even those who are asymptomatic. MRI provides excellent information regarding the position and thickness of elbow plicae. Consideration of a pathologic elbow plica revealed the following factors: (1) the thickness is >3 mm and (2) a pathologic plica is generally positioned posterior to lateral and/or covers more than one-third of the radial head quadrant. To evaluate the pathologies associated with elbow plicae, clinical and radiologic aspects should be considered.

Disclaimer

The authors, their immediate families, and any research foundations 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.

References

1. Akagi M, Nakamura T. Snapping elbow caused by the synovial fold in the radiohumeral joint. J Shoulder Elbow Surg 1998;7:427-9.
2. Antuna SA, O'Driscoll SW. Snapping plicae associated with radiocapitellar chondromalacia. Arthroscopy 2001;17:491-5.
3. Awaya H, Schweitzer ME, Feng SA, Kamishima T, Marone PJ, Farooki S, et al. Elbow synovial fold syndrome: MR imaging findings. AJR Am J Roentgenol 2001;177:1377-81.
4. Bosworth DM. The role of the orbicular ligament in tennis elbow. J Bone Joint Surg Am 1955;37-A:527-33.
5. Brahe Pedersen J, Kristensen PK, Monsted P, Thillemann TM. Short-term results after arthroscopic resection of synovial plicae in the radiohumeral joint: a case series of 64 procedures. SICOT J 2017;3:42. https://doi.org/10.1051/sicotj/2017021

6. Celikyay F, Inanir A, Bilgic E, Ozmen Z. Ultrasonographic evaluation of the posterolateral radiohumeral plica in asymptomatic subjects and in patients with osteoarthritis. Med Ultrason 2015;17:155-9. https://doi.org/10.11152/mu.2013.2066.172.usev
7. Choi SH, Ji SK, Lee SA, Park MJ, Chang MJ. Magnetic resonance imaging of posterolateral plica of the elbow joint: asymptomatic vs. symptomatic subjects. PloS One 2017;12:e0174320. https://doi.org/10.1371/journal.pone.0174320
8. Clarke RP. Symptomatic, lateral synovial fringe (plica) of the elbow joint. Arthroscopy 1988;4:112-6.
9. Del Grande F, Aro M, Farahani SJ, Wilckens J, Cosgarea A, Carrino JA. Three-Tesla MR imaging of the elbow in non-symptomatic professional baseball pitchers. Skeletal Radiol 2015;44:115-23. https://doi.org/10.1007/s00256-014-2018-z
10. Duparc F, Putz R, Michot C, Muller JM, Freger P. The synovial fold of the humeroradial joint: anatomical and histological features, and clinical relevance in lateral epicondylalgia of the elbow. Surg Radiol Anat 2002;24:302-7. https://doi.org/10.1007/s00276-002-0055-0
11. Feller RJ, Gil JA, DaSilva M. Snapping at the lateral aspect of the elbow: a case report and review of the literature. JBJS Case Connect 2018;8:e48. https://doi.org/10.2106/JBJS.CC.17.00198
12. Fukase N, Kokubu T, Fujioka H, Iwama Y, Fujii M, Kurosaka M. Usefulness of MRI for diagnosis of painful snapping elbow. Skeletal Radiol 2006;35:797-800. https://doi.org/10.1007/s00256-005-0940-9
13. Garcia-Valtuille R, Abascal F, Cerezal L, Garcia-Valtuille A, Pereda T, Canga A, et al. Anatomy and MR imaging appearances of synovial plicae of the knee. Radiographics 2002;22:775-84. https://doi.org/10.1148/radiographics.22.4.g02jl03775
14. Howick J, Chalmers I, Glasziou P, Greenhalgh T, Heneghan C, Liberati A, et al. The 2011 Oxford CEBM levels of evidence. Oxford: Oxford Centre for Evidence-Based Medicine; 2011.
15. Huang GS, Lee CH, Lee HS, Chen CY. A meniscus causing painful snapping of the elbow joint: MR imaging with arthroscopic and histologic correlation. Eur Radiol 2005;15:2411-4. https://doi.org/10.1007/s00330-005-2685-1
16. Husarik DB, Saupe N, Pfirrmann CW, Jost B, Hodler J, Zanetti M. Ligaments and plicae of the elbow: normal MR imaging variability in 60 asymptomatic subjects. Radiology 2010;257:185-94. https://doi.org/10.1148/radiol.10092163
17. Isogai S, Murakami G, Wada T, Ishii S. Which morphologies of synovial folds result from degeneration and/or aging of the radiohumeral joint: an anatomic study with cadavers and embryos. J Shoulder Elbow Surg 2001;10:169-81.
18. Kang ST, Kim TH. Lateral sided snapping elbow caused by a meniscus: two case reports and literature review. Knee Surg Sports Traumatol Arthrosc 2010;18:840-4. https://doi.org/10.1007/s00167-010-1076-6
19. Kholinne E, Lee HJ, Lee YM, Lee SJ, Deslivia MF, Kim GY, et al. Mechanoreceptor profile of the lateral collateral ligament complex in the human elbow. Asia Pac J Sports Med Arthrosc Rehabil Technol 2018;14:17-21. https://doi.org/10.1016/j.asmart.2018.04.001
20. Kim DH, Gambardella RA, Elattrache NS, Yocum LA, Jobe FW. Arthroscopic treatment of posterolateral elbow impingement from lateral synovial plicae in throwing athletes and golfers. Am J Sports Med 2006;34:438-44. https://doi.org/10.1177/0363546505281917
21. Koh S, Morris RP, Andersen CL, Jones EA, Viegas SF. Ultrasonographic examination of the synovial fold of the radiohumeral joint. J Shoulder Elbow Surg 2007;16:609-15. https://doi.org/10.1016/j.jse.2006.10.019
22. Kongmalai P, Chanlalit C. Demographic Causes of Chronic Lateral Elbow Pain along Arthroscopic Criteria. J Med Assoc Thai 2016;99(Suppl 8):S79-83.
23. Lee HI, Koh KH, Kim JP, Jaegal M, Kim Y, Park MJ. Prominent synovial plicae in radiocapitellar joints as a potential cause of lateral elbow pain: clinico-radiologic correlation. J Shoulder Elbow Surg 2018;27:1349-56. https://doi.org/10.1016/j.jse.2018.04.024
24. Merida-Velasco JA, Sanchez-Montesinos I, Espin-Ferra J, Merida-Velasco JR, Rodriguez-Vazquez JF, Jimenez-Collado J. Development of the human elbow joint. Anat Rec 2000;258:166-75.
25. Mete BD, Gursoy M, Resnick D. A rare cause of posterolateral elbow pain: radiohumeral plica syndrome with typical MRI findings. JBR-BTR 2014;97:371. https://doi.org/10.5334/jbr-btr.152
26. Meyers AB, Kim HK, Emery KH. Elbow plica syndrome: presenting with elbow locking in a pediatric patient. Pediatr Radiol 2012;42:1263-6. https://doi.org/10.1007/s00247-012-2407-1
27. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 2009;151:264-9, W264. https://doi.org/10.7326/0003-4819-151-4-200908180-00135
28. Mullett H, Sprague M, Brown G, Hausman M. Arthroscopic treatment of lateral epicondylitis: clinical and cadaveric studies. Clin Orthop Relat Res 2005;439:123-8. https://doi.org/10.1097/01.blo.0000176143.08886.fe
29. Munzinger U, Ruckstuhl J, Scherrer H, Gschwend N. Internal derangement of the knee joint due to pathologic synovial folds: the mediopatellar plica syndrome. Clin Orthop Relat Res 1981:59-64.
30. Nakayama A, Sugita T, Aizawa T, Takahashi A, Honma T. Incidence of medial plica in 3,889 knee joints in the Japanese population. Arthroscopy 2011;27:1523-7. https://doi.org/10.1016/j.arthro.2011.06.022
31. Natwa N, Zakaria A, Pujalte G. Unusual cause of elbow pain in a baseball pitcher. BMJ Case Rep 2018;2018:bcr2018224287. https://doi.org/10.1136/bcr-2018-224287
32. Phorkhar T, Chanlalit C. Functional Results in Arthroscopic Treatment in Patients with Chronic Lateral Elbow Pain. J Med Assoc Thai 2015;98(Suppl 10):S130-4.
33. Rajeev A, Pooley J. Arthroscopic resection of humeroradial synovial plica for persistent lateral elbow pain. J Orthop Surg (Hong Kong) 2015;23:11-4. https://doi.org/10.1177/230949901502300103
34. Ruch DS, Papadonikolakis A, Campolattaro RM. The posterolateral plica: a cause of refractory lateral elbow pain. J Shoulder Elbow Surg 2006;15:367-70. https://doi.org/10.1016/j.jse.2005.08.013
35. Ruiz de Luzuriaga BC, Helms CA, Kosinski AS, Vinson EN. Elbow MR imaging findings in patients with synovial fringe syndrome. Skeletal Radiol 2013;42:675-80. https://doi.org/10.1007/s00256-012-1523-1
36. Sanghi A, Ly JQ, Bush RJ, Folio LR. Case for diagnosis. Elbow synovial fold syndrome. Mil Med 2007;172:xii-xiii.
37. Steinert AF, Goebel S, Rucker A, Barthel T. Snapping elbow caused by hypertrophic synovial plica in the radiohumeral joint: a report of three cases and review of literature. Arch Orthop Trauma Surg 2010;130:347-51. https://doi.org/10.1007/s00402-008-0798-0
38. Tateishi K, Tsumura N, Matsumoto T, Fujioka H, Kokubu T, Kuroda R, et al. Bilateral painful snapping elbows triggered by daily dumbbell exercises: a case report. Knee Surg Sports Traumatol Arthrosc 2006;14:487-90. https://doi.org/10.1007/s00167-005-0692-z