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# Anatomical and Histomorphometric Study of the Ulnar Nerve at the Wrist

## Estudio Anatómico e Histomorfométrico del Nervio Ulnar en la Muñeca

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**SUMMARY:** The ulnar nerve (UN) is the main nerve responsible for innervation of the intrinsic musculature of the hand. It is of great importance to have a deep anatomical knowledge of the UN. The aim of this study is to enrich the knowledge of the UN anatomy at the wrist and provide useful reference information for clinical and surgical applications. In this descriptive cross-sectional study, 44 upper limbs of fresh cadavers were evaluated. The UN, the superficial branch of the ulnar nerve (SBUN), and the deep branch of the ulnar nerve (DBUN) were evaluated. Morphometric variables were measured using a digital caliper, and samples of nervous tissue were taken to evaluate the histomorphometry. Before entering the Guyon's canal, the UN had a diameter of 3.2 ± 0.4 mm. In 36 samples (82 %) the UN presented a bifurcation pattern and in the remaining 8 samples (18 %) a trifurcation was shown. The diameter of the DBUN was 1.9 ± 0.33 mm and that of the SBUN was 1.29 ± 0.22 mm. In the bifurcation patterns, the SBUN had a trunk of 5.71 ± 1.53 mm before bifurcating into the common digital nerve (fourth and fifth fingers) and an ulnar digital collateral nerve (fifth finger). The DBUN had an area of 2.84 ± 0.7 mm2 and was made up of 8 ± 1.4 fascicles and 3595 ± 465 axons. The SBUN area was 1.31 ± 0.27 mm2, it was made up of 6 ± 1.1 fascicles and 2856 ± 362 axons. The reported findings allow the hand surgeon to improve his understanding of the clinical signs of patients with UN pathologies at the wrist level and thus achieve greater precision while planning and performing surgical approaches and dissections.

**KEY WORDS: Ulnar nerve; Wrist; Ulnar Nerve Compression Syndromes; Anatomy; Axons.**

## INTRODUCTION

The ulnar nerve (UN) corresponds to the medial cord terminal branch of the brachial plexus. It is of great clinical importance, as it is the main nerve responsible for the innervation of the intrinsic musculature of the hand (Wolfe *et al*., 2017; Dalley & Agur, 2022). On its course through the forearm, it innervates the flexor carpi ulnaris muscle and the medial component of the flexor digitorum profundus muscle (Wolfe *et al*., 2017; Dalley & Agur, 2022). Around 8 to 10 cm proximal to the wrist crease, the UN gives off the dorsal cutaneous branch (Polatsch *et al*., 2007; Depukat *et al*., 2017) and subsequently enters into the anterior compartment of the hand through the ulnar tunnel (UT) along with the ulnar artery (Wolfe *et al*., 2017; Dalley & Agur, 2022).

The UT is an osteofibrous tunnel located in the anteromedial region of the wrist. It was first described in 1861 by Jean Guyon, a French surgeon and anatomist (Guyon, 1861). Guyon proposed the configuration of this tunnel consisting of four walls (Guyon, 1861). The roof is formed by the palmar carpal ligament, the floor by the transverse carpal ligament, the medial wall by the pisiform bone (PB), and the lateral wall by the transverse carpal ligament and the hamulus of the hamate (Zeiss *et al*., 1992; Cobb *et al*., 1996; Ombaba *et al*., 2010; Gil *et al*., 2015). The UT (known as Guyon's canal), begins at the proximal margin of the palmar carpal ligament and extends distally to the fibrous arch of the hypothenar muscles at the level of hamulus of the hamate (Ombaba *et al*., 2010). After

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entering the hand through the UT, the UN branches off into its two terminal branches: a superficial sensory branch (SBUN) and a deep motor branch (DBUN) (Polatsch *et al*., 2007; Depukat *et al*., 2017).

A compressive neuropathy of the UN has been described during its path in the UT known as ulnar tunnel syndrome (Dupont *et al*., 1965; Waugh & Pellegrini Jr., 2007; Chen & Tsai, 2014). The entrapment can be located at three levels according to Gross & Gelberman (1985): proximal to the bifurcation, (triggering mixed motor and sensory symptoms), distal to the bifurcation (compromising only the SBUN, causing sensory deficit in the fifth finger and the medial half of the fourth finger); and distal to the bifurcation (with compromise of the DBUN, where functional deficit of the hypothenar, interosseous, third and fourth lumbrical and adductor pollicis muscles can be identified).

Histomorphometry provides useful clinical information in the field of nerve transfers, including variables such as diameter, area, number of fascicles, number of axons and axonal density of the nerves. There are few anatomical studies that asses the histomorphometric variables of the UN at the wrist level. Sukegawa *et al*. (2014) in a Japanese population reported an average of 7.8 fascicles and 1523 axons for the DBUN. Schenck *et al*. (2015) in a German population reported 8.6 fascicles and 2900 axons for the DBUN.

There are no previous studies that evaluate the UN anatomical variables and its histomorphometry at the wrist level in a Latin American mestizo sample. As a result, this study enriches the knowledge of this anatomical territory and provides useful reference information for clinical and surgical applications that involve this nerve structure.

## MATERIAL AND METHOD

In this descriptive cross-sectional study, 44 upper limbs were evaluated from 22 fresh cadavers that underwent autopsy at the Instituto Nacional de Medicina Legal y Ciencias Forenses in Bucaramanga, Colombia. The samples met this selection criterion: individuals over 18 years old. Subjects with evidence of direct trauma or scars in upper limbs were excluded. This study was carried out in compliance with the AQUA checklist, ethics guidelines for the study of research specimens obtained from deceased human subjects (Henry *et al*., 2018). The research protocol was endorsed by the Scientific Research Ethics Committee of the Universidad Industrial de Santander (CEINCI-UIS).

A lateral incision was performed parallel to the flexor carpi ulnaris muscle. The incision was continued in a "Z" shape from the wrist crease to the hypothenar eminence. The flexor carpi ulnaris tendon was detached from the PB while the palmar carpal ligament was longitudinally sectioned to access the ulnar neurovascular bundle. Under 3,5X magnification with surgical magnifying glasses (ZEISS EyeMag Pro S), the muscular structures of the hypothenar eminence and the ulnar neurovascular bundle were dissected.

Morphometric variables were measured using a digital caliper (Mitutoyo 500 series). The diameters of the UN, DBUN, and SBUN and their distances to relevant anatomical landmarks were measured. Samples of the evaluated nerve branches were taken and fixed with 5 % buffered formalin. Histological slides were stained with hematoxylin-eosin and photographed at 4X, 10X, and 40X magnification (Fig. 1) using a microscope with an integrated camera (Leica DM500).

The histomorphometry was analyzed using Image-Pro Plus 7 software (Media Cybernetics), applying the semi-automated method for axonal counting. The statistical analysis was performed with SPSS Statistics 27 software (IBM). The continuous quantitative variables were described with their means and standard deviations. The student's t-test was performed accepting an alpha error of up to 5 %.

## RESULTS

Of the 22 fresh cadavers, there were 18 males (82 %) and 4 females (18 %). The average age of the specimens was 31.6 years. The dorsal cutaneous branch (DCBUN) originated 89 ± 16mm proximal to the PB. Before entering Guyon's canal, the UN had a diameter of 3.2 ± 0.4 mm. The proximal edge of the palmar carpal ligament was 2.5 ± 0.5 mm proximal to the PB. The length of the UT was 44 ± 5 mm.

The UN division occurred 8.7 ± 2.6 mm distal to the proximal margin of the PB. In all cases, this division took place during the UN pathway in the UT (Fig. 1). In 36 samples (82 %) the UN presented a bifurcation pattern into a superficial sensory branch and a deep motor branch. In the remaining 8 samples (18 %) a trifurcation was shown, consisting of a deep motor branch, a common digital nerve (fourth and fifth fingers) and an ulnar digital collateral nerve (fifth finger). The diameter of the DBUN was 1.9 ± 0.33 mm and that of the SBUN was 1.29 ± 0.22 mm.

In the bifurcation patterns, the SBUN had a trunk of

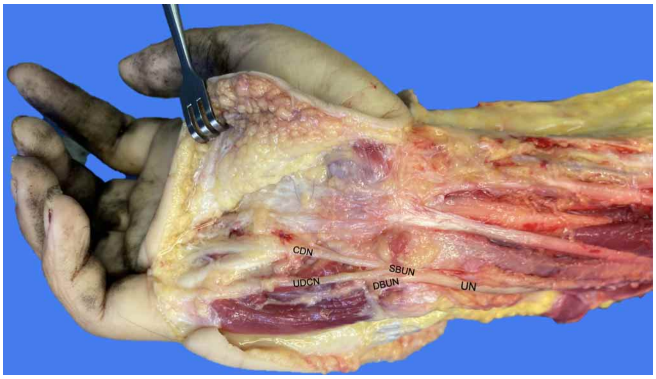



Fig. 1. Course of the ulnar nerve in the wrist. At the level of the ulnar tunnel, it bifurcates into its two terminal branches. The tendon of the flexor carpi ulnaris has been released from its insertion and the palmar carpal ligament has been sectioned longitudinally. UN: Ulnar nerve. DBUN: Deep branch ulnar nerve. SBUN: Superficial branch ulnar nerve. CDN: Common digital nerve. UDCN: Ulnar digital collateral nerve.

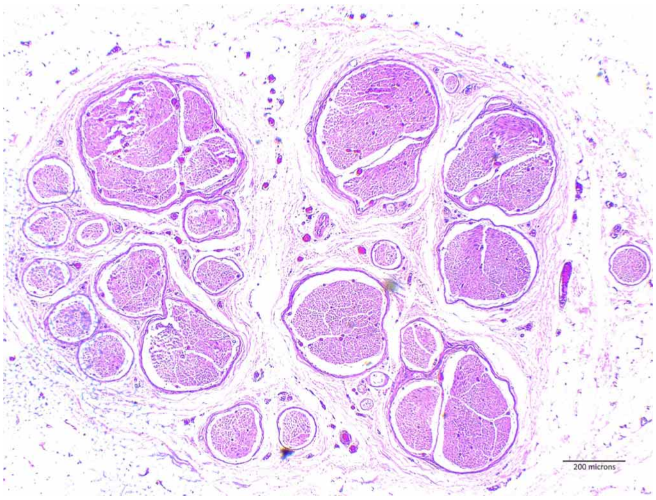
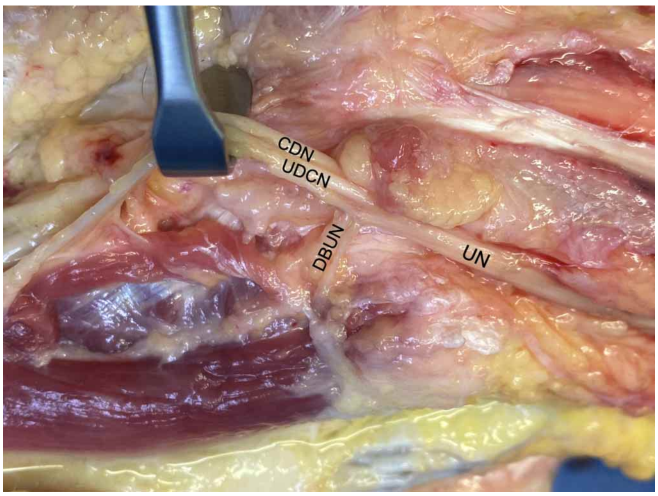



Fig. 3. Histological section with hematoxylin-eosin staining of the ulnar nerve before its bifurcation in the ulnar tunnel under 4X magnification. 8 fascicles can be appreciated.




5.71 ± 1.53 mm before bifurcating into a common digital nerve (fourth and fifth fingers) and an ulnar digital collateral nerve (fifth finger). No anastomoses were found between the DCBUN and the SBUN. The DBUN and SBUN diameters were 1.9 ± 0.3 mm and 1.3 ± 0.3 mm respectively. After getting through the UT, the UN sends a branch to the abductor digiti minimi, then it continues its course to supply the opponens digiti minimi and the flexor digiti minimi (Fig. 2). It then goes across the midpalmar space to supply the 3rd and 4th lumbricals, the adductor pollicis, flexor pollicis brevis and all the interossei.

The DBUN had an area of 2.84 ± 0.7 $mm^2$ and was made up of 8 ± 1.4 fascicles and 3595 ± 465 axons, with an axonal density of 1400 ± 532 axons/$mm^2$. The SBUN area was 1.31 ± 0.27 $mm^2$, made up of 6 ± 1.1 fascicles and 2856 ± 362 axons, with an axonal density of 2185 ± 600 axons/mm2 (Fig. 3). Of all the evaluated variables, there were no statistically significant differences between left and right forearms or between male and female specimens ($p > 0.05$).

## DISCUSSION

In our findings, the UT length is in a similar range to the previously reported findings by Lindsey & Watumull (1996) and Ombaba *et al*. (2010). The UN division can occur at three different levels: before entering the UT, in the proximal UT segment and in the distal UT segment (Niitsu *et al*., 2010). In the present study, all the divisions occurred during the UN path through the UT, mostly in the PB distal segment, in agreement with that reported by Gil *et al*. (2016). In this study, we found the UN bifurcation at 8.7 mm from the PB proximal edge, similar to that reported by Lindsey & Watumull (1996), while Gross & Gelberman (1985) and Zeiss *et al*. (1992) reported in North American population lengths of 11 and 11,6 mm respectively. This difference could be explained by the fact that the North American population is taller and has longer forearms. The division pattern most frequently found in the present study was bifurcation (82 % of cases), similar to that previously reported Depukat *et al*. (2017) and Murata *et al*. (2003). Bozkurt *et al*. (2005) reported the distal segment of «Guyon's canal» as the most common site of compression and a thickened fibrous

Fig. 2. The DBUN goes through the hypothenar muscles at the level of the hook of the hamate and continues its pathway in a deep plane. UN: Ulnar nerve. DBUN: Deep branch ulnar nerve. CDN: Common digital nerve. UDCN: Ulnar digital collateral nerve.

fascial arch as the most common etiology. Relating this parameter to our findings, the compression would occur once the UN has forked. At this level, the symptoms would be motor or sensory deficit depending on whether it compromises the DBUN or the SBUN respectively. These disorders can be exacerbated during wrist flexion, which is when the fibrous fascial arch generates the greatest compression (Ombaba *et al*., 2010). At the wrist level, the UN is mainly motor. In the present study, we evidenced a greater area and axonal count of the DBUN compared to the SBUN, consistent with previous studies (Osman *et al*., 1998; Sukegawa *et al*., 2014; Schenck *et al*., 2015). These findings reassert the clinical importance of the UN, as it is the main nerve responsible for the innervation of the intrinsic musculature of the hand.

In the present study, the number of fascicles and axons of the SBUN is similar to that reported by Schenck *et al*. (2015). Likewise, the number of fascicles of the DBUN is consistent with that reported by Sukegawa *et al*. (2014), however we found a significantly higher axonal count (3595 vs 1523 axons). The explanation for this divergence could be given by the fact that in this study, we evaluated the UN of individuals with an average age of 31.6 years, an age at which there is still a significant neuronal reserve, while the average age of the Sukegawa *et al*. (2014) study was 88.2 years. Aging is related to a reduction in the number of axons but with an increase in their diameter (Stahon *et al*., 2016).

Functional motor recovery after a peripheral nerve injury is determined by the time between its injury and the reinnervation of the motor endplate and the total number of regenerated motor axons that reach the goal (Barbour *et al*., 2012). In nerve transfers, to achieve an adequate reinnervation, the transferred branch must have at least 30 % of the axonal count of the receiving nerve (de Zepetnek *et al*., 1992). This study evaluated the histomorphometry of the UN in a Latin American mestizo sample. Further studies that evaluate the histomorphometry of nerve transfers for the DBUN in high ulnar nerve injuries, will help to determine which of these procedures provides an absolute number of regenerated axons as close as possible to the DBUN with the aim of obtaining better functional results.

## CONCLUSIONS

The present study enriches the knowledge of this anatomical territory, highlighting the absence of previous studies of this type in the Latin-American mestizo population. The reported findings allow the hand surgeon to improve his understanding of the clinical signs of patients with UN pathologies at the wrist level and thus achieve greater precision while planning and performing surgical approaches and dissections in UN traumatic injuries and in ulnar tunnel releases for compressive neuropathies of the UN. In the findings of this study, the axonal count of the DBUN is higher than previously reported, possibly related to the fact that the cadaveric specimens in this study correspond to young individuals with a significant neuronal reserve. Knowledge of the histomorphometry of the DBUN is a necessary step, so that future studies that evaluate nerve transfers for the DBUN in high ulnar nerve injuries, identify which transfer provides an absolute number of regenerated axons as close as possible to the DBUN with the aim of obtaining better functional results.

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**RESUMEN:** El nervio ulnar (NU) es el principal nervio responsable de la inervación de la musculatura intrínseca de la mano. Es de gran importancia tener un profundo conocimiento anatómico del NU. El objetivo de este estudio fue enriquecer el conocimiento de la anatomía del NU en la muñeca y proporcionar información de referencia útil para aplicaciones clínicas y quirúrgicas. En este estudio descriptivo transversal se evaluaron 44 miembros superiores de cadáveres frescos. Se evaluó el NU, el ramo superficial del nervio ulnar (RSNU) y el ramo profundo del nervio ulnar (RPNU). Las variables morfométricas se midieron con un caliper digital y se tomaron muestras del nervio para evaluar la histomorfometría. Antes de ingresar al canal del nervio ulnar (canal Guyon), el ONU tenía un diámetro de 3,2 ± 0,4 mm. En 36 muestras (82 %) el ONU presentó un patrón de bifurcación y en las 8 muestras restantes (18 %) se presentó una trifurcación. El diámetro del RPNU fue de 1,9 ± 0,33 mm y el del RSNU de 1,29 ± 0,22 mm. En los patrones de bifurcación, el RSNU presentó un tronco de 5,71 ± 1,53 mm antes de bifurcarse en el nervio digital común (cuarto y quinto dedo) y un nervio digital colateral ulnar (quinto dedo). El RPNU tenía un área de 2,84 ± 0,7 $mm^2$ y estaba formado por 8 ± 1,4 fascículos y 3595 ± 465 axones. El área del RSNU fue de 1,31 ± 0,27 $mm^2$, estaba formado por 6 ± 1,1 fascículos y 2856 ± 362 axones. Los hallazgos reportados permiten al cirujano de mano mejorar su comprensión de los signos clínicos de los pacientes con patologías del NU a nivel de la muñeca y así lograr una mayor precisión en la planificación y realización de abordajes y disecciones quirúrgicas.

**PALABRAS CLAVE: Nervio ulnar; Muñeca; Síndromes de compresión del nervio ulnar; Anatomía; Axones.**

## REFERENCES


Barbour, J.; Yee, A.; Kahn, L. C. & Mackinnon, S. E. Supercharged end-to-side anterior interosseous to ulnar motor nerve transfer for intrinsic musculature reinnervation. *J. Hand Surg., 37(10)*:2150-9, 2012.

Bozkurt, M. C.; Tagil, S. M.; Özçakar, L.; Ersoy, M. & Tekdemir, I. Anatomical variations as potential risk factors for ulnar tunnel syndrome: A cadaveric study. *Clin. Anat., 18(4)*:274-80, 2005.

Chen, S. H. & Tsai, T. M. Ulnar tunnel syndrome. *J. Hand Surg., 39(3)*:571-9, 2014.

Cobb, T. K.; Carmichael, S. W. & Cooney, W. P. Guyon's canal revisited: An anatomic study of the carpal ulnar neurovascular space. *J. Hand Surg., 21(5)*:861-9, 1996.

Dalley, A. F. & Agur, A. M. R. *Moore's Clinically Oriented Anatomy*. 9th ed. New York, Lippincott Williams & Wilkins, 2022.

de Zepetnek, J. T.; Zung, H.; Erdebil, S. & Gordon, T. Innervation ratio is an important determinant of force in normal and reinnervated rat tibialis anterior muscles. *J. Neurophysiol., 67(5)*:1385-403, 1992.

Depukat, P.; Henry, B. M.; Popieluszko, P.; Roy, J.; Mizia, E.; Konopka, T.; Tomaszewski, K. A. & Walocha, J. A. Anatomical variability and histological structure of the ulnar nerve in the Guyon's canal. *Arch. Orthop. Trauma Surg., 137(2)*:277-83, 2017.

Dupont, C.; Cloutier, G. E.; Prevost, Y. & Dion, M. A. Ulnar-tunnel syndrome at the wrist: A report of four cases of ulnar-nerve compression at the wrist. *J. Bone Joint Surg. Am., 47(4)*:757-61, 1965.

Gil, Y. C.; Shin, K. J.; Lee, J. Y.; Hu, K. S.; Kim, H. J.; Song, W. C. & Koh, K. S. Topographic anatomy of the ulnar tunnel. *Surg. Radiol. Anat., 37(7)*:757-64, 2015.

Gil, Y. C.; Shin, K. J.; Lee, S. H.; Koh, K. S. & Song, W. C. Anatomy of the deep branch of the ulnar nerve. *J. Hand Surg. Eur. Vol., 41(8)*:843-7, 2016.

Gross, M. S. & Gelberman, R. H. The anatomy of the distal ulnar tunnel. *Clin. Orthop. Relat. Res., (196)*:238-47, 1985.

Guyon, F. Note sur une disposition anatomique propre a la face antericure de la region du poignet et non encore decrite par le docteur. *Bull. Soc. Anat. Paris, 6*:84-186, 1861.

Henry, B. M.; Vikse, J.; Pekala, P.; Loukas, M.; Tubbs, R. S.; Walocha, J. A.; Jones, D. G. & Tomaszewski, K. A. Consensus guidelines for the uniform reporting of study ethics in anatomical research within the framework of the anatomical quality assurance (AQUA) checklist. *Clin. Anat., 31(4)*:521-4, 2018.

Lindsey, J. T. & Watumull, D. Anatomic study of the ulnar nerve and related vascular anatomy at Guyon's canal: A practical classification system. J. Hand Surg., 21(4):626-33, 1996.

Murata, K.; Shih, J. T. & Tsai, T. M. Causes of ulnar tunnel syndrome: A retrospective study of 31 subjects. *J. Hand Surg., 28(4)*:647-51, 2003.

Niitsu, M.; Kokubo, N. & Nojima, S. Variations of the ulnar nerve in Guyon's canal: In vivo demonstration using ultrasound and 3 T MRI. *Acta Radiol., 51(8)*:939-46, 2010.

Ombaba, J.; Kuo, M. & Rayan, G. Anatomy of the ulnar tunnel and the influence of wrist motion on its morphology. *J. Hand Surg., 35(5)*:760-8, 2010.

Osman, N.; Bhatia, A.; Cadot, B.; Geffroy, M.; Ledroux, D. & Oberlin, C. Histomorphometry of the ulnar nerve and of its branches. Surg. Radiol. Anat., 20(6):409-11, 1998.

Polatsch, D. B.; Melone, C. P.; Beldner, S. & Incorvaia, A. Ulnar nerve anatomy. *Hand Clin., 23(3)*:283-9, 2007.

Schenck, T.; Stewart, J.; Lin, S.; Aichler, M.; Machens, H.-G. & Giunta, R. Anatomical and histomorphometric observations on the transfer of the anterior interosseous nerve to the deep branch of the ulnar nerve. *J. Hand Surg. Eur. Vol., 40(6)*:591-6, 2015.

Stahon, K. E.; Bastian, C.; Griffith, S.; Kidd, G. J.; Brunet, S. & Baltan, S. Age-related changes in axonal and mitochondrial ultrastructure and function in white matter. *J. Neurosci., 36(39)*:9990-10001, 2016.

Sukegawa, K.; Kuniyoshi, K.; Suzuki, T.; Ogawa, Y.; Okamoto, S.; Shibayama, M.; Kobayashi, T. & Takahashi, K. An anatomical study of transfer of the anterior interosseous nerve for the treatment of proximal ulnar nerve injuries. *Bone Joint J., 96(6)*:789-94, 2014.

Waugh, R. P. & Pellegrini Jr., V. D. Ulnar tunnel syndrome. *Hand Clin., 23(3)*:301-10, 2007.

Wolfe, S. W.; Pederson, W. C.; Kozin, S. H. & Cohen, M. S. Median and Ulnar Nerve Palsy. In: Wolfe, S. W.; Hotchkiss, R. N.; Pederson, W. C.; Kozin, S. H. & Cohen, M. S. *Green's Operative Hand Surgery*. 7th ed. Philadelphia, Elsevier, 2017.

Zeiss, J.; Jakab, E.; Khimji, T. & Imbriglia, J. The ulnar tunnel at the wrist (Guyon's canal): normal MR anatomy and variants. *AJR Am. J. Roentgenol., 158(5)*:1081-5, 1992.



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