

The debatable Arcade of Struthers: is it still time to consider it?

Marco Guidi¹, Valentin Neuhaus², Bartolomeo Scarsi³, Maurizio Calcagni¹,
Andreas Prescher⁴, Bernhard Dimitri Ciritsis³

¹Dept. of Plastic Surgery and Hand Surgery, Universitätsspital Zürich, Switzerland, ²Dept. of Traumatology, Universitätsspital Zürich, Switzerland, ³Orthopaedic Dept., Regional Hospital San Giovanni, Bellinzona, Switzerland, ⁴Institute of Molecular and Cellular Anatomy, University of Aachen, Germany

SUMMARY

The Arcade of Struthers is reported to be a structure that may play a role in ulnar nerve compression in the arm. The aim of this research is to better understand the relationship between the ulnar nerve and this anatomical structure of the medial aspect of the arm, and to investigate its morphology. In 54 fresh arms (26 female, 28 male, 24 left and 30 right limbs), with a median age of 67 years (range 45-83 years), the ulnar nerve and all the surrounding structures were dissected from the brachial plexus to the ulnar groove of the medial epicondyle.

We identified muscular fibers from the medial head of the triceps over the ulnar nerve in 12 examined limbs (24%). In all specimens the ulnar nerve was not compressed by any band and no sign of hourglass constriction was found. The extension of the muscular fibers was 34mm (min 20 mm, max 51 mm) and their average distance from the medial epicondyle was 61 mm (min 25 mm, max 80 mm). The findings of this study are not supportive for the presence of an arcade as previously described. Although this structure was reported to be a rare site of ulnar nerve compression at the elbow, it was not described by Struthers. The terminology "Arcade of Struthers" seems to be misleading due to the similarity with the other eponym "Ligament of Struthers".

Key words: Arcade of Struthers – Internal brachial ligament – Medial intermuscular septum – Ulnar

nerve – Entrapment – Anatomical study – Compressive neuropathy

INTRODUCTION

The Arcade of Struthers is a controversial structure that is reported to be a potential compression site of the ulnar nerve in the arm, and there is still no agreement in the literature about its existence.

In the literature this structure was differently identified as: ligamentous structure, a thickening of the brachial fascia, fibrous band, musculo-tendinous arcade, fibrous canal, muscle fibers or fascial condensation of the medial head of the triceps (Kane et al., 1973; Vesley and Killian, 1983; Amadio, 1986; Al-Qattan and Murray, 1991; Gonzalez et al., 2001; Von Schroeder and Scheker, 2003; Siqueira and Martins, 2005; Tiyaworanan et al., 2010; Tubbs et al., 2011; Caetano et al., 2017) (Table 1). Although this structure rarely causes ulnar nerve compression in patients, some anatomical studies have found an arcade-like structure (Kane et al., 1973; Vesley and Killian, 1983; Amadio, 1986; Al-Qattan and Murray, 1991; Gonzalez et al., 2001; Von Schroeder and Scheker, 2003; Siqueira and Martins, 2005; Tiyaworanan et al., 2010; Tubbs et al., 2011; Caetano et al., 2017), whereas some others have reported that it does not exist (Dellon, 1986; Bartels et al., 2003; Wehrli and Oberlin, 2005). Furthermore, this arcade was not originally described by Struthers (1848, 1854a, 1854b, 1854c, 1854d), and the use of this term can be misleading due to the similarity with the term "Ligament of Struthers" (Terry, 1930; Barnard and McCoy, 1946), which covers the median nerve and the brachial artery. Struthers (1848, 1854a,

Corresponding author: Marco Guidi, M.D. Dept. of Plastic Surgery and Hand Surgery, Universitätsspital Zürich, Rämistrasse 100, 8901 Zurich, Switzerland. Phone: +41765419886. E-mail: marcoguidi984@hotmail.com

Submitted: 14 April 2019. Accepted: 2 May, 2019.

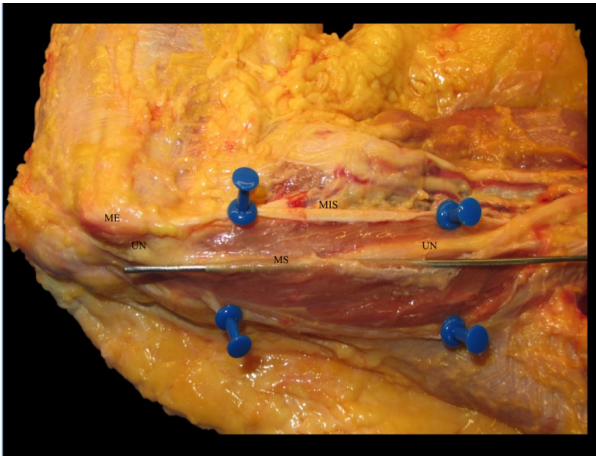


Fig 1. Muscular fibers from medial head of the triceps. ME: medial epicondyle, MS: muscular structure, IBL: internal brachial ligament, MIS: medial intermuscular septum, UN: Ulnar nerve.



Fig 2. The incomplete release of the brachial fascia can simulate an arcade-like structure. However, this is only a dissection artifact. ME: medial epicondyle, UN: ulnar nerve, *: dissection artifact of the brachial fascia, Blue arrows: release of the brachial fascia.

1854b, 1854c, 1854d) in his works identified 9 musculotendinous and fibrous structures in the arm: 8 were associated with the median nerve and the brachial artery, one was associated with the ulnar nerve. In the original paper, Struthers never described an arcade-like structure over the ulnar nerve, but reported the existence of a ligamentous cord, next to the medial intermuscular septum (MIS), continuous to the brachial fascia. He nominated this the "internal brachial ligament" (IBL).

The first English literature description of the Arcade of Struthers was popularized by Kane et al. in 1973 who referred it to Struthers's writings. They stated the arcade was made by a thickening of the deep fascia of the distal arm by superficial fibers of the medial head of the triceps muscle. They identified this structure in 70% of their cadaveric dissections. Since then, several anatomical studies reported different definition and results with non-uniform incidence of this structure (Kane et al., 1973; Vesley and Killian, 1983; Amadio, 1986; Al-Qattan and Murray, 1991; Gonzalez et al., 2001; Von Schroeder and Scheker, 2003; Siqueira and Martins, 2005; Tiyaworanan et al., 2010; Tubbs et al., 2011; Caetano et al., 2017).

The aim of this research is to understand the historical steps linked to the origin of the term Arcade of Struthers and to investigate its morphology and its potential role in compression neuropathies of the ulnar nerve.

The procedures followed are in compliance with the ethical standards of the responsible human experimentation committee and the 1975 Declaration of Helsinki, revised in 2000.

MATERIALS AND METHODS

Fifty-four fresh specimens, with ages at death from 45 to 83 years (67 years), were carefully dissected using a 4.0x loupe magnification by a hand surgeon. The medical history of all cadavers was

reviewed and none had a history of ulnar neuropathy, previous ulnar nerve surgery, joint disease, or trauma to the extremity. The ulnar nerve and the surrounding tissues were analyzed in the macroscopic morphology. The following structures' relationship with the ulnar nerve has been observed and noted: the MIS, the IBL, the brachial fascia. In case of fibrous bands, ligaments or muscular fibers over the ulnar nerve, length measurements of the structures in their complete extension were made in millimeter, and the distance from the most prominent point of the medial epicondyle was calculated. The investigation also was carried out for additional triceps attachments and abnormal fascial bands. The ulnar nerve then was examined to determine possible signs of compression.

Dissection protocol

The authors performed an arciform incision in the anteromedial side of the limb from the axilla to the middle third of the forearm with the elbow flexed at 90°. Therefore, two skin flaps were developed by including the subcutaneous tissue and exposing the entire medial surface of the arm. The brachial fascia was always identified with its transverse fibers. The brachial fascia was incised longitudinally and posteriorly to the MIS and carefully dissected to better identify every potential compression structure. The ulnar nerve was identified and its relationship with the soft tissues were noted.

RESULTS

Twenty-six female (12 left and 14 right limbs) and 28 male (12 left and 16 right limbs) cadavers were examined. Muscular fibers (Fig. 1) over the ulnar nerve were identified in 12 dissected arms (24%), 8 male and 4 female (9 right limbs and 3 left). These fibers had the same orientation as the medial head of the triceps. No evidence of fibrous struc-

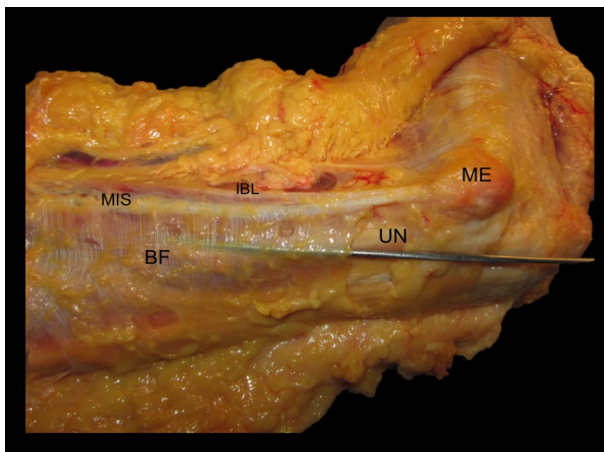


Fig 3. Appearance of the medial aspect of the arm with the typical transverse fibres of the brachial fascia. ME: medial epicondyle, IBL: internal brachial ligament, MIS: medial intermuscular septum, UN: Ulnar nerve, BF: Brachial fascia.

tures over the ulnar nerve were found. No thickening of the fascia or any fiber condensation was clearly identified. The average length of the muscular fibers was 34.2 mm (min 20 mm, max 51 mm) and their average distance from the most prominent point of the medial epicondyle was 61 mm (min 25 mm, max 80 mm). The IBL was present in 41 of 54 arms (75.9%).

In all the examined limbs, the nerve did not manifest any evidence of hourglass constriction between the MIS and the IBL. 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 segment were found.

DISCUSSION

The Arcade of Struthers is reported in the literature (Kane et al., 1973; Vesley and Killian, 1983; Amadio, 1986; Al-Qattan and Murray, 1991; Gonzalez et al., 2001; Von Schroeder and Scheker, 2003; Siqueira and Martins, 2005; Tiyaworanan et al., 2010; Tubbs et al., 2011; Caetano et al., 2017) to be a compressive structure that may play a role in ulnar nerve neuropathy in the arm. But it was never mentioned by Struthers (1848, 1854a, 1854b, 1854c, 1854d) in his original writings. Struthers indeed described 9 musculotendinous and fibrous structures in the arm: 8 were associated with the median nerve and the brachial artery, one was associated with the ulnar nerve. This last was next to the MIS, continuous to the brachial fascia and he named it the “internal brachial ligament” (IBL).

The Arcade of Struthers can be confused with the ligament known as the Ligament of Struthers

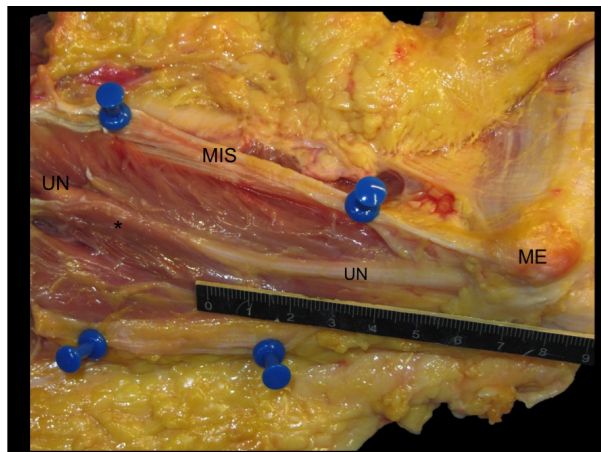


Fig 4. Release of the brachial fascia and identification of muscular fibers over the ulnar nerve. *: Muscular fibers from the medial head of the triceps, ME: medial epicondyle, IBL: internal brachial ligament, MIS: medial intermuscular septum, UN: Ulnar nerve.

described by Struthers (1848, 1854a, 1854b, 1854c, 1854d) between the medial epicondyle and the supracondylar process, a residual of the supracondylar foramen found in mammals, along the path of the median nerve and the brachial artery. The Ligament of Struthers' incidence is reported however to be very infrequent, between 0.7 and 2.5% (Terry, 1930; Barnard and McCoy, 1946) of the population.

The term “Arcade of Struthers” for the ulnar nerve was used for the first time in 1973 by Kane et al., who observed this arcade in 14 limbs of their cadaveric dissections. They used the original drawing of Struthers' work with the supracondylar process, and they added a proximal oblique band in their illustration.

Later on, Vesley and Killian in 1983 made a review on Struthers' original paper and defined as the Arcade of Struthers the ligament over the ulnar nerve described originally by Struthers.

In 1986, Amadio identified the arcade in 100% of 20 limbs and he stated that this structure is located 6-10 cm proximal to the medial epicondyle. Dellon (1986) in 64 limbs did not find any arcade. Furthermore, he reported that in more than 300 ulnar nerve releases he could not identify a real arcade but the fascial thickening from the medial head of the triceps to the MIS. Al-Qattan and Murray (1991) and Gonzalez et al. (2001) in their anatomical studies observed the existence of an arcade of Struthers respectively in 68% and 67% of their specimens. Bartels et al. in 2003 in 10 cadavers did not find any arcade, and he stated that in more than 200 ulnar nerve surgeries he did not observe such structure. Von Schroeder and Scheker (2003) reported the presence of this structure in 100% of cases, while Siqueira et al. (2005) in 13.5% of dissected cadavers (8 of 60 specimens). Wherli and Oberlin (2005) in 30 limbs did not find an arcade. Tubbs et al. (2011) and Tiyaworanan et al. (2010)

observed an arcade respectively in 86.7% (26 of 30 limbs) and 85.4% (54 of 62 limbs).

Tubbs et al. (2011) in his paper proposed an interesting and clear classification: Type I arcade, made by a thickening of the brachial fascia; Type II arcade, made by the IBL; Type III arcade, made by the MIS. Unfortunately, this classification was not applicable to the results we found.

Caetano et al. (2017) reported a muscular arcade in 72.5% of the examined specimens. Al-Qattan and Murray (1991) and von Schroeder and Scheker (2003) found multiple additional bands over the ulnar nerve. The homogeneous lack in the results (Table 1) can be due to the definition of the Arcade of Struthers. This was defined by the above-mentioned authors as: ligamentous structure, thickening of the brachial fascia, fibrous band, musculo-tendinous arcade, fibrous canal, muscle fibers or a fascial condensation of the medial head of the triceps (Kane et al., 1973; Vesley and Killian, 1983; Amadio, 1986; Al-Qattan and Murray, 1991; Gonzalez et al., 2001; Von Schroeder and Scheker, 2003; Siqueira and Martins, 2005; Tiya-woranan et al., 2010; Tubbs et al., 2011; Caetano et al., 2017) (Table 1). The discordant prevalence found in these studies may be due not only to a clear anatomical definition but even to the different dissection methods.

Moreover, the authors agree with Bartels et al. (2003): an arcade can be easily reproduced in specimens in laboratory by an incomplete release of the brachial fascia (Fig. 2). Every further anatomical study should clearly show a brachial fascia dissection and the structures underneath it (Figs. 3-4).

The Arcade of Struthers was reported in literature to be located between 6 cm to 10 cm from the medial epicondyle (Kane et al., 1973; Vesley and Killian, 1983; Amadio, 1986; Al-Qattan and Murray, 1991; Gonzalez et al., 2001; Von Schroeder and Scheker, 2003; Siqueira and Martins, 2005; Tiya-woranan et al., 2010; Tubbs et al., 2011; Caetano et al., 2017). In the present study, the mean distance of the muscular fibers from the most prominent point of the medial epicondyle was 61 mm (min 25 mm, max 80 mm).

According to Reidenbach and Schmidt (1994), at early stage of fetal development of the elbow, there is no evidence of any ligament structure over the ulnar nerve. In their interesting topographical anatomy of the elbow, they showed that the MIS is not fully formed and the nerve lies along the medial head of the triceps at this time of fetal growth. According to the present research, during the development of the division between the anterior and posterior compartment of the arm the ulnar nerve could receive some fibers of the contiguous medial head of the triceps found in many anatomical studies. Spinner and Kaplan (1976) underlined that the Arcade of Struthers may play an important role in anterior transposition of the ulnar nerve. They

advised to transect this arcade during anterior transposition of the ulnar nerve to prevent a secondary neuritis. Bartels et al. (2003) stated that the margin of the brachial fascia with an incomplete release in the first ulnar nerve surgery appear fibrotic in a second operation and this can look like an arcade and wrongly identified as the Arcade of Struthers. The authors agree that the brachial fascia, the IBL and the MIS are related to a secondary neuropathy if not adequately released during nerve transposition surgery.

In the literature only a few cases of Arcade of Struthers in the living patient were neurographically and surgically diagnosed. Simamura et al. (1984) were the first to present a case report based on a neurographic examination. Ochiai et al. (1992) described a case report of primary ulnar neuropathy by the arcade of Struthers confirmed with electrophysiological and surgical findings. Therefore, Ochiai et al. (2000) presented two more cases, Kim et al. (2005) 2 more cases and Iyer and Thirkannad (2010) reported 1 case. With only 7 reported cases in the literature, its significance is very debatable as primary ulnar nerve compression site.

In the present research, the available anatomical studies in literature were reviewed (411 limbs in 12 papers and more than 5 description of the Arcade of Struthers, Table 1). It is difficult to give a definitive answer in this regard for the different dissection protocols and for the interpretation of the tissues. The authors believe that this lack of clarity is due to the heterogeneous morphology of the fibrous-musculoskeletal tissue in this anatomical site and due to the variability of the findings in the literature, as well as the deficiency of a common definition of the single parts that contribute to form this Arcade. Therefore, this leaves doubts to the authors about its effective existence. The results of this anatomical study warrant further dissections. Furthermore, its potential to cause primary ulnar neuropathy is disputable with only a few cases reported in the living subject, and it appears to have a lower importance in clinical practices than it was suggested in the last decades.

REFERENCES

- AL-QATTAN MM, MURRAY KA (1991) The arcade of Struthers: an anatomical study. *J Hand Surg Br*, 16B: 311-314.
- AMADIO PC (1986) Anatomical basis for a technique of ulnar nerve transposition. *Surg Radiol Anat*, 8: 155-161.
- BARNARD LB, MCCOY SM (1946) The supracondyloid process of the humerus. *J Bone Joint Surg Am*, 28: 845-850.
- BARTELS RHMA, GROTENHUIS JA, KAVER JMG (2003) The arcade of Struthers: an anatomical study. *Acta Neurochir*, 145: 295-300.

- CAETANO EB, SABONGI NETO JJ, VIEIRA LA, CAETANO MF (2017) The arcade of Struthers: an anatomical study and clinical implications. *Rev Bras Ortop*, (3): 331-336.
- DELLON AL (1986) Musculotendinous variations about the medial humeral epicondyle. *J Hand Surg Br*, 11: 175-181.
- GONZALEZ MH, LOTFI P, BENDRE A, MANDLBOY Y, LIESKA N (2001) The ulnar nerve at the elbow and its local branching: An anatomic study. *J Hand Surg*, 26: 142-144.
- IYER V, THIRKANNAD S (2010) Focal hand dystonia in a patient with ulnar nerve neuropathy at the elbow. *Hand*, 5(4): 453-457.
- KANE E, KAPLAN EB, SPINNER M (1973) Observations of the course of the ulnar nerve in the arm (Sur le trajet du nerf cubital au niveau du bras). *Ann Chir*, 27: 487-496.
- KIM PT, JEON IH, MIN WK, KIM JS (2005) High ulnar nerve palsy by the arcade of Struthers in the elbow: Report of 2 cases. *J Korean Orthop Assoc*, 40: 372-375.
- OCHIAI N, HAYASHI T, NINOMIYA S (1992) High ulnar nerve palsy caused by the arcade of Struthers. *J Hand Surg Br*, 17: 629-631.
- OCHIAI N, HONMO J, TSUJINO A, NISIURA Y (2000) Electrodiagnosis in entrapment neuropathy by the arcade of Struthers. *Clin Orthop*, 378: 129-135.
- REIDENBACH MM, SCHMIDT HM (1994) Topographical anatomy of the posterior elbow region during fetal development. *Anat Anz*, 176: 209-216.
- SIMAMURA T, ICHINOHE S, ABE M (1984) A case report of ulnar nerve palsy due to Struthers' arcade combined with carpal tunnel syndrome. *Touhokuseisaikiyo (Japanese)*, 28: 82.
- SIQUEIRA MG, MARTINS RS (2005) The controversial arcade of Struthers. *Surg Neurol*, 64: 17-21.
- SPINNER M, KAPLAN EB (1976) The relationship of the ulnar nerve to the medial intermuscular septum in the arm and its clinical significance. *Hand*, 8: 239-242.
- STRUTHERS J (1848) On a peculiarity of the humerus and humeral artery. *Monthly J Med Sci*, 8 New Series XXVIII: 264-267.
- STRUTHERS J (1854a) On some points in the abnormal anatomy of the arm. *Br For Med Chir Rev*, 13: 407-415.
- STRUTHERS J (1854b) On some points in the abnormal anatomy of the arm. *Br For Med Chir Rev*, 13: 523-533.
- STRUTHERS J (1854c) On some points in the abnormal anatomy of the arm. *Br For Med Chir Rev*, 14: 170-179 [concluded from p 415].
- STRUTHERS J (1854d) On some points in the abnormal anatomy of the arm. *Br For Med Chir Rev*, 14: 224-236 [concluded from p 533].
- TERRY RJ (1930) On the racial distribution of the supracondyloid variation. *Am J Phys Anthropol*, 14: 459-462.
- TIYAWORANAN P, JIANMONGKOL S, THAMMAROJ T (2010) Anatomical study of arcade of Struthers. *Hand Surg*, 15(3): 157-159.
- TUBBS RS, DEEP A, SHOJA MM, MORTAZAVI MM, LOUKAS M, COHEN-GADOL AA (2011) The arcade of Struthers: An anatomical study with potential neurosurgical significance. *Surg Neurol Int*, 2: 184.
- VESLEY DG, KILLIAN JT (1983) Arcades of Struthers. *J Med Assoc State Alabama*, 52: 33-36.
- VON SCHROEDER HP, SCHEKER LR (2003) Redefining the arcade of Struthers. *J Hand Surg Am*, 28: 1018-1021.
- WEHRLI L, OBERLIN C (2005) The internal brachial ligament versus the arcade of Struthers: an anatomical study. *Plast Reconstr Surg*, 115(2): 471-477.