Original Article

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Anatomy Section

Anatomic Study of the Distal Arcade of Superficial Layer of Supinator Muscle

JENNY JACOB[1], BINA ISAAC[2]

ABSTRACT

Introduction: Compression of the Posterior Interosseous Nerve (PIN) can cause pain on the lateral aspect of the proximal forearm and weak extension of the wrist and fingers. The distal arcade of the superficial layer of the supinator muscle can entrap the PIN, as it passes beneath it. Knowing the exact location of the distal arcade in relation to adjacent anatomical landmarks can help in decompression of the PIN.

Aim: The aim of the study was to describe the morphology of the distal arcade of the supinator muscle and its relation with the PIN.

Materials and Methods: An anatomic dissection of 40 upper extremities was conducted and the distances of the distal arcade and the PIN from adjacent landmarks were determined from Jan 2016 to Jun 2017. The mean, standard deviation and range were calculated for each of the measurements. The comparison of the parameters between sides was done using paired t-test. Data obtained was tabulated and analysed in Statistical Package For Social Sciences (SPSS) Software version 16.0.

Results: A muscular distal arcade was the most common type seen in 17 (42.5%) upper limb. Distances between the distal arcade and the humero-radial and trans-epicondylar lines were 90.27 mm and 105.62 mm, respectively. The distance from the lateral epicondyle and the entrance and exit of the PIN from supinator was 61.47 mm and 85.60 mm, respectively. The distance between the proximal and distal arcades showed statistically significant difference (p-value=0.041).

Conclusion: Knowledge of the anatomic findings of the distal arcade of the superficial layer of the supinator and the localisation of the PIN are important in the surgical management of PIN entrapment.

Keywords: Entrapment neuropathy, Posterior interosseous nerve, Radius, Upper limb

INTRODUCTION

The supinator muscle surrounds the proximal third of the radius. It consists of superficial and deep parts. Both the parts arise together from the lateral epicondyle, the radial collateral ligament, the annular ligament, the supinator crest of ulna and an aponeurosis that covers the muscle. The motor branch of the radial nerve or PIN is the deep terminal branch of the radial nerve. It arises anterior to the elbow joint at the level of the lateral epicondyle of the humerus and reaches the back of the forearm by passing around the lateral aspect of the radius between the two heads of supinator. It leaves the distal arcade of the supinator muscle and travels along the interosseous membrane, supplying the forearm extensor muscles [1].

The PIN syndrome is a compressive neuropathy of the PIN which affects the nerve supply of the forearm extensor muscles. The pain in the PIN syndrome is insidious in onset and is felt just distal to the lateral epicondyle. There is weakness of wrist and finger extension. The pain is exacerbated by repetitive acts of pronation [2]. The most frequent site of entrapment of PIN is found to be at the proximal arcade of the superficial layer of supinator muscle (arcade of Frohse) [3-5]. Another site that can cause compression is at the distal arcade of the superficial layer of supinator muscle. The exit of PIN from the supinator was identified as a point of entrapment by Spinner (1978). The proximal fibrous edge of the Extensor Carpi Radialis Brevis (ECRB), the leash of Henry, and ganglions are other structures that can cause compression of PIN [6-8].

There are not many studies on the distal arcade of the superficial layer of supinator muscle and its relation to adjacent landmarks in the Indian population. The present study was done to facilitate further comparative studies and to assist surgeons in the treatment and rehabilitation of patients with PIN syndrome. The aim of the current study was to make a detailed anatomic description of the distal arcade of the supinator muscle and its relation with the PIN.

MATERIALS AND METHODS

This was an observational study done on 40 upper limbs belonging to 20 adult cadavers (14 males and 6 females) available in the Department of Anatomy, Christian Medical College, Vellore, India. The age of the cadavers ranged from 40 to 90 years.

Inclusion criteria: All normal upper limbs were included in the study.

Exclusion criteria: Deformed limbs and limbs which showed signs of trauma were excluded from the study.

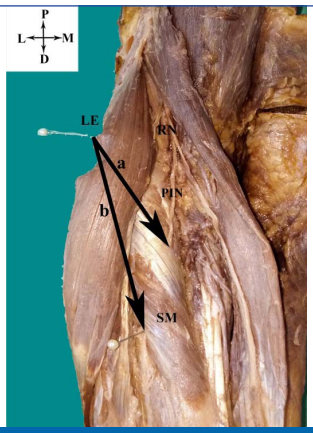
The study was done in an eighteen months period, between January 2016 and June 2017. Ethical clearance was obtained from the Institutional Ethical Committee to conduct this study (no. is 9719).

The limbs were maintained in a mid-prone position during dissection. The palpable bony landmarks like the lateral and medial epicondyles, head of the radius, radial styloid process, and ulnar styloid process were identified. A longitudinal incision was made from 5 cm above the cubital fossa till the wrist and the fascio-cutaneous flaps were reflected. The proximal and distal arcades of the superficial layer of supinator muscle were exposed. The radial nerve was identified between the brachio-radialis muscle and the brachialis muscle and the division of the nerve into superficial branch and the posterior interosseous nerve were dissected. The lateral epicondyle, points of entry and exit of PIN from the supinator were marked using pins. The distances were measured using a measuring tape. The transepicondylar line was determined in the following manner - the lateral and medial epicondyles were palpated and pins placed on these bony points. A white thread was used to measure the distance between these two points and the mid-point was determined. In a similar manner, the mid-point of the humero-radial joint line was determined.

The following variables were examined and analysed:

- Nature of the distal arcade of superficial layer of supinator muscle (in males and females)

- Distance between tip of lateral epicondyle and proximal arcade (arcade of Frohse) of superficial layer of supinator muscle
- Distance between proximal and distal arcades of superficial layer of supinator muscle
- Distance between humeroradial joint line and distal arcade of superficial layer of supinator muscle
- Distance between transepicondylar line and distal arcade of superficial layer of supinator muscle
- Distance between lateral epicondyle and entrance of PIN at arcade of Frohse [Table/Fig-1]
- Distance between lateral epicondyle and exit of PIN from supinator [Table/Fig-1]



[Table/Fig-1]: Lateral epicondyle and posterior interosseous nerve.
a: Distance between lateral epicondyle (LE) and entry of PIN at arcade of Frohse; b: distance between lateral epicondyle and exit of PIN at distal arcade of superficial layer of supinator; LE: Lateral epicondyle; RN: Radial nerve; PIN: Posterior interosseous nerve; SM: Supinator muscle

STATISTICAL ANALYSIS

All the measurements were taken twice and the average was taken to reduce the error. Data obtained from the observation was tabulated and analysed using Statistical Package for the Social Sciences (SPSS) version 16.0 software. The measurements made were compared between the sides of the specimen using paired t-test. A p-value <0.05 was considered to be significant.

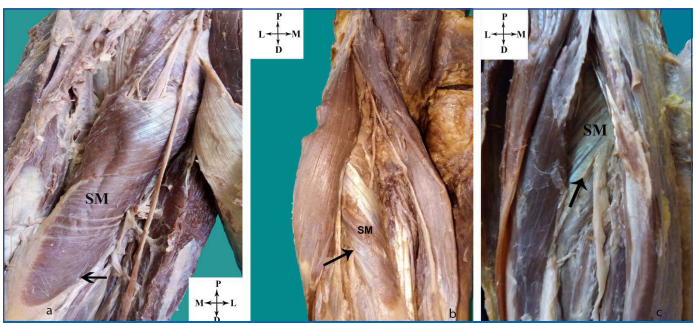
RESULTS

Forty forearms and elbows were dissected. The types of distal arcade observed are shown in [Table/Fig-2].

The nature of the distal arcade of superficial layer of supinator muscle that was most commonly seen was the muscular type 17(42.5%) [Table/Fig-3a], followed by the musculotendinous [Table/Fig-3b] and tendinous types [Table/Fig-3c]. The membranous type was not found in the present study. The distances of the distal arcade and PIN from adjacent bony landmarks are shown in [Table/Fig-4].

Nature of distal arcade	Total n (%)	Males n (%)	Females n (%)
Tendinous	8 (20)	4 (14.2)	4 (33.3)
Musculotendinous	15 (37.5)	11 (39.2)	4(33.3)
Muscular	17 (42.5)	13 (46.4)	4 (33.3)

[Table/Fig-2]: Nature of distal arcade of superficial layer of supinator muscle (n=40).



[Table/Fig-3]: Types of distal arcade of superficial layer of supinator muscle (Arrow); a) Muscular type ; b) Musculotendinous type; c) Tendinous type SM, supinator muscle.

Parameter	Right side (Mean±SD) (mm)	Left side (Mean±SD) (mm)	p-value
Distance between tip of lateral epicondyle and proximal arcade of superficial layer of supinator muscle	60.15±9.080	59.05±10.990	1.000
Distance between proximal and distal arcades of superficial layer of supinator muscle	54.75±14.896	50.15±14.485	**0.041**
Distance between humeroradial joint line and distal arcade of superficial layer of supinator muscle	91.40±11.390	89.15±11.398	0.481
Distance between transepicondylar line and distal arcade of superficial layer of supinator muscle	105.15±15.059	106.10±10.518	1.000
Distance between lateral epicondyle and entry of PIN into supinator at the proximal arcade	62.80±10.719	60.15±10.373	1.000
Distance between lateral epicondyle and exit of PIN from supinator	86.30±12.351	84.90±9.947	0.359

[Table/Fig-4]: Distances from the distal arcade and Posterior Interosseous Nerve (PIN) to important anatomical landmarks; Paired t-test used to calculate p-value

The distance between the proximal and distal arcades of the superficial layer of supinator muscle of the right and left sides showed statistically significant difference (p-value=0.041).

DISCUSSION

The supinator muscle has a close relationship with the motor branch of the radial nerve or the PIN. The PIN travels in the narrow space between the superficial and deep layers of the supinator and while doing so, can become compressed leading to a dull aching pain on the lateral aspect of the elbow and proximal aspect of the lateral forearm [9]. The texture of the superficial layer of supinator is said to have a potential compressive effect on the PIN [10]. The medial aspect of the Extensor Carpi Radialis Brevis (ECRB) muscle, the vascular arcade of the radial recurrent artery and its branches, and a capsular- tendon-aponeurosis group located on the anterior aspect of both the humeroradial joint and the radial head are other elements that have been implicated in PIN entrapment [11-13]. Neuromas [14], schwannomas [15], traumatic aneurysms of the posterior interosseous artery [9], neurofibromas [16], ganglion cysts [17], and myxomas [18] are other structures that have been reported as causes of paralysis of the PIN. Trauma may cause paralysis of this nerve; however, many cases of PIN entrapment have no history of antecedent trauma [19].

The PIN entrapment syndrome is common in tennis players [20]. It is mainly a motor syndrome characterised by a reduction or loss of extension of all digits and atrophy of the posterior forearm muscles with the exclusion of the brachioradialis and extensor carpi radialis longus. Since the extensor carpi radialis longus muscle is usually innervated by the radial nerve trunk, there is usually no wrist drop. When wrist extension is examined, it deviates radially because of contraction of the extensor carpi radialis longus muscle [21].

The proximal edge of the superficial layer of the supinator muscle (arcade of Frohse) is the one most often implicated as the causative factor for the PIN syndrome [3,13]. Repetitive movements of pronation and supination can promote compression of the PIN under the arcade of Frohse [12,15]. It was observed that fibrous or tendinous arcades only compress the PIN [22,23]. In 1908, Frohse F and Frankel M first described the arcade of Frohse as a normal anatomical tendinous structure [3]. Spinner suggested that the most proximal part of the superficial layer of the supinator muscle was always muscular in the newborn full-term foetuses and it became a semicircular structure in adults due to the repeated rotatory movements of pronation and supination of the forearm [8]. Tatar I et al., reported the same findings in their study on 40 foetuses' forearms [24].

The distal arcade of the superficial layer of the supinator muscle is another structure which can cause compression of the PIN. Sponseller PD and Engber WD (1983) first described the distal arcade as a potential compressive element for the PIN as it exits the supinator [25]. Riffaud L et al., found in their study, the majority of distal arcades possessed a muscular nature [13] whereas, the nature was tendinous in the studies by Berton C et al., ; Konjengbam M and Elangbam J and Prasartritha T et al., [Table/Fig-5] [2,12,26]. In similar studies, by Hohenberger GM et al., and Caetano EB et al., the distal arcade was found to be muscular rather than tendinous in more number of specimens [27,28]. The findings in the present study, regarding the nature of the distal arcade, are in accordance with those of Riffaud L et al., Hohenberger GM et al., and Caetano EB et al., [13,27,28]. Repetitive pronation and supination can aggravate the compression of PIN, as it leaves the supinator muscle under the distal arcade. In males, the muscular type of distal arcade was the commonest type seen, in keeping with their heavy body build.

Study (year)	Place	n	Tendinous (%)	Musculotendinous (%)	Muscular (%)	Membranous (%)
Berton C et al., (2012) [2]	France	30	37	33	27	3
Ozturk A et al., (2005) [4]	Turkey	55	87	0	0	13
Konjengbam M and Elangbam J (2004) [12]	India	46	65	11	22	2
Riffaud L et al., (1999) [13]	France	25	4	8	88	0
Prasartritha T et al., (1993) [26]	Thailand	60	65	0	0	35
Hohenberger GM et al., (2020) [27]	Austria	100	35	0	65	0
Caetano EB et al., (2020) [28]	Brazil	30	23.5	0	76.5	0
Present study	India	40	20	37.5	42.5	0

[Table/Fig-5]: Nature of the distal arcade of the superficial layer of supinator muscle in different studies.

The relationship of the PIN to adjacent bony landmarks should be kept in mind by surgeons, while treating PIN entrapment [11,29]. The lateral epicondyle is a useful anatomical reference landmark that can be used to locate the arcades of the supinator muscle. In the present study, the distance between the arcade of Frohse and the lateral epicondyle was 59.60 mm. This is almost in line with the results of Ozturk A et al., (46.2 mm), Artico M et al., (53 mm), Werner CO, (47 mm) and Papadopoulos N et al., (49.1 mm) [4,11,30,31]. In the present study, the distance between the proximal and distal arcades was 52.45 mm. This is almost similar to the findings of Berton C et al., (41.4 mm) and Konjengbam M and Elangbam J (42 mm) [2,12], but is different from those of Artico M et al., (31 mm) [11].

The knowledge of the distances of the entrance and exit of PIN from supinator is important in the surgical treatment of the PIN entrapment. In the present study, the distances from the lateral epicondyle and the entrance of PIN at the arcade of Frohse and exit of PIN at the distal arcade was found to be 61.47 mm and 85.60 mm, respectively. These findings are in accordance with the findings in the study by Tubbs RS et al., where the mean distance from the lateral epicondyle and the entrance of PIN at the arcade of Frohse was found to be 60 mm (45-75 mm) and the mean distance from the lateral epicondyle to the exit of PIN at the distal arcade was found to be 120 mm (100-150 mm) [21]. Other anatomical landmarks that can be used to localise PIN are the humero-radial joint line and the trans-epicondylar line [2].

If functional recovery is absent or if symptoms worsen after 3 months of conservative therapy then, surgical therapy for an entrapped PIN is indicated. Operative release of the PIN is generally successful [32], providing relief to the patient. The findings in the present study will aid the surgeon in decompression of the PIN with least amount of surgical morbidity.

The distal arcade though known to be a zone of compression for the PIN has not been well described. In this study, the observation of a muscular distal arcade in most of the specimens is valuable as chronic repetition of pronation-supination movements can cause modifications of this muscular structure, leading to real pathology. The localisation of the PIN in relation to lateral epicondyle should help at the time of PIN neurolysis. Knowledge of the position of the distal arcade in relation to the humero-radial and trans-epicondylar lines may be helpful for the surgeon whose target is to decompress the PIN in the surgical management of lateral elbow pain.

Limitation(s)

The limitation of the present study was that it was done on hard fixed formalin embalmed upper extremities. In the actual surgical setting, the tissues are supple and soft.

CONCLUSION(S)

The anatomic findings of the distal arcade of superficial layer of supinator muscle, must be considered in the pathophysiology of the PIN syndrome. Knowledge of the distances of the distal arcade of the superficial layer of supinator from certain anatomic landmarks is an essential pre-requisite to the surgical management of the PIN neuropathy. The localisation of the entrance and exit of the PIN in relation to a reference point like the lateral epicondyle will help to prevent iatrogenic injuries during the treatment of PIN entrapment. Further studies in fresh cadaveric specimens are required, so that anatomic data derived from such studies can be applied to the clinical setting during the treatment of PIN entrapment.

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PARTICULARS OF CONTRIBUTORS:
1. Assistant Professor, Department of Anatomy, Christian Medical College, Vellore, Tamil Nadu, India.
2. Professor, Department of Anatomy, Christian Medical College, Vellore, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Bina Isaac,
Department of Anatomy, Christian Medical College, Vellore, Tamil Nadu, India.
E-mail: binaisaac28@gmail.com

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