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Posterior interosseous nerve of the elbow at the arcade of Frohse: Ultrasound appearance in asymptomatic subjects

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KEYWORDS
Ultrasound;
Arcade of Frohse;
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Supinator muscle;
Anatomic studies

Abstract
Purpose: To assess the normal values of the antero-posterior (AP) diameter of the posterior interosseous nerve (PIN) of the elbow as it passes beneath the arcade of Frohse and to search for PIN-diameter differences between the upstream, entry point and downstream of the arcade.
Material and methods: Thirty asymptomatic patients prospectively underwent bilateral B-mode ultrasound of the PIN of the elbow. There were 15 men and 15 women with a mean age of 30.2 ± 5.31 (SD) years (range: 26—43 years). Of these, 23 patients were right-handers (23/30; 77%) and 7 were left handers (7/30; 23%). AP diameter of the PIN was measured in long axis at three different locations including the entry point of the arcade, 5-mm upstream and 5-mm downstream the arcade. A comparison between the three measurements was performed using paired *t*-test.
Results: The mean AP diameters of the PIN were 0.83 ± 0.21 (SD) mm (range: 0.43—1.31 mm), 0.6 ± 0.17 (SD) mm (range: 0.29—1.16 mm) and 0.49 ± 0.13 (SD) mm (range: 0.26—0.86 mm) at 5-mm upstream, entry point of the arcade and 5-mm downstream the arcade of Frohse, respectively. Significant drops in PIN diameter were found between upstream and the arcade (−0.23 mm; 27%; $P < 0.001$), between the arcade and downstream (−0.11 mm; 17%; $P < 0.001$), and between upstream and downstream the arcade (−0.34 mm; 40%; $P < 0.001$).
Conclusion: Disparity in AP diameter of the PIN of the elbow in the arcade of Frohse is a normal finding and should not be erroneously interpreted as entrapment when present alone.

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The posterior interosseous nerve (PIN) of the elbow (also called deep branch of radial nerve), is a terminal motor branch of the radial nerve, which is itself a branch of the posterior cord of the brachial plexus with contributions from fifth to eighth cervical nerve roots (distal nerve territory). PIN syndrome is an uncommon peripheral neuropathy [1] during which the PIN is usually compressed as it passes between the two heads of the supinator muscle, beneath a fibrous band called the arcade of Frohse. Indeed, this compression site also called the supinator arch, has been described by Frohse and Fränkel and corresponds to a normal fibromuscular structure. Other PIN entrapment sites such as medial edge of the extensor carpi radialis brevis, radial recurrent blood vessels, and inferior margin of the superficial layer of the supinator muscle have been described [2,3].

PIN syndrome, alternatively named radial tunnel syndrome or supinator syndrome, is clinically characterized by a loss of strength during fingers extension and amyotrophy of posterior muscles of the forearm with the exception of brachioradialis and extensor carpi radialis longus muscles [4]. A deaf pain is generally felt in the dorsoradial aspect of proximal forearm. A partial infringement can affect only the extension of fourth and fifth fingers, which may suggest an ulnar nerve impairment. There is no associated sensory symptom [4]. The diagnosis of PIN syndrome is usually confirmed by a multimodal approach, which includes electromyography and ultrasound or magnetic resonance imaging (MRI).

During the past decade, improvements of high-resolution ultrasound allowed direct visualisation of small nerves [5] and detection of their shape and echostructure changes as well as extrinsic causes of compression. Ultrasound signs consistent with PIN syndrome are an abnormal swelling of the nerve and an abrupt caliber change at the entrapment site [6]. However, in daily practice, a shrinkage of the PIN as it passes beneath the arcade of Frohse is sometimes observed in asymptomatic patients, rising the interest of measuring its diameter. Studies reporting the role of ultrasound in the diagnosis of PIN syndrome are scarce [7—10]. Accordingly, it appears necessary to confirm and determine the normal values of the antero-posterior (AP) diameter of the PIN at this level in order to avoid overdiagnosis of PIN entrapment.

The purpose of this study was to assess the normal values of the AP diameter of the PIN of the elbow as it passes beneath the arcade of Frohse and to search for PIN-diameter differences between the upstream, entry point and downstream of the arcade.

Materials and Methods

Patients

The study was approved by the institutional review board. All patients gave written permission for anonymized use of their medical data for scientific purposes before the ultrasound examination. They were referred by their physician for elbow ultrasound examination and prospectively included between march 2017 and september 2017. Inclusion criteria included an age > 18 years and acceptance for written signed consent. Exclusion criteria included prior elbow surgery and/or any symptom of PIN syndrome.

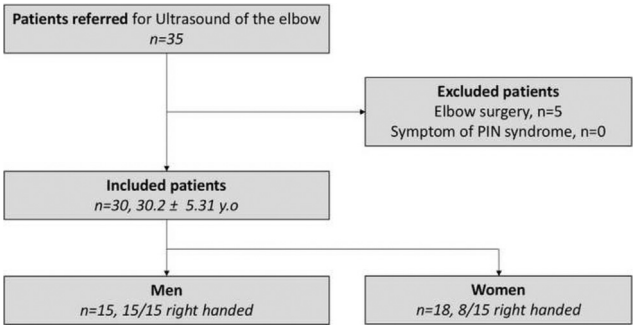

Figure 1. Flowchart of the study population ($n = 30$).

A total of 30 consecutive patients were included. There were 15 men and 15 women with a mean age of 30.2 ± 5.31 (SD) years (range: 26—43 years) (Fig. 1). One hundred percent (15/15) of men were right-handers. Fifty-three percent (8/15) of women were right-handers versus 47% (7/15) left-handers women.

Ultrasound protocol

All ultrasound examinations were bilateral according to a standardized protocol using a RS80A Samsung device (Samsung Medison®) equipped with a 18-MhZ superficial linear transducer. Examinations were performed by one radiologist (A.P.) with 4 years of experience in musculoskeletal ultrasound.

Patients were positioned in front of the radiologist, elbow extended in supination on the gurney. The examination began with grayscale B mode ultrasound study of the radial nerve and its division at the elbow fold by sweeping the probe from top to bottom in transverse section. The PIN was first identified on axial images, then longitudinally analysed by turning the probe 90°. Images analysis were done in consensus by two radiologists (A.P. and T.C) to ensure the accuracy of the measurements by using VuePACS® software (Version 12.1.5.1156, Carestream). On both arms, the AP diameter of the PIN was measured at three locations in long axis at three different locations including the entry point of the arcade, 5-mm upstream and 5-mm downstream the arcade of Frohse (Fig. 2). The nerve echostructure was also analyzed in terms of echogenicity and fasciculation.

Anatomic study

An anatomic dissection of a 80-year-old woman was performed for anatomoradiological correlation. The upper extremity was dissected in the long axis while limb was maintained in pronation and 30° flexion. Longitudinally from 5 cm atop the radio-humeral joint to the middle of the forearm, the fascia of brachio-radialis muscle was dissected and muscle reclined outside, so that direct visualisation of radial nerve between brachio-radialis and brachialis muscles was possible (Fig. 3). Its deep terminal branch, the NIP, crosses dorso-lateraly beneath the arcade of Frohse and enters in the supinator muscle. AP diameter of the NIP was then measured with a micrometer at the same sites on both sides of the arcade of Frohse.

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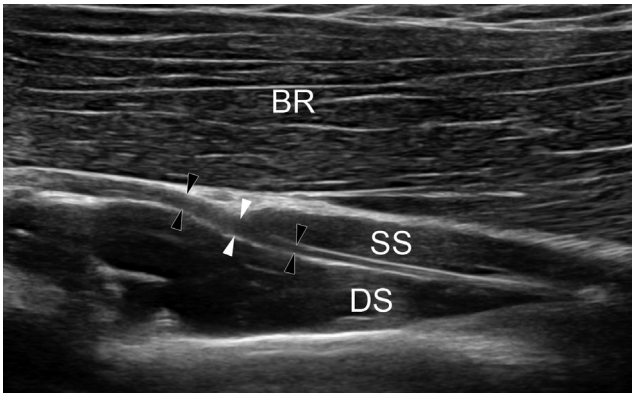

Figure 2. A 26-year-old man with no clinical sign of posterior interosseous nerve (PIN) syndrome. B-mode ultrasound longitudinal image shows posterior interosseous nerve as an hypoechoic linear structure that passes between superficial (SS) and deep (DS) heads of the supinator muscle. The antero-posterior diameter of the nerve has been measured at the arcade of Frohse (white arrowheads), then 5 mm upstream and downstream (black arrowheads). BR: brachio-radialis muscle.

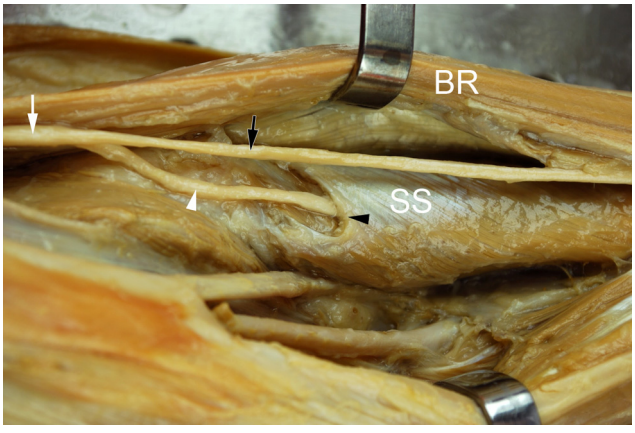

Figure 3. Anatomic view. The radial nerve (white arrow) divides into a superficial branch (black arrow) and a deep branch, the posterior interosseous nerve (white arrowhead). The latter goes in depth to the arcade of Frohse (black arrowhead), and passes under the superficial head of the supinator muscle (SS). Brachio-radialis muscle (BR) has been reclined.

Statistical analysis

The absolute variation in PIN diameter was calculated as the difference between two diameters as follows: $\Delta = D1 - D2$ (mm). The relative variation (%) in PIN diameter was calculated using the following equation (E1):

$$E1\% = (D1 - D2) \times 100/D1$$

Continuous variables were expressed as mean ± standard deviation (SD) and range. A P-value < 0.05 was considered statistically significant. Differences in AP diameter of PIN between the three locations were searched for using the paired t-test. The influence of gender and dominance on AP diameter was studied by univariate analysis. Statistical analysis was performed using SAS for Windows version 9.3 (SAS Institute Inc.).

Results

Morphologically, the PIN appeared hypoechoic and monofasciculated in all patients. The mean AP diameters of the PIN on ultrasound were 0.83 ± 0.21 (SD) mm (range: 0.43—1.31 mm), 0.6 ± 0.17 (SD) mm (range: 0.29—1.16 mm) and 0.49 ± 0.13 (SD) mm (range: 0.26—0.86 mm) at 5-mm upstream, entry point of the arcade and 5-mm downstream the arcade of Frohse, respectively.

Significant drops in PIN diameter were found between upstream and the arcade (−0.23 mm; 27%; $P < 0.001$), between the arcade and downstream (−0.11 mm; 17%; $P < 0.001$), and between upstream and downstream the arcade (−0.34 mm; 40%; $P < 0.001$).

There were no significant differences in PIN diameter between right and left sides upstream ($P = 0.257$), at the arcade ($P = 0.45$) and downstream ($P = 0.11$). There were no significant effects of the dominance on PIN diameter upstream ($P = 0.951$), at the arcade ($P = 0.941$) and downstream ($P = 0.152$). There were no significant differences in PIN diameter between men and women ($P = 0.417$ upstream, $P = 0.779$ at the arcade and $P = 0.369$ downstream).

Changes in PIN diameter were also observed macroscopically during anatomic dissection. AP diameter was 0.7 mm upstream, and 0.5 mm at the entry point and downstream the arcade.

Discussion

Our study confirms the physiological drop in AP diameter of PIN when it passes the arcade of Frohse in asymptomatic patients. Our results are consistent with those of two previously published works on this matter (Table 1). Raeburn et al. measured AP and lateral diameters of the PIN on short axis ultrasound images only at two points, 5 mm downstream and 5 mm upstream the arch. They found a significant difference in AP proximal diameter (1.1 mm proximal vs. 0.85 mm distal; $P < 0.001$) and in lateral diameter (2.6 mm proximal vs. 3.4 mm distal; $P < 0.001$) [11]. There was no difference concerning mean cross-sectionnal area (CSA), measured 0.022 cm^2 proximally, and 0.023 cm^2 distally [11]. Kim et al. showed a reduction of the AP diameter of the PIN distal to the arcade of Frohse when compared to the measurements at the arcade and proximal to the arcade [9]. The AP diameter was 1.0 mm 1 cm proximally, 1.2 mm at the arcade and 0.6 mm 1 cm distally ($P < 0.0001$). The measure of mean CSA was concordant with the other study, the PIN measured 0.016 cm^2 proximally, 0.019 cm^2 at the arcade and 0.018 cm^2 distally ($P = 0.59$).

Prospective PIN assessment of AP diameter in long axis at three points makes it possible to be more precise. Indeed, PIN flattening is more important at the entry point of the arcade of Frohse, but continues slowly downstream. The results of anatomic studies corroborate ultrasound results [12,13]. Spinner et al. [12] and Prasarthrita and al. [13] dissected upper limbs and described 2 types of arcade of Frohse. One is of membranous type (43%, slim, mobilizable with tweezers) and the other of fibrous type (57%, thick and not mobilizable). Spinner et al. found fibrous arch in 30% of adults and none in full-term fetuses [12] and raised the hypothesis that the fibrous arcade was probably secondary

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Table 1 Comparison of mean AP diameter of the NIP between our study and previous studies.

	Mean AP diameter (mm)				
	Proximally		Arcade of Frohse	Distally	
	10	5		5	10
Our study		0.83	0.6	0.49	
Raeburn and al. [11]		1.1		0.85	
Kim and al. [9]	1		1.2		0.6

acquired in response to repeated rotary movement of the forearm. In all 20 patients with unilateral PIN syndrome operated in Lister's et al. series, the arcade was thickened and fibrous, which also would be a predisposing factor to entrapment [14]. Unfortunately, the difference between membranous and fibrous arcade is only visible during surgery or anatomic dissection, but not with ultrasound. In the 264 cases reported by Quignon and al., the two most frequent etiologies of PIN syndrome were ganglion cyst (19.7%) and a musculo-aponevrotic fibrotic band at the arcade of Frohse (16.7%) [15]. Iatrogeny is the cause of 10% of PIN syndromes, most frequently after a repair surgery of the distal tendon of biceps brachii muscle. Quignon and al. also showed a prevalence of manual profession [15], consistent with Spinner et al. hypothesis that repeated mechanical solicitation and anatomic predisposition can lead at an entrapment site.

In our study, dominance has no significant influence on the PIN at the arcade of Frohse. The unsignificant lower diameter at the right side downstream point compared to left side may be linked to inter-individual polymorphism or to the predominance of right-handers in our population (23/30; 77%). There was also no significant effect of gender on the PIN diameter. It contradicts previous results which found CSA of females both proximal and distal to the arcade of Frohse that were statistically lower than that of males on the left side ($P < 0.03$) [11]. These previous results remain unexplained and seem to need to be questioned.

The current role of ultrasound is to provide arguments that corroborate the diagnosis of PIN syndrome, and to seach for possible cause of extrinsic compression. Ultrasound findings in PIN syndrome are an abnormal swelling of the nerve and an abrupt change in its diameter at the entrapment site. A few studies have assessed the role of ultrasound in the diagnosis of PIN syndrome [7–9,16]. Djurdjevic et al. compared 15 patients with PIN syndrome confirmed by neurological, clinical examination and electromyography to 20 asymptomatic volunteers [8]. The mean AP diameter immediately proximal to the arcade was significantly greater in patients with PIN syndrome (2 mm) than in volunteers (1.1 mm) [8]. There was no overlap between minimum AP pathologic diameter (1.6 mm) and maximum physiological one (1.5 mm). Loss of fascicular structure and increased hypoechogenicity was observed in all patients when PIN enlarged. Similar results were reported by Kim et al. [9] These researchers found a AP diameter of 1.79 mm proximally and 1.02 mm in the controlateral upper limb ($P = 0.003$), but only 4/10 patients had a PIN syndrome caused by the arcade of Frohse [9]. Bodner and al. described ultrasonography appearance of 4 patients with supinator syndrome [7]. They showed that the nerve was enlarged (mean transverse diameter = 4.2 mm; AP diameter = 3.3 mm) and appeared hypoechoic in association with neovascularization. On the opposite, volunteers had a mean transverse diameter equal to 2.14 mm and an AP diameter equal to 1.31 mm. But these researchers did not compare patients to volunteers nor to the controlateral side [7].

One limitation of our study is that a single experienced radiologist made ultrasound because it may sometimes be difficult to obtain a perfect longitudinal image of this millimetric nervous structure. We may imagine that an oblique image would lead to measurement bias. As a consequence, no reproducibility study of the measurements was made. The rarity of this syndrome made it impossible to compare patients with PIN syndrome to healthy patients in our center, unlike other studies [7–9].

As a conclusion, a disparity in AP diameter of the PIN in the arcade of Frohse is physiological and should not be wrongly taken for an entrapment sign when seen in isolation. Today, correlation to clinical symptoms, electromyography and an ultrasound comparative study of contralateral PIN are still required in symptomatic patients to confirm this diagnosis.

Human and animal rights

The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association revised in 2013 for experiments involving humans.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patient(s).

The authors declare that they obtained a written informed consent from the patients and/or volunteers included in the article. The authors also confirm that the personal details of the patients and/or volunteers have been removed.

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Author contributions

All authors attest that they meet the current International committee of medical journal editors (ICMJE) criteria for authorship.

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Resources	Sébastien Aubry
Software	Sébastien Aubry
Supervision	Mona Alilet, Eléonore Brumpt, SébastienAubry
Validation	Sébastien Aubry
Visualization	Tulay Ceri, Sébastien Aubry
Roles/Writing	
original draft	Tulay Ceri, Andrea Podda, Julien Behr
Writing—review & editing	Tulay Ceri, Eléonore Brumpt, Mona Alilet, Sébastien Aubry

Disclosure of interest

The authors declare that they have no competing interest.

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