




The Controversy Surrounding the Arcade of Struthers: A Systematic Review of Literature

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Abstract

The arcade of Struthers was first described by Kane et al in 1973 as a thickening of the deep investing fascia of the distal arm and superficial fibers of the medial head of the triceps muscle extending to the medial intermuscular septum. However, existence of anatomical structure remains disputed, lacking a unanimous consensus. This systematic review aims to provide an overview of all findings and conclusions on this subject. A literature search was conducted using Cumulative Index to Nursing and Allied Health Literature (CINAHL), Medline, Embase, and Web of Science. The QUality Appraisal for Cadaveric Studies (QUACS) scale was used for quality appraisal. In total, 12 studies (including 348 arms) agreed with the existence of the arcade of Struthers and its role in ulnar nerve entrapment. One study agreed with the existence of the structure, but disagreed with its nomenclature. On the other side, five studies (describing 224 arms) were against the existence of the structure. In literature, studies can be divided into two groups. The first group agrees with the existence of the arcade of Struthers as described by Kane et al in 1973, emphasizing its role in ulnar nerve entrapment. The second group disagrees with the existence of the arcade of Struthers, and is further divided into those who believe the structure is best described as an accessory origin of the head of the triceps muscle and those who consider it a dissection artifact.

Keywords

- ▶ arcade of Struthers
- ▶ ulnar nerve entrapment
- ▶ Struthers' ligament

Introduction

The arcade of Struthers (→ **Fig. 1A**) was described for the first time by Kane et al as a thickening of the deep investing fascia in the distal arm and superficial fibers of the medial head of the triceps muscle extending into the medial intermuscular septum.¹

Despite this description, some surgeons firmly believe that the arcade does not exist.²

This systematic review aims to investigate the reasons behind these doubts and to examine the arguments behind this controversy.

Materials and Methods

Search Strategy

Four databases were used in our literature search: Ovid MEDLINE, Ovid Embase, CINAHL, and Web of Science. The databases were searched without any language restrictions. The search strategy was performed until January 2022. A detailed search strategy can be found in **▶ Supplementary Material 1** (available in the online version). After inclusion, the reference list was checked for any missing articles.

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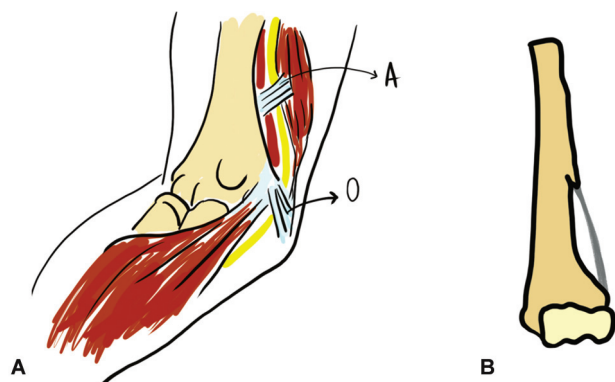


Fig. 1 (A) An illustration of the arcade of Struthers, which is a thin fibrous aponeurotic band extending from the medial head of the triceps to the medial intermuscular septum, approximately 6 to 10 cm proximal to the medial epicondyle of the humerus. (B) An illustration of Struthers' ligament that arises from a supracondylar process and inserts into the medial epicondyle of the humerus. A, arcade of Struthers; O, Osborne's ligament.

Inclusion and Exclusion Criteria

Two reviewers independently reviewed all identified studies. Studies were included if they met the following criteria: study with self-identified arcade of Struthers and clearly defined numbers of findings. Studies were excluded when no self-identified data were present and in case of unclear report on numbers. Case reports and reviews were also excluded.

Assessment of Methodological Quality

Assessment of methodological quality was independently performed by two reviewers using the Quality Appraisal for Cadaveric Studies (QUACS) scale. The QUACS scale consists of a 13-item checklist that reflect the design, conduct, and report of cadaveric dissection studies.³ After scoring, classifications such as “low,” “fair,” and “good” to studies with, respectively, 0 to 5, 6 to 9, and 10 to 13 points were given. Studies were included regardless of their quality classification. All disagreements between reviewers were solved by discussion between the authors.

The inter-rater reliability of the quality assessment was evaluated using kappa statistics and the mean absolute rating difference.

Data Extraction

Where available, the following information was collected from the studies: author, journal, title, publication year, type of study, level of evidence, funding, number of limbs, distribution of left or right limbs, gender, age of subjects, number of limbs with arcade of Struthers, definition given in the study for the arcade of Struthers, anatomical findings regarding the arcade of Struthers, arguments in favor or against the existence of the arcade of Struthers, and conclusion about arcade of Struthers.

Results

The initial search found 234 studies. Titles and abstracts were screened for eligibility, yielding 34 citations for full-text

review. Of these studies, 15 were excluded after full-text assessment. One study met our inclusion criteria but was a retracted study due to copyright infringement. Therefore, it was not included in this review. In total, 215 studies were excluded, leaving 19 studies to be included in our review (►Fig. 2).

The included studies have been published from 1973 until 2019. The average methodological quality using the QUACS scale was graded as moderate (see ►Table 1 for detailed characteristics of the included studies). The inter-rater agreement was measured using a Cohen kappa test and was found to be 0.71, indicating a substantial agreement between the reviewers concerning the quality assessment of the included articles.

In total, 660 dissected limbs were investigated for the presence of the arcade of Struthers. The arcade of Struthers was found in 288 arms. One study searched for the arcade of Struthers ultrasonically in an additional 40 limbs.⁴ In total, 12 studies (including 348 arms) agreed with the existence of the arcade of Struthers and its role in ulnar nerve entrapment, of which 6 presented arguments that led to their conclusion.^{1,5-15} In contrast, five studies (describing 224 arms) were against the existence of the structure; of these studies, four studies gave arguments leading to their conclusion about the structure.^{2,16-19} An overview of the arguments is shown in ►Table 2.

One study agreed with the existence of the structure, but disagreed with its nomenclature.⁴ Finally, one study did not provide a conclusion or an opinion about the arcade of Struthers.²⁰ The extracted data and anatomical findings are presented in ►Supplementary Materials 2 and 3, respectively.

Discussion

To this day, the literature remains divided about the existence of the arcade of Struthers.²¹ Opinions can be divided into two groups. The first group of authors are convinced about the existence of the arcade of Struthers and its ability to compress the ulnar nerve in patients causing proximal ulnar nerve entrapment. The second group doubts the existence of the structure due to its absence intraoperatively or in cadaveric studies. Finally, some authors agree on the existence of the structure while claiming its nomenclature should be changed. This is due to the fact that the structure was not described by John Struthers in 1854.²² Moreover, the similarity with the “ligament of Struthers” with its relation to the median nerve can be misleading (►Fig. 1B).

The first description of the arcade of Struthers is found in the anatomical study by Kane et al in 1973, more than a century after the anatomist John Struthers published his work on the anatomy of the arm. The authors described the arcade of Struthers as “the internal brachial ligament forming an arcade for passage of the ulnar nerve.” In 14 of 20 dissected patients, the arcade of Struthers was found, concluding that the incidence of the structure lies around 70%.¹²

Since it was first described in the literature, the incidence of the arcade of Struthers varies between 0 and 100%.

In 2016, Zhong et al conducted an ultrasonic observation as well as an anatomical study and found an arcade of

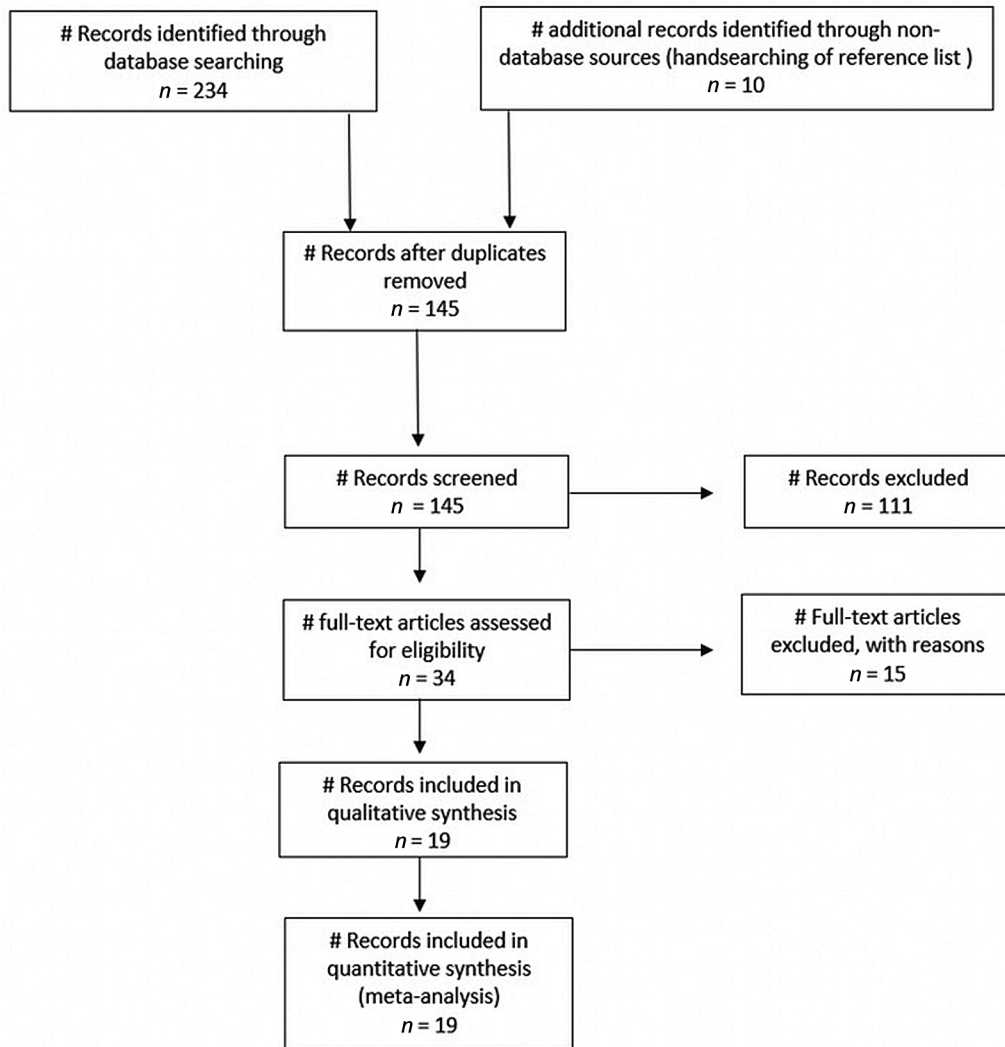


Fig. 2 Flowchart of study selection.

Table 1 Detailed characteristics of the included studies

Sl. no.	Study	Title	Journal	Country	Type of study	Funding or conflict of interest
1	al-Qattan and Murray ¹⁰	The arcade of Struthers: an anatomical study	Journal of Hand Surgery: British Volume	Canada	Anatomical study	Not measured
2	Amadio ⁸	Anatomical basis for a technique of ulnar nerve transposition	Surgical Radiologic Anatomy	United States	Anatomical study	Not measured
3	Bain and Bajhau ¹⁵	Endoscopic release of the ulnar nerve at the elbow using the Agee device: a cadaveric study	Arthroscopy: The Journal of Arthroscopic and Related Surgery	Australia	Anatomical study	Not measured
4	Bartels et al ²	The arcade of Struthers: an anatomical study	Acta Neurochirurgica	The Netherlands	Anatomical study	Not measured
5	Caetano et al ⁶	The arcade of Struthers: an anatomical study and clinical implications	Revista Brasileira de Ortopedia	Brazil	Anatomical study	None

(Continued)

Table 1 (Continued)

Sl. no.	Study	Title	Journal	Country	Type of study	Funding or conflict of interest
6	Dellon ¹⁶	Musculotendinous variations about the medial humeral epicondyle	The Journal of Hand Surgery	United States	Anatomical study	Not measured
7	Gabel and Amadio ⁷	Reoperation for failed decompression of the ulnar nerve in the region of the elbow	The Journal of Bone and Joint Surgery American Volume	United States	Case series	Yes
8	Gonzalez et al ¹¹	The ulnar nerve at the elbow and its local branching: an anatomic study	Journal of Hand Surgery	United States	Anatomical study	Not measured
9	Guidi et al ¹⁷	The debatable arcade of Struthers: is it still time to consider it?	European Journal of Anatomy	Switzerland	Anatomical study	Not measured
10	Kane et al ¹²	Observations of the course of the ulnar nerve in the arm (Sur le trajet du nerf cubital au niveau du bras)	Annales de Chirurgie	United States	Case report, anatomical study	Not measured
11	Mirza et al ¹⁸	An anatomical basis for endoscopic cubital tunnel release and associated clinical outcomes	Journal of Hand Surgery	United States	Anatomical study	None
12	Novak et al ¹³	Laxity of the ulnar nerve during elbow flexion and extension	Journal of Hand Surgery	Canada	Anatomical study	None
13	Poujade et al ²⁰	Ultrasound-guided surgical treatment for ulnar nerve entrapment: a cadaver study	Chirurgie de la Main	France	Anatomical study	None
14	Siqueira and Martins ⁹	The controversial arcade of Struthers	Surgical Neurology	Brazil	Anatomical study	Not measured
15	Tiyaworanan et al ¹	Anatomical study of arcade of Struthers	Hand Surgery: Journal of the Asia-Pacific Federation of Societies for Surgery of the Hand	Thailand	Anatomical study	Not measured
16	Tubbs et al ⁵	The arcade of Struthers: an anatomical study with potential neurosurgical significance	Surgical Neurology International	United States	Anatomical study	Not measured
17	von Schroeder and Scheker ¹⁴	Redefining the "arcade of Struthers"	Journal of Hand Surgery	Canada	Anatomical study	None
18	Wehrli and Oberlin ¹⁹	The internal brachial ligament versus the arcade of Struthers: an anatomical study	Plastic and Reconstructive Surgery	Switzerland	Anatomical study	Not measured
19	Zhong et al ⁴	Ultrasonic observation and clinical application of arcade of Struthers in the mid-arm	World Neurosurgery	China	Anatomical study	None

Table 2 Overview of arguments presented in included studies

Arguments in favor of the existence of AoS	Arguments against the existence of AoS
Reports on 35 patients undergoing revision, of whom 26 (74%) were significantly improved or completely relieved of symptoms by submuscular transfer (included release of the AoS) ⁸	Struthers did not describe an arch. Instead, he reported several muscular and tendinous arches in the arm, the supracondylar process, the ligament between this process and the medial epicondyle (that nowadays is known as the ligament of Struthers), and the influence of all these structures on the median nerve and brachial artery. He also reported the existence of a ligamentous cord, posterior to the medial intermuscular septum, lying within or continuous to the brachial fascia, and he called this the internal brachial ligament. The internal brachial ligament runs parallel to the medial intermuscular septum and does not cross it or form an arcade ²
Reports on 35 patients undergoing revision, of whom 26 (74%) were significantly improved or completely relieved of symptoms by submuscular transfer (included release of the AoS) ⁷	If the incidence of the supposed anatomical structure is between 68 and 70%, we should have encountered the arcade in 6 or 7 arms (dissected 10 arms) ²
Proximal to the medial epicondyle, the accessory origin of the medial head of the triceps from the medial intermuscular septum was found in 2 of the 26 specimens. We believe only 1 of 2 that were found could have been a potential compression site because we saw some compression of the nerve ¹⁸	In over 200 operations for ulnar nerve compression at the elbow, we did not encounter an arcade of Struthers, even though we always incised the brachial fascia overlying the ulnar nerve as far as the mid-arm ²
Ultrasound guidance and manual palpation led us to cut Struthers' arcade in three more instances in our study ²⁰	We simulated an anterior transposition and looked at the brachial fascia. If not divided sufficiently, there can be an increase in the density of the fibers. Although the normal fascia is only locally compressed, this could easily be called an arcade of Struthers ²
We present the case of a 25-year-old man with a partial laceration of the ulnar nerve just proximal to the olecranon notch. The nerve was mobilized anteriorly to reduce the gap between the stumps after resection and trimming, and while dissecting proximally to the medial humeral epicondyle, we found an asymptomatic arcade of Struthers ⁹	Although an arcade of Struthers was never present, it was possible to create an arcade or at least an indication of it in all specimens ²
Regarding the classical description of the arcade of Struthers, our type II most coincides with this anatomy, which is consistent with the so-called internal brachial ligament and was found in 19.2% of sides ⁵	Our personal observation in more than 300 cubital tunnel surgeries is that we have not yet encountered a discrete fibrous band in this location, proximal to the elbow, as a source of ulnar compression neuropathy ¹⁶
	In the 12 arms with the muscular fibers, the ulnar nerve could be easily handled and slid through. We did not find any arcade-like structure in any of the specimen. The ulnar nerve had a straight course within the muscular fibers. A dissection instrument glided easily underneath it. No additional bands or multiple muscular segments were found ¹⁷
	An arcade can be easily reproduced in specimens in laboratory by an incomplete release of the brachial fascia ¹⁷
	The anatomical structure bearing the legend arcade of Struthers on their pictures corresponds in fact to the internal brachial ligament observed in our dissections ¹⁹

Struthers in 57.8% of 64 dissected limbs.⁴ They found a tendinous arcade of Struthers in 32.5% and a muscular arcade of Struthers in 17.5% of 40 investigated limbs. They concluded the arcade of Struthers does exist and should be released during surgery. Additionally, a proposition has been made to rename the arcade of Struthers to emphasize its anatomic characteristics as the "medial head of the triceps canal."⁴

In this light, Dellon et al¹⁶ could not identify the arcade of Struthers in any of the 104 limbs investigated and suggested that the arcade can be created as a band of the fascial condensations from the medial head of the triceps muscle

to the medial intermuscular septum. In the case of anterior transposition of the ulnar nerve and no proximal release of this fascial sheath, a restraining "arcade" could be created. This is, however, not what Struthers described in his original works. Therefore, there is disagreement regarding the existence of the structure, with the author suggesting it is best described as the accessory origin of the head of the triceps muscle.¹⁶ Moreover, these findings were observed by Bartels et al in a cadaver by simulating an anterior transposition of the ulnar nerve with special attention to the brachial fascia. They found that when not divided sufficiently, there can be

an appearance of an increase in the density of fibers in the brachial fascia. In their opinion, this can be mistaken for the arcade of Struthers. In 10 dissected limbs and in more than 200 ulnar nerve surgeries they performed, a structure like the arcade of Struthers was not observed.² In the same year, Wehrli and Oberlin did not find an arcade of Struthers as mentioned by Kane et al in 30 investigated limbs. They did mention, however, that the arcade can be created as a dissection artifact of the brachial fascia. They concluded that the structure that impinges the nerve and is called the arcade of Struthers is in fact an insufficient proximal liberation of the brachial fascia.¹⁹

Conclusion

The controversy about the existence of the arcade of Struthers can be divided into the studies that support its existence and its role in ulnar nerve entrapment and those that do not support its existence. Studies that disagree with the existence of the arcade of Struthers can be further divided into those describing it as an accessory origin of the head of the triceps muscle and those describing the structure as a dissection artifact.

In our included studies on the existence of the arcade of Struthers, the structure was found in 44% of the investigated limbs. This incidence differs from that initially described by Kane et al.¹² The group of experts who agree with the existence of the arcade of Struthers and emphasize its role in ulnar nerve entrapment proposed renaming the structure to better emphasize its anatomical characteristics.

Discussion on the existence of the arcade of Struthers has clinical implications.^{1,6,23} Ulnar nerve compression should be treated effectively. Denial of the existence of the arcade of Struthers would imply that no release proximal to the cubital tunnel is required. If the arcade of Struthers does not exist in all individuals, could its presence in some individuals explain incomplete release of ulnar nerve compression? When treating residual ulnar nerve compression, would the advice be to perform a release especially more proximally or not? In our opinion, to have the greatest effect of ulnar nerve compression release, it would be wise to act as if the arcade does exist.

We believe that an anatomical study with a large sample size, clear outline of dissection method, and predissection imaging of structures in the upper arm may solve this disagreement. However, given that this structure has been described as one to be released during proximal decompression of the ulnar nerve, a randomized controlled trial (RCT) involving patients with ulnar nerve compression at the elbow undergoing operative simple decompression is also necessary. This will help properly understand its existence and, if it does exist, determine whether releasing this structure will benefit patients following ulnar nerve decompression surgery.

Furthermore, renaming the structure according to its anatomical position will eliminate confusion between the arcade of Struthers and the ligament of Struthers.

Authors' Contributions

All the authors approved the final contents of the submission and were actively involved in the planning and enactment of the study and in the preparation of the submitted article.

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Conflict of Interest

None declared.

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