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Penetration of the posterior interosseous nerve fibers into the dorsal capsule of the wrist — a new perspective on wrist innervation

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Abstract: The dorsal capsule of the wrist and the DCSS may play a significant role in the conduction of nerve signals transmitted from proprioceptors present in SL to PIN, which is located above the dorsal capsule. Hence, this study aimed to determine if nerve fibers of PIN penetrate inside the dorsal capsule. The dorsal capsules of the wrist were dissected from both sides from 15 cadavers. Eventually, 30 dorsal capsules were dissected.
It can be concluded that the PIN nerve fibers penetrate the dorsal capsule of the wrist, as the penetration was noticeable in every part evaluated.
The present study proves that afferent fibers from the mechanoreceptors of the SLIL potentially pass through the DCSS and subsequently through the dorsal capsule of the wrist to the PIN. This knowledge can surely be of great use for hand surgeons that perform procedures on the dorsal wrist.

Keywords: wrist innervation, pin, dorsal capsule of the wrist.

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Introduction

Several articles published related to carpal anatomy, and its biomechanical function has provided a substantial amount of information about the innervation of the wrist joint. Nevertheless, striving for a successful diagnosis requires further research on carpal neuron structures. This paper is focused on the innervation of the dorsal articular capsule. The anatomical studies have shown the existence of dorsal capsulo-scapholunate septum (DCSS) connecting dorsal capsule with the scapholunate interosseous ligament (SLIL) [1]. Furthermore, it was found that DCSS may play a role in carpal stability [1]. Moreover, above this area, it has been demonstrated the presence of posterior interosseous nerve (PIN) branches [2], which was an essential milestone in pursuing a comprehensive understanding of the wrist biomechanisms (Fig. 1).

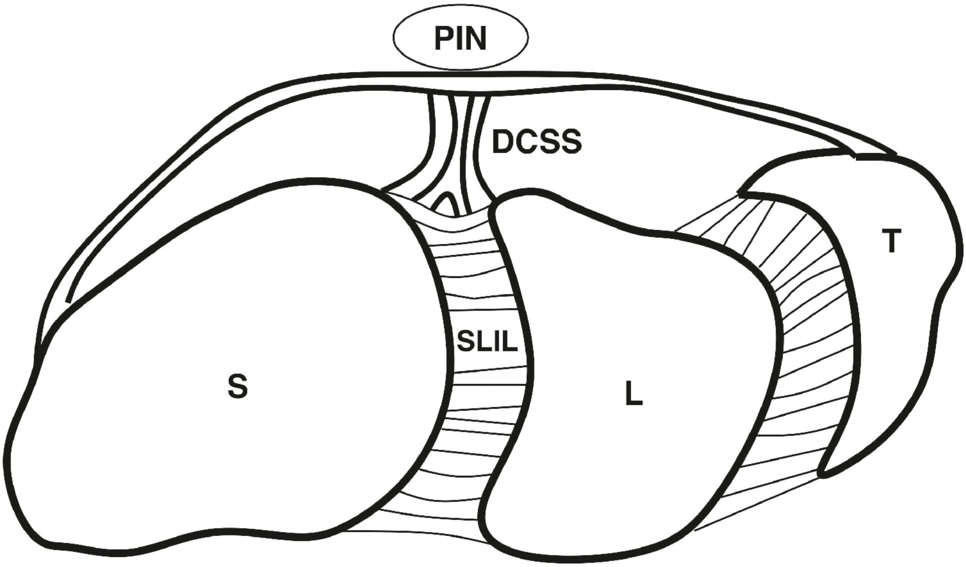

Fig. 1. Transverse view of the anatomy of the carpal region. PIN — posterior interosseous nerve. DCSS — dorsal capsuloligamentous scapholunate septum. SLIL — scapholunate interosseous ligament. S — scaphoid. L — lunate. T — triquetrum.

Wrist innervation research has risen to prominence since the introduction of wrist denervation procedures for treating pain in irreparable injuries. In the 1970s and the 1980s, surgeries were performed on the entire wrist, so a great deal of emphasis in scientific work was placed on a precise assessment of the innervation range to remove all pain-conducting nerves effectively. Over the years, these procedures became more selective and included only the nerves that comprised the wrist's damaged part. However, with the appearance of more complex research on somaesthesia, a debate arose as to whether it is advisable to eliminate the nerves responsible for proprioception. In the 1990s, articles about the location of these receptors were published. After the year 2000, Hagert's articles gained popularity, which indicated SLIL as a location with a high density of sensory corpuscles [3]. Subsequently, other papers were released highlighting the significance of preserving these nerves during a surgical procedure. Accessing the dorsal compartment was to be made with preserving PIN.

Despite the knowledge about the nerve course and receptors distribution in external ligaments, the missing link is a location of initial nerve fibers coming out of receptors towards a nerve trunk. Therefore, authors speculate that the dorsal capsule of the wrist and the DCSS may play a significant role in the conduction of nerve signals transmitted from proprioceptors present in SL to PIN, which is located above the dorsal capsule. Hence, this study aimed to determine if nerve fibers of PIN penetrate inside the dorsal capsule.

Materials and Methods

The research protocol was submitted for evaluation and approved by the Jagiellonian University Bioethical Committee, Cracow, Poland. Further stages of the study were carried out in accordance with the approved guidelines [4]. The dorsal capsules of the wrist were dissected from both sides of 15 cadavers. Furthermore, each dorsal capsule was stretched and fixed in a formalin solution. Subsequently, each of the dorsal capsules was divided into four parts (Fig. 2). Out of each part, three preparations

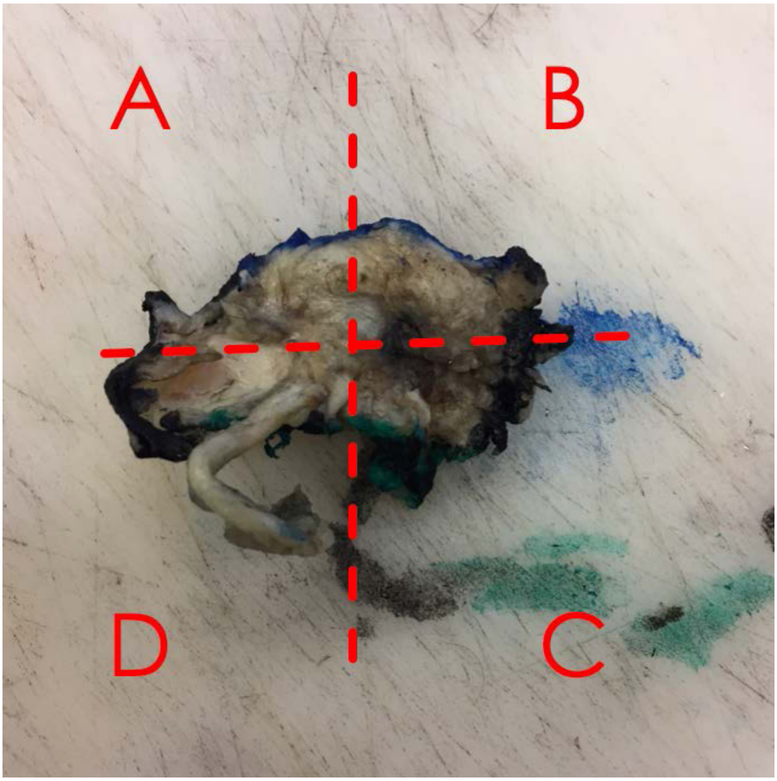

Fig. 2. Dissected dorsal capsule of the wrist divided into four parts.

were made. In general, from every part of each of the dorsal capsules, there were three preparations: one from the deepest, most palmar part of the dorsal capsule and two preparations from layers located above the deepest one. Eventually, a total of 360 preparations were made. Furthermore, to expose the PIN fibers, each preparation was stained with: (1) recombinant anti-vitimentin antibody [EPR3776] and (2) anti-neurofilament heavy polypeptide antibody (ab8135). After staining, each preparation was manually examined. Each preparation was also scanned, at a four-fold magnification, using a scanning confocal microscope (FluoView FV1200, Olympus, Tokyo, Japan) and cellSens software (version 1.15; Olympus, Tokyo, Japan).

Results

The dorsal capsules of the wrist were dissected from both sides from 15 cadavers, at a median age of 44 to 82 years (median: 70.5 years old; SD: 8.89), of which 7 (47.0%) were women and 8 (53.0%) were men. Eventually, 30 dorsal capsules were dissected. All subsequent results are presented in relation to the number of dorsal capsules of the wrist instead of the patients. Each dorsal capsule was divided into four parts; therefore, a total of 120 parts were enrolled. In addition, a total of 360 preparations were created and stained. Of these, 117 were excluded from further examination due to: (1) the presence of significant artifacts; (2) ambiguous results of staining; (3) unfinished reactions or (4) significant tissue damage. The remaining 243 preparations were qualified for a more detailed examination. Of the remaining preparations, an image of 6, complete dorsal capsules (four overlapping, three layers) were established. During a microscopical evaluation, each nerve fiber seen in the preparation was checked for occurrence in a similar area in the other two preparations to establish the potential penetration of the PIN nerve fibers into the dorsal capsule. Eventually, in these 6 dorsal capsules (24 parts, 72 preparations), PIN fibers penetrating the dorsal capsule (overlapping transverse cuts) were present in all the evaluated parts. To recognize a part as penetrated by the PIN nerve fibers, at least 15 transverse cuts of PIN had to be found. To acknowledge and enroll a structure as a PIN fiber, it had to be (1) clearly a nerve fiber; (2) properly stained; (3) uncontaminated with any artifacts. The authors did not perform geometrical statistical analysis and a heat map of the occurrence of the penetration of the PIN fibers due to several unclear stained structures that could potentially burden the results with a relatively large bias. Therefore, it can be concluded that the PIN nerve fibers penetrate the dorsal capsule of the wrist, as the penetration was noticeable in every part evaluated (Fig. 3).

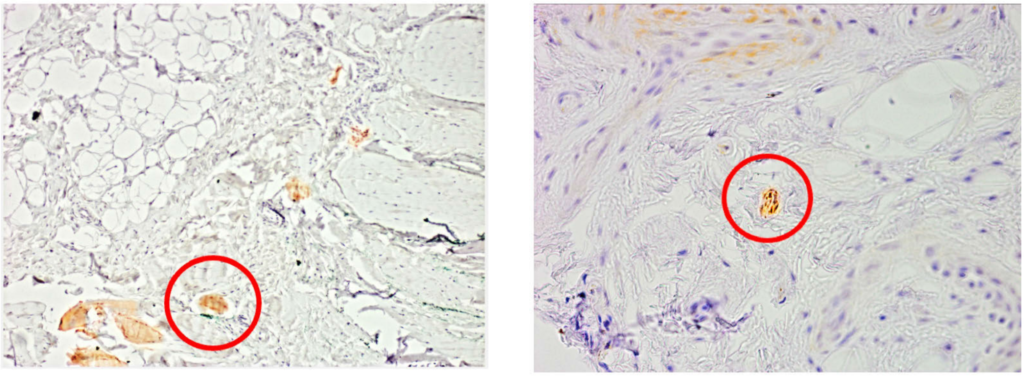

Fig. 3. Transverse cuts of the PIN fibers in the histological preparations.

Discussion

Numerous nerves innervate the wrist joint. However, there is an ongoing debate about the extent to which each nerve innervates the wrist. Van de Pol *et al.* demonstrated that the primary innervation to the wrist capsule and the periosteal nerve network came from the anterior interosseous nerve, lateral antebrachial cutaneous nerve, and PIN. Nevertheless, other nerves were also found to give off branches to the joint capsule [5]. Many studies have shown that the PIN accounts for the majority of the innervation to the dorsal side of the wrist [2, 5, 6]. The PIN is a continuation of the deep branch of the radial nerve as it passes the two heads of the supinator muscle. After giving off a final motor branch to the extensor pollicis longus, the PIN courses distally in the radial part of the floor of the fourth extensor compartment and divides into two to four branches, some with interconnections, that spread over the dorsal capsule and toward the carpometacarpal joints [2, 7]. Several PIN branches run laterally to the periosteum and wrist capsule, while others run distally, parallel to the main trunk within the periosteum, conveying the dorsal radius and ulna to the dorsal scapholunate and lunotriquetral intervals and the dorsal wrist ligaments [8]. Notwithstanding, numerous studies have shown that a radial branch perforating the dorsal capsule on the radial side at the level of the scapholunate space is frequently present [9–11].

Articular nerves transmit sensory impulses from the joint that contribute to the sense of proprioception, which provides an awareness of movement and position of the body [12]. The ligaments and capsule of the wrist joint are innervated by articular nerves that reach the capsule as independent branches of adjacent nerves (such as the PIN on the dorsal side of the wrist) and by nonspecific nerves that run within the muscle or the interfascicular connective tissue [5].

The extrinsic and intrinsic ligaments play a significant role in the stability of the wrist joint. Ligaments are made up of densely packed collagen fibers (fascicles) in their core, with the outer portion consisting of loose connective tissue. Hagert *et al.* referred to the core as the fascicular region and the loose connective tissue surrounding it as the epifascicular region [13]. Many studies have proposed that the epifascicular part is the tissue through which nerves and blood vessels penetrate the ligaments [8]. This region is also the primary location of the mechanoreceptors [13]. For a joint to have a proprioceptive function, mechanoreceptors must be present in joint ligaments and/or the joint capsule [11].

The interosseous ligaments of the proximal row were the first to be examined for mechanoreceptors, with a particular focus on the SLIL [14]. The SLIL is a solid intrinsic ligament located between the scaphoid and lunate bones in the wrist [15]. Berger *et al.* demonstrated the constraint and material properties of the subregions of the SLIL in 1999 [16]. The ligament was divided into three subregions: the dorsal, proximal, and palmar regions. The dorsal region was described as a true ligament, with transversely oriented collagen fibers and histologic features typical for ligaments. It was also recorded as the thickest region of the ligament. The palmar region was described as relatively thin but also described as a true ligament. The proximal region differed morphologically from the aforementioned regions by being composed of fibrocartilage [16]. Mataliotakis *et al.* conducted a cadaveric study on the sensory innervation of the subregions of the SLIL in relation to their structural composition [17]. The study concluded that the palmar subregion contained the greatest amount of neural structures and mechanoreceptors. However, the dorsal subregion was described as having limited innervation. Notwithstanding, Hagert *et al.* published a study examining the dorsal subregion of the SCIL among other ligaments of the dorsal aspect of the wrist [13]. In the said study, Hagert *et al.* stated that the dorsal part of the SLIL was richly innervated. However, the innervation of the dorsal area of the SLIL was compared with the innervation of the extrinsic ligaments of the wrist, which have a similar amount of innervation. Studies have also shown that the innervation of the ligament was denser in the area of the insertion to the bone [13].

The (DCSS) is the attachment between the dorsal wrist capsule, the dorsal part of the SLIL, and the dorsal intercarpal ligament (DICL) and was first described by Overstraeten *et al.* in 2013 [18]. In the said study, the DCSS was thought to play a role in stabilizing the scapholunate joint as a secondary stabilizer. In a cadaveric study conducted by de Sambuy [1], the DCSS was observed in the 11 wrists of 6 specimens, proving that the DCSS is quite a constant structure that should be taken into consideration when performing the surgical procedures on the dorsal wrist. Numerous studies have shown the presence of nerve fibers (PIN) above the DCSS [2, 5, 19]. However, the present study is the first to show that the afferent nerve fibers of the PIN penetrate the dorsal capsule of the wrist. Likewise, DCSS is the only structure that connects the dorsal capsule of the wrist with the SLIL. Therefore, it may be stated that DCSS can play a significant role in the impulse conduction of deep proprioception of the wrist.

Knowledge about the exact innervation of the wrist joint is essential in procedures regarding its deliberate denervation. Indications of this procedure are very extensive because any form of wrist pain can be managed by denervation. Therefore, this procedure may be indicated in numerous pathologies, such as painful carpal instability, arthritis, scaphoid nonunion, and occult ganglion [10]. Wilhelm *et al.* were the first to thoroughly explain a surgical technique in which he completely denervated the wrist joint [20]. In the said technique, ten nerve branches are sectioned using five incisions. This makes the procedure technically difficult, and it may result in unwanted effects. Partial denervation creates the possibility of selective denervation of regions that most likely contribute to the formation of pain. Compared to the complete denervation procedure, partial denervation has a shorter recovery time and is technically easier [5]. A detailed understanding of the innervation of the wrist joint is essential for avoiding undesired denervation of other structures, such as the nerve fibers responsible for the proprioceptive function of the joint. Hagert *et al.* contributed two novel dorsal and palmar nerve-sparing approaches to the radiocarpal joint [11]. In the said study, it was pointed out that when the proximally based capsular flap is elevated to uncover the proximal carpal row and the radiocarpal joint by detaching its insertions on the dorsum of the scaphoid, lunate, and triquetrum, care must be taken to leave the most superficial fibers of both the lunotriquetral ligament and the SLIL attached to the capsular flap. This must be done because these ligaments contain mechanoreceptors from which afferent stimuli go to the PIN. In fact, the elevation of the capsular flap separates the joint capsule and the mechanoreceptors from the superficial part of the SLIL [8]. Consequently, nerve conduction will be lost unless there is another way to innervate the dorsal aspect of the SLIL. Our results show that the afferent fibers from the mechanoreceptors of the SLIL may pass through the DCSS and subsequently through the dorsal capsule of the wrist to the PIN. Therefore, this septum can be defined as a highly innervated area where the surgeon should show great care when performing procedures on the dorsal wrist.

Conclusion

The present study proves that afferent fibers from the mechanoreceptors of the SLIL potentially pass through the DCSS and subsequently through the dorsal capsule of the wrist to the PIN. This knowledge can surely be of great use for hand surgeons that perform procedures on the dorsal wrist.

Contribution

All authors contributed equally in an overall process of creating, planning and realizing research.

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The authors sincerely thank those who donated their bodies to science so that anatomical research could be performed. Results from such research can potentially increase mankind's overall knowledge that can then improve patient care. Therefore, these donors and their families deserve our highest gratitude [21].

Ethical approval

The research protocol was submitted for evaluation and approved by the Jagiellonian University Bioethical Committee, Kraków, Poland.

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Conflict of interest

None declared.

References

1. *Tommasini Carrara de Sambuy M., Burgess T., Cambon-Binder A., Mathoulin C.*: The Anatomy of the Dorsal Capsulo-Scapholunate Septum: A Cadaveric Study. Journal of Wrist Surgery. 2017; 6: 244–247. https://doi.org/10.1055/s-0036-1597922.
2. *Bonczar T., Walocha J.A., Bonczar M., Mizia E., Filipowska J., Tomaszewski K.*: The course of posterior interosseous nerve in the wrist capsule. An anatomical study using the modified Sihler's staining. Folia Med Cracov. 2020; 60: 33–43. https://doi.org/10.24425/fmc.2020.133484.
3. *Hagert E., Ljung B.-O., Forsgren S.*: General Innervation Pattern and Sensory Corpuscles in the Scapholunate Interosseous Ligament. Cells Tissues Organs. 2004; 177: 47–54. https://doi.org/10.1159/000078427.
4. *Alamneh Y.M.*: Knowledge and attitude towards ethical cadaver dissection among medical and health sciences students, 1997–2020: A systematic review and meta-analysis. Translational Research in Anatomy 2021; 25: 100149. https://doi.org/10.1016/j.tria.2021.100149.
5. *van de Pol G.J., Koudstaal M.J., Schuurman A.H., Bleys R.L.A.W.*: Innervation of the Wrist Joint and Surgical Perspectives of Denervation. The Journal of Hand Surgery. 2006; 31: 28–34. https://doi.org/10.1016/j.jhsa.2005.06.021.
6. *Dellon A.L.*: Partial dorsal wrist denervation: Resection of the distal posterior interosseous nerve. The Journal of Hand Surgery. 1985; 10: 527–533. https://doi.org/10.1016/S0363-5023(85)80077-0.

7. *Zwart K., Roeling T.A.P., Leeuwen W.F., Schuurman A.H.*: An Anatomical Study to the Branching Pattern of the Posterior Interosseous Nerve on the Dorsal Side of the Hand. Clinical Anatomy. 2020; 33: 678–682. https://doi.org/10.1002/ca.23486.
8. *Bonczar T., Bonczar M., Pękala J.R., Mann M.R., Walocha J.A.*: Innervation of the wrist joint: Literature review and clinical implications. Clinical Anatomy. 2021; 34: 1081–1086. https://doi.org/10.1002/ca.23734.
9. *Buck-Gramcko D.*: Denervation of the wrist joint. The Journal of Hand Surgery. 1977; 2: 54–61. https://doi.org/10.1016/S0363-5023(77)80010-5.
10. *Ferreres A., Suso S., Ordi J., Llusa M., Ruano D.*: Wrist Denervation. Journal of Hand Surgery. 1995; 20: 761–768. https://doi.org/10.1016/S0266-7681(95)80043-3.
11. *Hagert E., Ferreres À., Garcia-Elias M.*: Nerve-Sparing Dorsal and Volar Approaches to the Radiocarpal Joint. The Journal of Hand Surgery. 2010; 35: 1070–1074. https://doi.org/10.1016/j.jhsa.2010.03.032.
12. *Standring S., Borley N.R., Gray H.*: Gray's anatomy: the anatomical basis of clinical practice. 40th ed., anniversary ed. Churchill Livingstone: Elsevier; 2008.
13. *Hagert E., Garcia-Elias M., Forsgren S., Ljung B.-O.*: Immunohistochemical Analysis of Wrist Ligament Innervation in Relation to Their Structural Composition. The Journal of Hand Surgery. 2007; 32: 30–36. https://doi.org/10.1016/j.jhsa.2006.10.005.
14. *Kuo C.E., Wolfe S.W.*: Scapholunate Instability: Current Concepts in Diagnosis and Management. The Journal of Hand Surgery. 2008; 33: 998–1013. https://doi.org/10.1016/j.jhsa.2008.04.027.
15. *Cedryck V.*: What is the future for Scapholunate interosseous ligament reconstruction? Archives of Clinical and Experimental Orthopaedics. 2018; 2: 004–007. https://doi.org/10.29328/journal.aceo.1001004.
16. *Berger R.A., Imeada T., Berglund L., An K.-N.*: Constraint and material properties of the subregions of the scapholunate interosseous ligament. The Journal of Hand Surgery. 1999; 24: 953–962. https://doi.org/10.1053/jhsu.1999.0953.
17. *Mataliotakis G., Doukas M., Kostas I., Lykissas M., Batistatou A., Beris A.*: Sensory Innervation of the Subregions of the Scapholunate Interosseous Ligament in Relation to Their Structural Composition. The Journal of Hand Surgery. 2009; 34: 1413–1421. https://doi.org/10.1016/j.jhsa.2009.05.007.
18. *van Overstraeten L., Camus E., Wahegaonkar A., Messina J., Tandara A., Cambon-Binder A., et al.*: Anatomical Description of the Dorsal Capsulo-Scapholunate Septum (DCSS) — Arthroscopic Staging of Scapholunate Instability after DCSS Sectioning. Journal of Wrist Surgery. 2013; 2: 284–284. https://doi.org/10.1055/s-0033-1353387.
19. *Dellon A.L., Seif S.S.*: Anatomic dissections relating the posterior interosseous nerve to the carpus, and the etiology of dorsal wrist ganglion pain. The Journal of Hand Surgery. 1978; 3: 326–332. https://doi.org/10.1016/S0363-5023(78)80032-X.
20. *Wilhelm A.*: Denervation of The Wrist. Hefte Unfallheilkd. 1965; 81: 109–114.
21. *Iwanaga J., Singh V., Ohtsuka A., Hwang Y., Kim H., Moryś J., et al.*: Acknowledging the use of human cadaveric tissues in research papers: Recommendations from anatomical journal editors. Clinical Anatomy 2021; 34: 2–4. https://doi.org/10.1002/ca.23671.