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The supinator muscle and radial nerve entrapment: historical note and modern anatomical insight

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ABSTRACT

Due to its deep location, close to the elbow joint, the supinator muscle requires special dissection skills. This fact enhanced our interest for a more accurate knowledge of the anatomical relations of the muscle with the elbow joint and with the posterior branch of the radial nerve. There are many clinical consequences of these anatomic relations, such as epicondylar impingement syndromes. There resides an open field of research on the anatomical basis of radial nerve entrapment syndromes. In 1618, Da Cortona published a clear reference to the passage of the nerve in close relation to the deeper side of the supinator muscle. All the material here presented, corresponds to careful dissection work on embalmed corpses, prepared at our dissection lab, with original techniques. The classical approach through ventral dissection demonstrates the relation between the supinator muscle arcade (Fröhse) and the radial nerve, with its natural sliding adipose cushion sheath. The dorso-lateral surgical approach, allows deep dissection of the forearm muscles, in relation to the lateral epicondylar bundle, and the elbow joint capsule. Stereoscopic microscopy completed our macroscopic observations. Future histological and microscopic analysis of the nature of the supinator arcade; of the intricate relation of the supinator muscle fibers and the capsular fibers of the elbow; and also, the importance of the vascular elements of the muscle arcade and of the adipose bursa that surrounds the radial nerve, will further provide rich interesting research towards the improvement of pathogenic knowledge of the regional impingement, and compressive radial nerve syndromes.

Keywords: Da Cortona, epicondylitis, Fröhse arcade, radial nerve, radial tunnel, supinator muscle

INTRODUCTION

When we look at history, having particular interest for arts and medicine, we detect that those specific periods when human dissection was performed, were soon followed by great eras of development of Culture in general, with flourishing of the greatest scientific endeavors and discoveries (e.g. the Egyptian or the Greek civilizations, or more recently, the Renaissance times).

The accurate knowledge of the human body usually entices the development of natural scientific curiosity and better scientific reasoning [1, 2]. On the opposite pole, those times when human dissection was banned or neglected, for various religious or cultural reasons, usually correspond to periods when human knowledge and culture suffered slower development and poor scientific visibility, such as the long medieval times [2]. Nowadays, the international Medical academy is gradually gaining conscience of

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the utmost importance of anatomical dissection as the fundamental basis of Medical Studies [3, 4, 5].

Our Anatomy department maintains the habit of routine human dissection, both for undergraduate medical teaching, as for postgraduate, “hands-on” surgical training courses [6, 7]. We have carefully promoted and kept a fully legalized human cadaveric donation list (according to the most restrictive European laws), and we have developed innovations in embalming methods, through the introduction of a newly designed propulsion system for vascular perfusion, that permits thorough impregnation of the capillary beds [8, 9, 10].

The present work was born due to the requests of foreign anatomists to visit our lab with the purpose of learning from our innovations in embalming, to join our dissection teams for further practice, and to enlarge their series of dissections of the upper limb.

We soon became interested and involved in this aim to develop original anatomical knowledge of the supinator muscle and of the many clinical consequences of the intricate anatomical relation between the muscle and the elbow joint and with the posterior motor branch of the radial nerve.

Historical background

In deep location, close to the elbow joint, the supinator muscle demands special dissection skills; hence, the scarceness of anatomical studies dedicated to this particular muscle.

We find early traces of interest for the Supinator muscle in the very first anatomical notes and drawings from the 16th century, such as those by LEONARDO Da Vinci (cc.1510) [11], and by VESALIUS (1543) [12]. These early drawings of the upper limb muscles depict the Supinator as one of the elements of the deeper layers of the humeral epicondylar miology, as if those muscle fibers belonged to the intricate net of components of the elbow joint, in attachment to the lateral epicondylar muscle bundle (Figure 1a – 1543).

To our knowledge, Bartholomeo EUSTACHIUS (1564) [13], was the first to depict the accurate relation between the radial nerve and the two distinct shafts of the supinator muscle (Figure 1b –1564).

In 1585, on chapter XXVI of his Complete Works, Ambroise PARÉ [14] the “Father of Surgery”, presented the first description of the movements of pronation/supination, with enumeration of the muscles involved in those rotation movements of the elbow:

> «*La situation du Radius est obliqúe, et celle du cubitus droite, à fin que le mouvement du bras est étendu & fléchit, se fait en droite ligne: et le movement par lequel se fait que l'on tourne le bras à sevoir en figure prone & supine, se fait latéralement, & à cette cause le Radius est oblique, & le Cubitus droit; car l'os du coude est depute pour faire l'extésion & flexion & le Rayon aux mouvements latéraux & tournament, & pour cette raison la jointure de ces deux os avec le Brachium ou haut du bras est différente.*»

> “*The situation of the Radius bone, in obliquity to the right of the Ulna, allows the movements of the forearm, in extension or in flexion, following a straight line, and also the movements of pronation or supination, in which the radius spins around the straight ulna. This radial movement of the forearm in flexion explains the original juncture of the two bones, attached in asymmetric union, when the upper limb is extended.”*

> Author’s free translation from the medieval French original by Ambroise Paré, *Les Oeuvres Completes*, Gabriel Buon, Paris, 1585 (Éd. Louis Pariente, 1969) [14].

Not much later, on the 1618 first edition of his Anatomical Plates, Pierro Berrettini DA CORTONA [15] published a clear reference to the passage of the posterior motor branch of the radial nerve in close relation to the deeper side of the supinator muscle (Figure 1c+d – 1618). Four hundred years later, we pay tribute to this great pioneer of the Art of Anatomy.

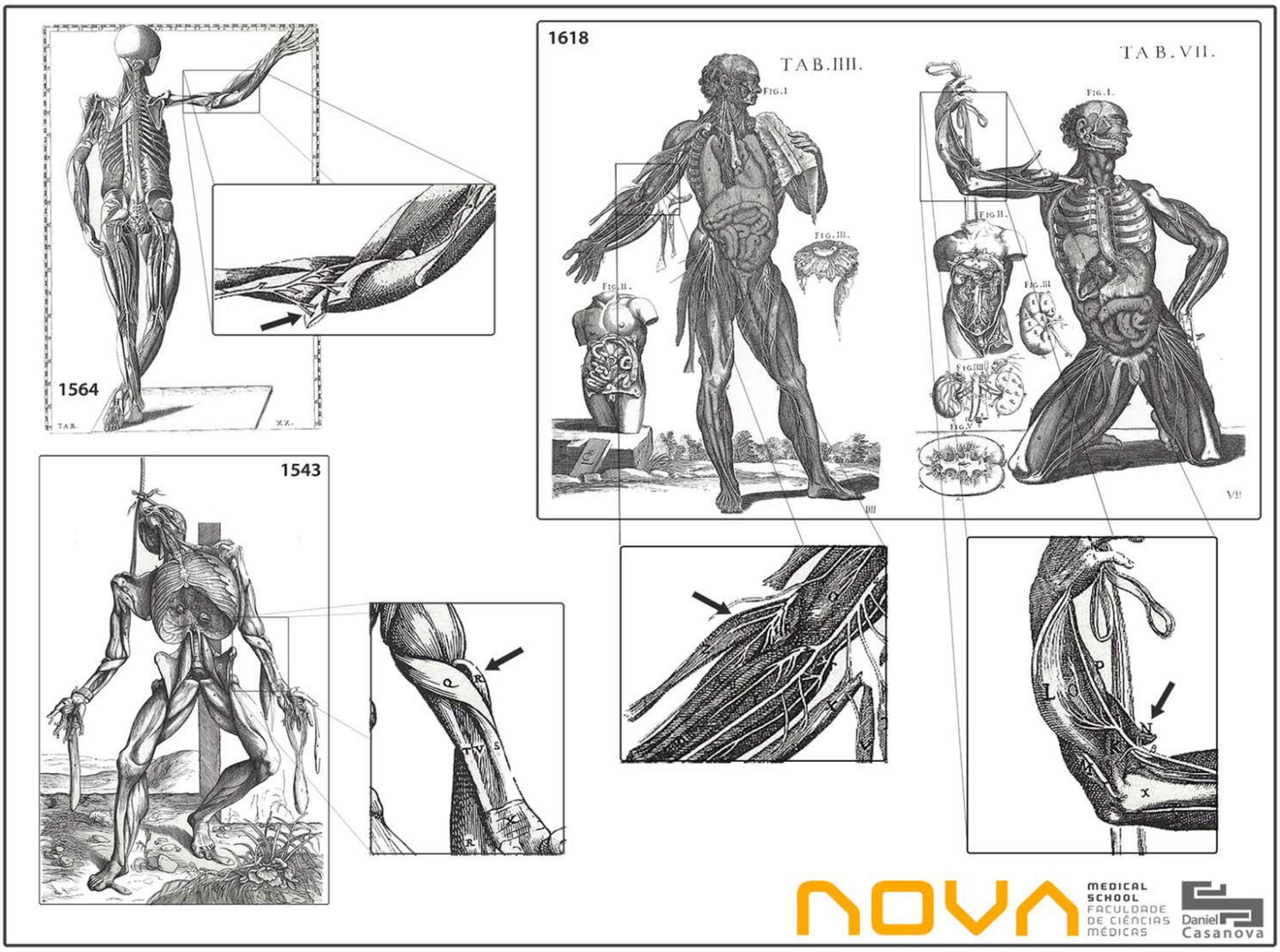

Figure 1: The earliest anatomical representations of the supinator Muscle: 1A: 1543 – Vesalius, 1543, De Humani Corporis Fabrica; 1B - 1564 – Eustachius, 1564, Opuscula Anatomica. Tabulae XVIIII; XX; XXXIII; 1C+D - 1618 - Da Cortona, 1618, tabulae Anatomica. Tab. IIII; Tab. VII.

F.FRÖHSE and M. FRANKEL (1908) [16] described the superior tendinous arcade of the supinator muscle, with distal convexity, in close relation to the deep branch of the radial nerve, which penetrates the arcade on its passage between the two shafts of the muscle. PATURÊT (1951) [17] offers a meticulous description of the several layers of the supinator muscle in relation to the radial nerve. In 1995, M. SPINNER [18] published an interesting note on the clinical interest of the Fröhse arcade, in relation to the symptoms of the radial nerve paralysis.

In clinical terms, we must remark the importance of the anatomical relations of the supinator muscle and every neighboring element. F. Runge (1873) [19] first described what we now call “epicondylitis humeri radialis”, i.e. what H. Morris (1882) called “Tennis elbow”[20, 21].

The superficial muscle fibers of the supinator are included in the tight insertion bundle of the lateral epicondylar muscles. “Overuse syndromes” of the epicondylar muscles, commonly referred as “tennis elbow”, are growing in clinical importance among the newly established functional impairment syndromes [22]. When affected by inflammation, from overuse (or repetitive misuse), the inflammatory process will lead to global lateral epicondylitis with the consequent impairment of every epicondylar muscle movement [23, 24].

According to Paturêt’s meticulous description, the deep muscular fibers of the supinator also serve as a functional “bed” for the sliding movements of the whole epicondylar muscle bundle [17]. This functional cohesion may lead to important ergonomic concepts, and its study may have a fundamental role in the modern physiatric approach to the management of lateral epicondylitis.

Moreover, the complex relation between the Supinator muscle fibers and the motor branch of the radial nerve, to which the deeper muscular fibers serve as a sliding protection arcade, are on its own, the anatomical fundament of Radial Nerve entrapment syndromes in strict relation to epicondylar impingement syndromes [18, 21, 25-32].

In terms of the anatomical variations of the Supinator muscle, we would need some more enlarged series of observations, to build a list of variations and their percentage. Nevertheless, from the histological perspective, after F. Fröhse and M Frankel's first original description (1908) [16] of the Supinator muscle arcade, Debouk and Rooze (1995) [35] on their study of 106 anatomic dissections of elbows, propose a histological classification of the arcade of Fröhse, in relation to the frequency of radial nerve compressive syndromes. According to these authors, the arcade is of tendinous nature (type A), in 64.10% of cases; musculo-tendinous (type B), in 21.70%; muscular (Type C), in 12.30%; or membranous (type D), in 1.90% of cases. The authors compare their results with Spinner's observations of a fibrous type arcade in 30%, and membranous nature, in 70% of cases [18].

MATERIAL AND METHODS

Cadaveric material

All the material here presented results from careful dissection of embalmed corpses from fully legalized donations. They were prepared at our dissection lab through intermittent arterial perfusion of an original modification of the Thiel's embalming fluids [8]. This allows our material to keep flexibility and fresh appearance for dissection, several years after embalmment. In the present study, we carefully dissected 5 forearms from three embalmed cadavers, two female donors, aged 89 and 90 years old, and another, from a male donor that died at the age of 62. None had previously known history of trauma. All were embalmed one year before dissection and kept in high-freezing chambers to maintain the freshness and odor free appearance that we observe in our current dissection works.

With the aim of dissecting the supinator muscle, we worked through two different approaches: On cadaver Nr. 0049, from a male 62 year-old donor, we experimented dissection through the classic ventral approach, carefully setting apart, the involving forearm musculature, to unveil the deep epicondylar insertion of the supinator (Figure 2). On cadaver Nr.0042, from a female 90 year-old donor, we undertook dissection through lateral approach, after 90º flexion and pronation of the elbow, thus permitting careful dissection of the epicondylar muscle bundle. This approach permits exposure of the proximal insertion of the epicondylar muscles, quite similarly to the "dorsal Henry" procedure, commonly used for the surgical management of radial tunnel compressive syndromes [28]. In this particular case, we previously added axillary arterial injection of gelatin with red dye addition, to facilitate the observation of the vascular supply to the regional anatomical elements (Figure 3).

Clearing technique and microscopic observations

We further performed fresh specimen stereoscopic microscopy observations, of the Fröhse supinator arcade, in relation to the deep branch of the radial nerve and its involving adipose sheath.

In future series of our research, we will prepare several specimens through the "clearing technique", and also with vascular injection and corrosion casts for further Scanning Electron Microscopy analysis.

RESULTS

The first specimen (serial Nr.0049) was prepared for macroscopic dissection through the classic ventral approach for dissection of forearm muscles. Figure 2 clearly depicts the intricate relation between the supinator muscle arcade (Fröhse) (Figure 2 – a.7) and the posterior, motor, branch of the radial nerve (Figure 2.11), in relation to the natural sliding adipose cushion sheath that surrounds the distal branch of the radial nerve, in the deep relation with the musculo-tendinous supinator arcade (Figure 2-a – magnified detail).

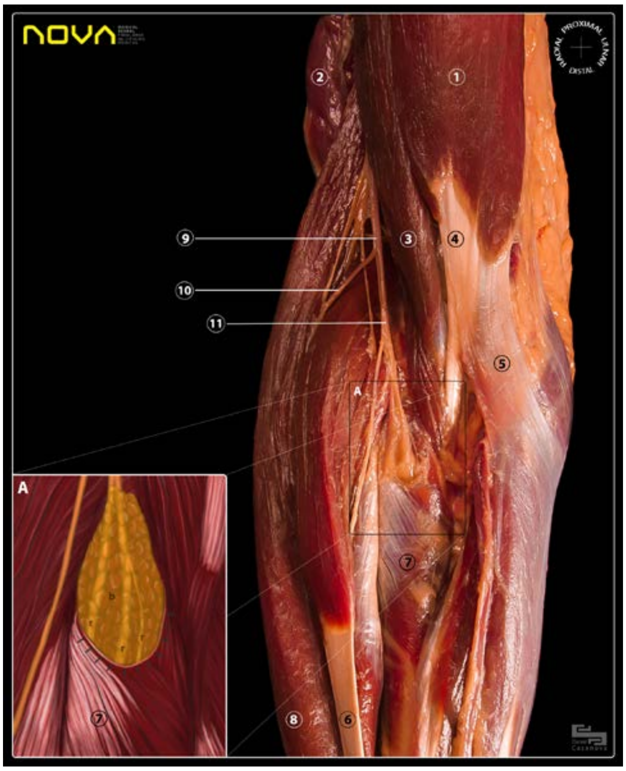

Figure 2: Anterior view of the right supinator muscle from a 62 year-old male cadaver, as dissected through the classical ventral approach. 1. Biceps brachii muscle; 2. Triceps brachii muscle; 3. Brachialis muscle; 4. Biceps brachii tendon; 5. Lacertus fibrosus (bicipital aponeurosis); 6. Extensor carpi radialis muscle; 7. Supinator muscle; 8. Brachioradialis muscle; 9. Radial Nerve; 10. Superficial branch of radial nerve; 11. Deep branch of radial nerve; a) – Magnified view of the Supinator Fröhse arcade(Gray arrows) , in relation with the deep branch of the radial nerve and its surrounding fatty bursa (art work by Daniel Casanova-Martinez).

On the second and third specimens (serial Nr. 0042) we experimented through different lateral approach, allowing deep dissection of the forearm muscles, in relation to the lateral epicondylar muscle bundle, and the close relation of these proximal muscle fibers with the elbow joint capsular elements.

On the left forearm of this female 90 year-old cadaver, the colorful arterial injection of gelatin with red dye, prior to the dissection, facilitated the meticulous dissection work and further improved the visual layout of the complex relations of the supinator muscle in the vicinity of the elbow joint, as depicted in Figure 3. Dissection through lateral approach clearly demonstrates the relationship between the radial nerve and the supinator arcade, as depicted on the enlarged view of the epicondylar insertion of the supinator muscle in Figure 3 (enlarged detail).

When we closely analyzed the complex composition of the supinator (Fröhse) arcade, in relation to the posterior branch of the radial nerve, we found a complex, three-layer composition that led us to further investigate, through microscopic observation. Stereoscopic microscopy observations of the supinator arcade revealed three distinct histological layers on the upper border of the arch: A musculo-tendinous arcade, covered by a fine, translucent membranous, connective sheath, to promote sliding of the penetrating nervous branch. This in turn, is covered by a thick and dense adipose bursa that further improves physiological protection and sliding capacity, to defend against compression, and from the stretching movements of the supinator muscle.

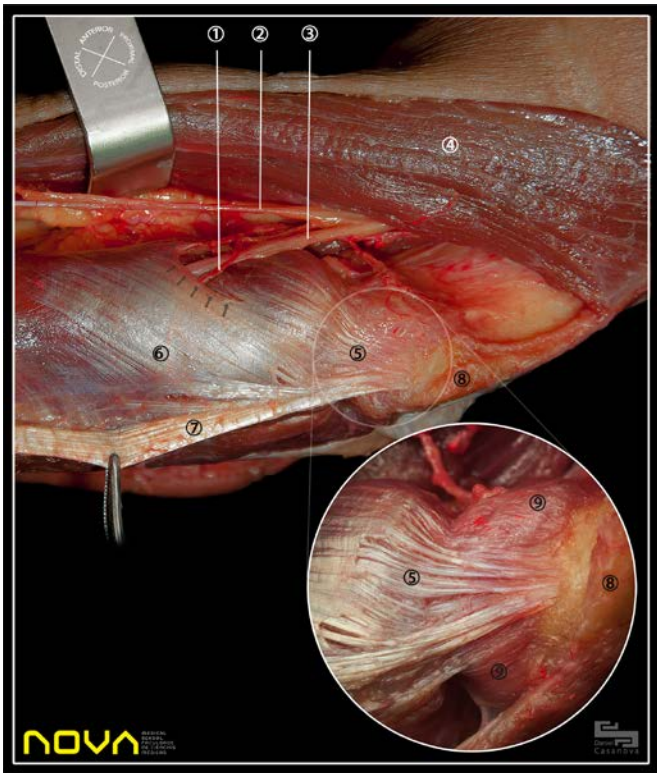

Figure 3: Deep anatomical dissection of the left forearm of a female 90 year-old cadaver, prepared through dorso-lateral anatomical approach. 1. Radial recurrent artery; 2. Superficial branch of radial nerve; 3. Deep branch of Radial nerve; 4. Brachioradialis muscle; 5. Supinator muscle tendon (epicondylar insertion); 6. Supinator muscle; 7. Extensor digiti minimi muscle; 8. Lateral epicondyle; 9. Elbow joint capsule; A - Proximal insertion of the supinator muscle in the lateral epicondyle where this tendon is in direct relation with the capsule of the elbow joint and to the annular ligament (blue arrows).

DISCUSSION

We never cease to be amazed at the perfection of the original descriptions by the earliest pioneers of Anatomy. Eustachius (1564) and Da Cortona (1618) (Figure 1) offered the first descriptions of the location of the posterior branch of the radial nerve in its deep passage through the supinator muscle arcade. Precisely four hundred years later, in 2018, we pay tribute to this great pioneer of anatomical studies, with the present works.

Although Ambroise Paré [14] was the first to establish the complexity of movements of the elbow joint, Winslow (1775) [33] was the first responsible for the accurate ergonomic analysis of the movements of pronation / supination. Ph Sappey (1869) [34] experimented on dissected cadaveric material, to conclude on the veracity of Winslow's functional description.

After F. Fröhse and M Frankel's first original description (1908) [16] of the Supinator muscle arcade that serves as a sliding sheath for the deep posterior branch of the radial nerve, Debouk and Rooze (1995) on their study of 106 anatomic dissections of elbows [35], propose a histological classification of the arcade of Fröhse, in relation to the frequency of radial nerve compressive syndromes. The arcade is of tendinous nature (type A), in the majority of cases; musculo-tendinous (type B); muscular (Type C); or membranous (Type D), in less frequent instances.

Our present observations of the supinator arcade lead us to consider a more complex mixed histological nature, in which all three components (muscular, tendinous, and membranous) should be seen in different proportions, according to the physiologic relation with the penetrating nerve branch, in regards to the ergonomics of the supination/pronation movements of the elbow, and the sliding nature of the perineurium and adipose bursa that surrounds the penetrating posterior motor branch of the radial nerve.

The aim of our future works is to enlarge this first series of observations of the Fröhse arcade, and progress with the histological study of the components of the relation between the deep branch of the radial nerve, the adipose cushion surrounding the perineurium, and the complex arcade that derives from the superficial fibers of the supinator muscle.

Different observations may also result from different embalming and/or dissection techniques. On their comprehensive study of the posterior interosseous nerve localization, based on 63 cadaveric upper-extremities study, S Kaminemi et al (2017) emphasize the problem and limitations of comparing fresh-cadaveric observations with formalin embalmed material [36].

Our particular embalming techniques, with no traces of formaldehyde addition, thus less dehydration, permit clear observation and preservation of the histological nature of specimens, in a very similar way to fresh material). On their recent publication on the evolution of embalming methods, from the Egyptian times to present days, the researchers from the University of Cork, Balta JY; Cronin M; Cryan JF; O'mahony SM (2015) [9], refer the Goyri-O'Neill embalming technique on top of the innovating modern embalming methods, with good results and less negative side-effects. Nazreen Sharif & Alia Amin (2017) [10] also cite our techniques (Although this recent article mentions that our original technique can preserve cadaveric material for one year, we have noticed good preservation results, in several instances, for more than 5 years, when kept in high freezing chambers).

The fact that we add no Formaldehyde to our embalming perfusion system allows several hours of dissection without disturbing odors, nor concern for our health.

Different observations may also derive and result from the different usage of the muscle, and/or from previous pathological findings, such as previous impingement syndromes of the elbow. The thickness of the sliding adipose sheath that surrounds the radial nerve on its passage through the supinator arcade may depend on a history of previous local inflammatory processes. On this purpose, Pfandl et al (1992) [21], call attention to the "Supinator Entrapment Syndrome" (or Posterior Interosseous Syndrome), as one of the major differential diagnosis of "Tennis Elbow".

Other less frequent, non-traumatic causes of focal posterior interosseous neuropathy can be considered, such as local lipoma [37-39].

R. Rosenbaum (1999) considers "true" neurogenic radial tunnel syndrome as an "uncommon condition caused by entrapment of the radial posterior interosseous nerve in the radial tunnel" [40].

As anatomists, we are quite aware that any segment of the human body bears its unique and fundamental importance, as part of the whole, not only in functional or physiological terms, but also in clinical terms. Every region of the body will affect the function of the vicinity segments, when injured or in ailment.

In the particular case of the supinator muscle, in clinical anatomy we have to consider the muscular relation with the common attachment on the lateral epicondyle of the humerus; the close relation of the muscle fibers with the elbow joint; and the complex relation of the muscular bundle with the posterior branch of the radial nerve, to which the muscle offers a deep sliding sheath arcade that protects from the movements of the elbow [17].

Although the intricate relation between the deep (motor) branch of the radial nerve and the two layers of the supinator muscle were well depicted since the 16th century, Guillain and Courtellemont (1905) [31] were the first to postulate the hypothesis of compression syndromes and paralysis of the deep branch of the radial nerve, in relation to its passage between the two layers of the supinator muscle.

On their extensive review of the anatomical variations of the nerves of the upper limb, M. A. Mahan and R. J. Spinner (2016) [25] refer the arcade of Fröhse, as one of the 5 anatomical zones of the so-called "radial tunnel", where the cause for radial nerve entrapment can be found (Quoting from Eversmann Jr. W. W., 1983 [24]).

We hope that our present series of observations, and our commitment to further improve the knowledge of the anatomical basis of the clinical interest of the supinator muscle, and its relation with the posterior, motor branch of the radial nerve will enable better understanding of the clinical features, management and surgical treatment of lateral epicondylitis; radial nerve entrapment; and repetition hand motion overuse syndromes that so frequently affect our modern society of small keyboard users [23].

Furthermore, as we analyze the enlarged detail on Figure 3, to depict the proximal insertion of the supinator muscle in the lateral epicondyle, this demonstrates the Supinator tendon in direct relation to the capsule of the elbow joint and to the annular ligament (blue arrows). As we compare the elbow components with other wide motion joints, such as the shoulder, this could lead us to consider the supinator muscle as an "active" muscular lateral collateral ligamentum of the elbow joint, in consequence of the close proximity to the capsule, to which this muscle certainly lends tendinous fiber elasticity and protection. On their concise anatomical description of the supinator muscle and anatomical variations, Akita & Nimura (2016) [41] indicate this close relation between the muscle and the radial collateral ligament of the elbow joint.

Our present works will lead to a more enlarged series of observations, before definitive conclusions. We will devote some of our future researches to the histological and microscopic analysis of the nature of the supinator arcade, and of the intricate relation of the supinator muscle fibers with the capsular fibers of the elbow. Also, the importance of the vascular elements of the muscle arcade, and of the adipose bursa that surrounds the radial nerve on entrance to the arcade tunnel, will provide rich interesting research, towards the improvement of knowledge on the pathogenesis of the regional impingement and compressive radial nerve syndromes.

CONCLUSIONS

The absolute modernity of our anatomical studies on the Supinator muscle and the Frohse arcade, in clinical terms, is well demonstrated by the most recent clinical review on posterior interosseous nerve entrapments, by Anania et al. 2018 [42].

The modern academic world is gradually gaining conscience of the utmost importance of anatomical dissection as the fundamental basis of Medical studies [43-48].

As much as one may meticulously perform anatomical works and research, we should never consider to have reached the final results on any subject. New fields of knowledge and new paths of novel research will inevitably arise.

We never cease to be impressed by the perfection of the earliest historical anatomical studies, such as those we selected on the subject of the Supinator muscle anatomy. The extraordinary descriptions of Leonardo, Da Cortona, or Eustachius demonstrate the innovative and perfectionist character that some would even refer as "visionary", but that we prefer to praise as the first pioneers of the Art of scientific dissection, especially when we consider the scarce technical conditions of work, in which they performed.

Those never ending lessons from the earliest anatomy pioneers, fully justify the need for careful bibliographic search, prior to any clinical or surgical work.

We wish to conclude with the same positive note with which we started: One should never neglect the efforts of those that struggle to keep honest efforts to teach and/or to research on anatomical subjects. There is always a novel approach to older subjects, when we wish to modernize.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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Daniel Casanova-Martinez wishes to dedicate his present works to Prof. Pau Golano, the late Anatomist from the University of Barcelona, with whom he first developed his growing interest for a modernized study of the supinator muscle.

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RESUMO

O músculo supinador e síndromes compressivas do nervo radial: nota histórica e visão anatômica moderna

O músculo supinador requer particular destreza da dissecação pela sua localização profunda e proximidade com a articulação do cotovelo. Esse fato aumentou o nosso interesse em aprofundar conhecimentos das relações anatômicas do músculo com articulação do cotovelo e com o ramo profundo do nervo radial. Existem muitas consequências clínicas destas relações anatômicas, tais como as síndromes compressivas do nervo ou as tendinopatias epicondilares. Existe todo um campo de pesquisa em aberto sobre as bases anatômicas das compressões do nervo radial. Em 1618 Da Cortona publicou referência clara à passagem do nervo em relação próxima com as fibras profundas do músculo supinador. Todo o material aqui apresentado corresponde a dissecação cuidadosa de corpos humanos embalsamados em nosso laboratório, segundo técnicas originais. A abordagem clássica por dissecação ventral demonstra a relação entre a arcada do músculo supinador (Fröhse) e o nervo radial, com sua bolsa adiposa de deslizamento. A abordagem cirúrgica (Henry) por via dorso-lateral permite dissecação profunda dos músculos epicondilares laterais, em relação com a cápsula articular do cotovelo. A microscopia estereoscópica completa estas observações macroscópicas. No futuro, a análise histológica e microscópica da natureza da arcada do supinador e das interrelações das fibras do supinador com as fibras da cápsula do cotovelo, e também da importância dos respectivos elementos vasculares e da bolsa adiposa em torno do nervo, irão fornecer rica e interessante pesquisa para melhorar conhecimentos sobre a patogênese das síndromes compressivas do nervo radial e das tendinopatias epicondilares.

Palavras-chave: Da Cortona, epicondilite, arcada de Fröhse, nervo radial, túnel radial, músculo supinador