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The course of posterior interosseous nerve in the wrist capsule. An anatomical study using the modified Sihler's staining

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Abstract: The aim of the study was to assess the course of posterior interosseous nerve in the wrist capsule in the transparent method of nerve staining.
Material and Methods: Thirty dorsal wrist capsules were collected bilaterally from 15 donors (thirty capsules) within 12 hours of death. By the dorsal incision the capsules were collected in the same manner. The specimens were stained according to the protocol of modified Sihler's staining technique. The preserved capsules were analysed under 8–16× magnification of optical microscope for the presence of major posterior interosseous nerve trunks, their major and minor branches, and nerve connections.
Results: Three main types of nerve course were identified within the joint capsule. Type I — the most common, with the presence of a single trunk with the excursion of the first main branch on the radial side, two main branches on the ulnar side, the presence of the prevailing number of small branches on the radial side and the presence of 3–4 branches extending beyond the level of the carpo-metacarpal joints. Type II with the presence of two main nerve trunks, running almost in parallel with the first main branch on the radial side, two main branches on the ulnar side with presence of a predominant number of small branches on the radial side and the presence of 3–4 branches running beyond the level of carpo-metacarpal joints. Type III (least often) with the presence of crossed main nerve trunks.
Conclusion: The modified Sihler's staining technique allows for transparent visibility of the nerves innervation the dorsal wrist capsule. However does not allow accurate assessment as histological examination, especially in evaluation of nerve endings, but it gives a significantly larger area of nerve observation.

Keywords: Wrist innervation, Sihler's staining technique, posterior interosseous nerve.

Introduction

The posterior interosseous nerve (PIN) is one of the nerves that innervates the wrist from the dorsal side. Its course and extent of innervation was examined based on loups magnification (gross anatomy dissection) [1] or using operating microscope for micro-dissection [2, 3]. These studies mainly described the large or small nerve branches falling into the wrist joins. However, there are differences in the literature as to the extent of its innervation and its course within the joint capsule [3–8]. The same also applies to different approaches to denervation of the wrist in terms of the number of nerves needed to remove and the number of incisions [9–11]. The exact range of innervation through individual nerves allows for a more selective approach to the denervation of the wrist, depending on the pathology that causes the pain. Therefore, the greater and more accurate the knowledge about the participation of individual nerves in the innervation of the wrist, the greater the chance that the choice of treatment method will be more effective. In 1895 Dr. Charles Sihler introduced a staining method that allows visualization of nerve distribution in soft tissues without the need for meticulous preparation. This technique has found particular application in assessing nerve fibres in skeletal muscle and mucosa [12], but also in the larynx and tongue [13]. Sihler staining is a technique for staining the nerve of the entire specimen that makes other soft tissues translucent or transparent when staining the nerves. It allows mapping patterns of supplying nerves with organs. In our study, we used Sihler's staining technique to assess the course of the posterior interosseous nerve within the wrist capsule. The advantage of this method is the ability to visualize small nerve branches, not visible during anatomical preparation, running inside the joint capsule. It therefore allows a more accurate assessment of the extent of innervation of the nerve under examination.

Material and Methods

Thirty dorsal wrist capsules were collected bilaterally from 15 donors (thirty capsules) within 12 hours of death. All dorsal capsules came from donors who had given their written consent to use their bodies after death for educational and scientific purposes. The capsules were collected within 3 months. The dissection was performed by the same experienced surgeon who simultaneously conducts education in anatomy. There were 11 male wrists (22 capsules) and 4 female (8 capsules). The age at death was 33–72 years. Neither donor had a history of upper limb trauma or scarring around the dorsal wrists after surgery. A longitudinal midline skin incision was made from 1/3 of the distal forearm to the middle of III metacarpal bone. The extensor retinaculum was completely dissected, exposing the dorsal wrist joint capsule. The posterior interosseous posterior nerve was prepared from the radius. The joint capsules were taken according to the following rule: the distal cutting line was carried out along 1 cm

above the bases of the metacarpal bones II–V, proximally along the edges of the distal end of the radius and ulna with a fragment of about 1 cm of the posterior interosseous nerve. The lateral and medial edges were determined by the lateral margin of the II and medial margin od V metacarpal respectively. The capsules were taken along with the extrinsic ligaments of the wrist dissected subperiosteally from all bony attachments in a sharp fashion, using loupe magnification, maintaining the cut line separating the capsule from the intrinsic ligaments of the wrist. To avoid errors in mapping of PIN, it was determined whether the capsule came from the right or left wrist. The proximal part of the capsule contained 1 cm of the posterior interosseous nerve, so there were no problems with the identification of the proximal and distal edges of the obtained capsule. The specimens were washed under running water and then fixed in a 10% unneutralized formalin solution for a period of 4 weeks. After this time the specimens were ready to start the Sihler's method of staining [12]. Maceration and depigmentation in a 3% KOH solution lasted 3 weeks with a change of solution to fresh each week of the process. The specimens were then immersed in Sihler I solution for another 3 weeks for decalcification, and then stained in Sihler II solution for another 3 weeks. In both phases, the solution was changed to fresh every week. In total, the processing time of collected specimens, ready for evaluation in an optical microscope, lasted over 3 months. This allowed the nerve to be analysed within the joint capsule using an optical microscope under 8–16x magnification (Fig. 1). The obtained image from

Fig. 1. The picture of PIN course and its branches within the dorsal wrist capsule in Sihler's method of staining.

the microscope was manually applied to the joint capsule diagram, divided into main quadrants and smaller fields with the wrist (right, left) and sides (radial, elbow) marked. The drawing obtained by hand was scanned and applied to a computer image with accurate reproduction (Fig. 2). Images were analysed for number of main trunks of the PIN, number of ulnar and radial sided branches, the location of the first main branch, number of terminal branches crossing the distal line incision, course of the main trunk of the posterior interosseous nerve within the capsule, presence of main branches (trunks) crossing inside the specimen, the side of presence the majority of small branches and presence of concomitant vessel with the main trunk.

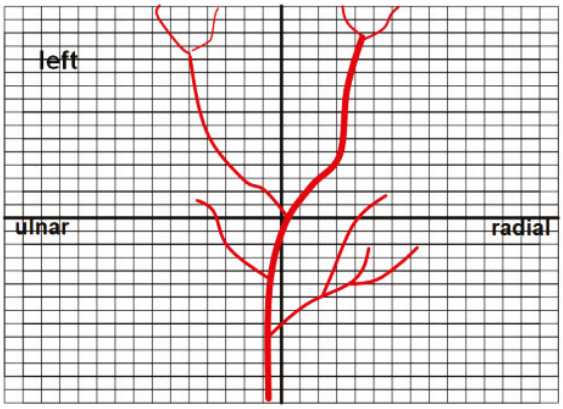

Fig. 2. Digitalised diagram of PIN course in left wrist, based on the microscope magnification of wrist capsule in Sihler's method of staining.

Results

1. Obtained data

The obtained data are given in Table 1. The number of main nerve trunks and branches on the ulnar or radial sides, determination of the side of departure of the first nerve branch, the number of terminal branches crossing the cutting line, the crossing of the main trunks or the main trunk with smaller branches, the main trunk course within the joint capsule and the dominant side of the smaller nerve branches are given in Table 2.

Table 1. Analysis of the course of PIN in thirty wrist capsules using the modified Sihler's staining. The optical microscope under 8–16× magnification was used and obtained image was manually applied to the joint capsule diagram and transformed to a computer image with accurate reproduction.

No/ Side	Sex	Number of trunks	Number of ulnar side branches	Number of radial side branches	Side of first main branch	Number of terminal branches (crossing distal line incision)	Main trunk course	Branch crossing	Side of majority of small branches	Conco-mitant vessels
1/L	M	1	2	3	radial	4	central	Yes	radial	Yes
1/R	M	1	2	4	radial	4	central	No	radial	Yes
2/L	M	1	2	3	radial	3	ulnar	No	ulnar	Yes
2/R	M	1	3	4	ulnar	4	central	No	equal	Yes
3/L	F	2	2	2	radial	2	central	Yes	radial	Yes
3/R	F	1	2	2	ulnar	3	central	No	ulnar	Yes
4/L	M	2	2	2	radial	2	central	No	radial	Yes
4/R	M	2	2	3	radial	3	central	No	radial	Yes
5/l	F	1	3	2	radial	5	central	No	ulnar	Yes
5/R	F	1	1	4	radial	2	central	No	radial	Yes
6/L	M	2	2	2	radial	2	central	Yes	radial	Yes
6/R	M	2	2	4	radial	3	central	No	radial	Yes
7/L	M	1	1	3	radial	2	central	No	radial	Yes
7/R	M	1	2	4	ulnar	4	central	No	ulnar	Yes
8/L	F	1	2	0	ulnar	1	ulnar	No	ulnar	Yes
8/R	F	1	2	2	radial	4	central	No	radial	Yes
9/L	M	2	1	1	ulnar	1	ulnar	No	ulnar	Yes
9/R	M	2	2	2	radial	5	ulnar	Yes	radial	Yes
10/L	M	2	3	0	ulnar	5	central	No	ulnar	Yes
10/R	M	1	3	1	radial	2	central	No	ulnar	Yes
11/L	F	2	2	2	ulnar	3	central	No	equal	Yes
11/R	F	1	2	2	radial	4	central	No	radial	Yes
12/L	M	2	3	2	ulnar	5	central	No	ulnar	Yes
12/R	M	1	1	2	radial	2	central	No	radial	Yes
13/L	M	1	2	2	radial	3	central	No	ulnar	Yes

Table 1. Cont.

No/ Side	Sex	Number of trunks	Number of ulnar side branches	Number of radial side branches	Side of first main branch	Number of terminal branches (crossing distal line incision)	Main trunk course	Branch crossing	Side of majority of small branches	Conco-mitant vessels
13/R	M	1	3	3	radial	3	central	No	ulnar	Yes
14/L	M	1	2	2	ulnar	4	central	No	radial	Yes
14/R	M	2	2	4	ulnar	5	ulnar	Yes	radial	Yes
15/L	M	2	2	4	radial	4	central	No	ulnar	Yes
15/R	M	2	3	3	radial	2	central	No	radial	Yes

Table 2. Quantitative analysis of PIN and its branches in thirty wrist capsules using the modified Sihler's staining.

Observation	Description	Amount	Percentage
Number of main trunk	1 2	17 13	56.6% 43.4%
Number of ulnar side branches	1 2 3	4 19 7	13.3% 63.3% 23.3%
Number of radial side branches	0 1 2 3 4	2 2 13 6 7	6.7% 6.7% 43.3% 20% 23.3%
First main branch	radial ulnar	20 10	66.7% 33.3%
Number of terminal branches (crossing distal line incision)	1 2 3 4 5	2 8 7 8 5	6.7% 26.6% 23.3% 26.7% 13.7%
Trunk or main branches crossing	yes no	5 25	16.7% 83.3%
Main trunk course	central ulnar	25 5	83.3% 16.7%
Side of majority of small branches	equal Radial ulnar	2 16 12	6.7% 53.3% 40%

2. Main trunks

Despite the fact that in all specimens — the 1 cm segment of harvested PIN was macroscopically assessed by a single trunk, in microscopic examination, up to 13 capsules (43.4%), there were visible two main trunks before entry into the joint capsule (Fig. 3). In 25 specimens (83.3%), the main nerve trunk (or both trunks) ran centrally within the midline capsule or slightly ulnary in 5 cases (16.7%).

Fig. 3. The PIN in the wrist capsule with two main trunks.

3. PIN nerve branches

Although in 20 capsules (66.7%) the first main branch was present on the radial side of main trunk, in 2 cases (6.7%) the main branch on the radial side was not visible at all. However, in all preparations small branches emerging on the radial side were in the dominance of this side in 16 cases (53.3%). In all specimens, branches crossing the distal cut line of the joint capsule were visible in an amount of 1–5, in equal distribution of 2 and 4 branches (26.6% each) and 3 and 5 — 23.3% and 16.7% respectively.

4. Main types of nerve

Due to the distribution of the obtained quantitative results into numerous subgroups, no statistically significant relationship was possible to obtain. This concerned all data, as well as the division according to the number of main nerve trunks, differences in the group including men and women, the number of end branches depending on the number of main nerve trunks etc. However, due to the large amount of image data, three main types of nerve course were identified within the joint capsule. Type I — the most common, with the presence of a single trunk with the excursion of the first main branch on the radial side, two main branches on the ulnar side, the presence of the prevailing number of small branches on the radial side and the presence of 3–4 branches extending beyond the level of the carpo-metacarpal joints (Fig. 4A). Type II with the presence of two main nerve trunks, running almost in parallel with the first main branch on the radial side, two main branches on the ulnar side with presence of a predominant number of small branches on the radial side and the presence of 3–4 branches running beyond the level of carpo-metacarpal joints (Fig. 4B). Type III (least often) with the presence of crossed main nerve trunks (Fig. 4C). However, it was not possible to determine the percentage dependence of individual types.

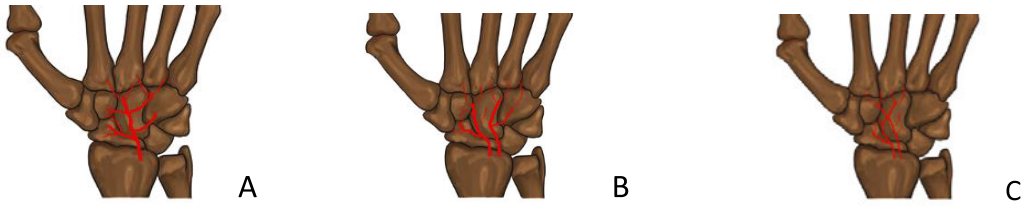

Fig. 4. Three main types of PIN course within the dorsal wrist capsule. A — presence of a single trunk. B — presence of double trunks. C — presence of crossed main nerve trunks.

5. PIN innervation extension

Only in two capsules — a single branch was visible crossing the distal cut line (6.7%). In 5 cases (16.7%) the presence of crossing inside the capsule of the main nerve trunks (single intersection) was demonstrated. In 4 capsules it concerned the crossing of double nerve trunks, and in 1 case — the main, single trunk was crossed by a larger branch, departing on the radial side of the trunk.

Discussion

The key findings of this study are the consistency of the terminal branches crossing the distal line incision, which was performed 1 cm distal to the CMC joints II–V. Only in 2 of 30 specimens there was only one branch, in the remaining ones the number of branches varied from 2 to 5, on average 3.6 per one capsule. In our material, these branches were crossing the cutting line, not showing the presence of small end branches. So these are not branches ending and innervating the CMC joints. So this is an observation that fully shares the results of research on those obtained by Zwart [3], that indicates the extension of the PIN on the dorsal hand. Dellon dissecting the PIN and its branches showed that in 2 of the 10 cadavers, terminal branches of the PIN appeared to extend to the metacarpal-phalangeal joint, traveling in the deep fascia overlying the interosseous muscles [1]. The methodology of our study does not allow the conclusion that all of these branches innervate the metacarpophalangeal joints, but the number of PIN nerve branches that run through the metacarpus is undoubtedly bigger. McCarthy showed that 14 of 41 (34%) specimens in which the 3.5× magnification of PIN dissection was performed, had innervations of terminal branches included carpometacarpal joints, the interossei, and the metacarpal periosteum [14]. They also observed the three levels of innervation that were present in most specimens: radiocarpal, midcarpal, and terminal branches. But only fourteen of the specimens had innervations to all three levels. Twelve had branches to the midcarpal level and terminal level without any proximal innervations in the radiocarpal level. In the recent publication Gregory showed that PIN was divided into 3 terminal segments in the dorsal wrist joint (proximal, middle, and distal segments) [15]. He was able to observe that branches to the distal radial periosteum were constant and emerged from the middle segment where the nerve is enclosed in a sturdy fibro-fatty sheath adhered to the dorsal periosteum of the distal radius. In our study, we did not obtain such results, but it is rather due to the method of collecting the joint capsule, where the cutting line ran at the border of the radiocarpal joint. Ferreres dissecting 20 cadaver wrists using 3 to 12.5× magnification found that there was always was a radial branch of the PIN that perforated the dorsal capsule at a level corresponding to radio-carpal joint and the scapho-lunate space [2]. In our study in addition to large branches departing both on the radial and ulnar sides of the main PIN trunk, due to Sihler's staining, small branches which could not be seen during direct dissection in previous studies were also visible. They occurred along the course of the nerve trunk (trunks) and covered the area the entire joint capsule. There was also constantly present a communicating branch to medial antebrachial cutaneous nerve, which is consistent with previous observations by Ferreres [2, 16] (Fig. 5). This is in contrast with observation by Zwart who stated that no anastomoses with other nerves were observed [3]. We also confirm the statement of Ferreres, who did not see recurrent twigs of the deep branch of the

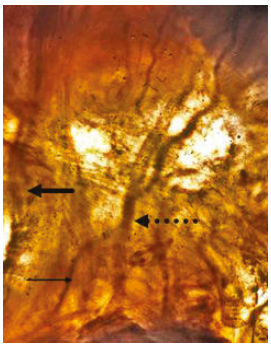

Fig. 5. Ramus of PIN (narrow arrow) communicating the main PIN trunk (wide arrow) and medial antebrachial cutaneous nerve (wide dotted arrow).

ulnar nerve directed to the carpometacarpal (CM) joints, and they could not confirm the existence of the branches that are said to cross the interosseous metacarpal spaces, in a palmar to dorsal direction, to innervate the dorsal aspect of the CM joints [2]. In our opinion the innervation of dorsal aspect of these joints comes from PIN (second and third CMC) and medial cutaneous antebrachial nerve by means of its anastomosis with the PIN (fourth and fifth CMC). The present study proposes that the statement of PIN innervating the central two-thirds of posterior wrist joint [17] does not exists anymore. Although our study was conducted at a single institution with the small sample and no strong statistical data can be provided, the use of a staining technique that has not previously been used to assess PIN and its branches within the wrist joint capsule, gives greater assessment capabilities than nerve preparation. Larger multi-institutional studies with adequate sample size are needed.

Conclusions

A better understanding of the detailed anatomy of the PIN within the wrist joint can improve surgical procedures and avoid iatrogenic injury. Based on our study, the innervation of PIN goes beyond the area of radiocarpal, midcarpal and carpometacarpal joints, gives the small branches along its course within the wrist capsule, but also gives connections with other nerves innervating the dorsal side of the wrist.

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Conflict of interest

None declared.

References

1. *Dellon A.L., Seif S.S.*: Anatomic dissections relating the posterior interosseous nerve to the carpus, and the etiology of dorsal wrist ganglion pain. J Hand Surg Am. 1978 Jul; 3 (4): 326–332.
2. *Ferreres A., Suso S., Ordi J.M., Llusa M., Ruano D.*: Wrist denervation. Anatomical considerations. J Hand Surgery Br. 1995. 20B: 6: 761–768.
3. *Zwart K., Roeling T., Leeuwen W., Schuurman A.*: An Anatomical Study to the Branching Pattern of the Posterior Interosseous Nerve on the Dorsal Side of the Hand. Clinical Anatomy. 2019. doi: 10.1002/ca.23486.
4. *Berger R.A.*: Partial denervation of the wrist: a new approach. Tech Hand Upper Extrem Surg. 1998; 2: 25–35.
5. *Jariwala A., Krishnan B., Soames R., Wigderowitz C.A.*: Important anatomical relationships of the posterior interosseous nerve in the distal forearm for surgical planning: A cadaveric study. J Wrist Surg. Feb. 2014; 3 (1): 60–63.
6. *Fukumoto K., Kojima T., Kinoshita Y., Koda M.*: An anatomic study of the innervation of the wrist and Wilhelm's technique for denervation. J Hand Surg. 1993. 18A: 484–489.
7. *Hagert E., Persson J.*: Desensizing the posterior interosseous nerve alters wrist proprioceptive reflexes. J Hand Surg. 2010; 35A: 1059–1066.
8. *Hagert E., Ferrearas A., Garcia-Elias M.*: Nerve sparing dorsal and volar approach to the radiocarpal joint. J Hand Surg. 2010; 35A: 1070–1074.
9. *Chin K., Engelsman A., van Gulik T., Strackee S.*: Selective denervation of the wrist for chronic pain: a systematic literature review. Journal of Hand Surgery (European Volume). 2020 Mar; 45 (3): 265–272.
10. *Delclaux S., Elia F., Bouvet C., Aprédoaei C., Rongières M., Mansat P.*: Denervation of the wrist with two surgical incisions. Is it effective? A review of 33 patients with an average of 41 months' follow-up. Hand Surgery and Rehabilitation. 2017; 36 (4): 281–285.
11. *Van Hernen J., Lans J., Garg R., Eberlin K., Chen N.*: Factors Associated With Reoperation and Conversion to Wrist Fusion After Proximal Row Carpectomy or 4-Corner Arthrodesis. Journal of Hand Surgery. 2020 Feb; 45 (2): 85–94.e2.
12. *Mu L., Sanders I.*: Sihler's whole mount nerve staining technique: a review. Biotech Histochem. 2010 Feb; 85 (1): 19–42.
13. *Won S.Y., Kim D.H., Yang H.M., Park J.T., Kwak H.H., Hu K.S., Kim H.J.*: Clinical and anatomical approach using Sihler's staining technique (whole mount nerve stain). Anat Cell Biol. 2011 Mar; 44 (1): 1–7.
14. *McCarthy C.K., Breen T.F.*: Arborization of the Distal Posterior Interosseous Nerve. J Hand Surg. 1995; 20A: 218–220.
15. *Gregory T., Goutard M., Gregory J., Hurst S., Merlini L., Pierrart J.*: A Cadaveric Study of the Posterior Interosseous Nerve and Its Branches at the Level of the Distal Radius. Journal of Hand Surgery Global Online. 2019; 1 (2): 70–73.
16. *Ferreres A., Foucher G., Suso S.*: Extensive Denervation of the Wrist. Tech Hand Upper Extrem Surg. 2002; 6 (1): 36–41.
17. *Lin Y.T., Berger R.A., Berger E.J., Tomita K., Jew J.Y., Yang C., An K.N.*: Nerve endings of the wrist joint: a preliminary report of the dorsal radiocarpal ligament. J Orthop Res. 2006 Jun; 24 (6): 1225–1230.