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Anatomical Factors/Countermeasures in/against Iatrogenic Injury of the Deep Branch of Radial Nerve in the Thompson Approach Via Middle and Proximal Segments of Forearm

Factores Anatómicos/Contramedidas en/Contra la Lesión Iatrogénica del Ramo Profundo del Nervio Radial en el Abordaje de Thompson a Través de los Segmentos Medio y Proximal del Antebrazo

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SUMMARY: This study aimed to investigate the anatomical factors affecting iatrogenic injury of the deep branch of radial nerve during the Thompson approach and to propose corresponding countermeasures. Thompson approach was used to measure the horizontal/longitudinal distance from the position where the deep branch of radial nerve leaves the supinator to the ulnar margin of extensor carpi radialis brevis/humeroradial joint line. Measurements were obtained by using 48 adult cadaver specimens, which were used in teaching. We observed the lentor situation of the extensor digitorum and extensor carpi radialis brevis in proximal forearm segments and measured the distance from the deep branch of radial nerve to the humeroradial joint line at the lateral side of the radius in the neutral position of forearm rotation. The horizontal distance from the point where the deep branch of radial nerve leaves the inferior margin of supinator to the ulnar margin of extensor carpi radialis brevis was 1.3 ± 0.3 cm. The distance to the humeroradial joint line was 61.3 ± 17.6 mm. The distance to the lentor extent of extensor digitorum and extensor carpi radialis brevis at the distal part of humeroradial joint was 7.1 ± 2.1 cm. The distance from the deep branch of radial nerve to the humeroradial joint line at the lateral side of the radius is 3.2 ± 0.6 mm. Anatomical factors are observed in iatrogenic injury of the deep branch of radial nerve during the Thompson approach. Stretching the extensor digitorum before the dissection of the supinator is hazardous.

KEY WORDS: Thompson approach; Deep branch of radial nerve; Anatomy

INTRODUCTION

Thompson approach is one of the most complicated and appropriate operative approaches used in surgery of extremities. This is the most commonly used operative approach to manage middle and proximal segment fractures of radius and tumors. Cases involving the occurrence of iatrogenic injury of the deep branch of radial nerve during the Thompson approach are common, but few injuries have been reported (Tabor *et al*., 1995; Spinner *et al*., 1998). In general, it is unlikely that the iatrogenic injury of the deep branch of radial nerve results from carelessness during the operation because doctors are aware of the risks of iatrogenic injury of the deep branch of radial nerve that could occur during the Thompson approach. Consequently, doctors are more careful during the surgical operation. The primary cause is the anatomical complexity of the approach (Tornetta *et al*., 1997; Calfee *et al*., 2011; Catalano *et al*., 2011; Jockel *et al*., 2013). Therefore, we aim to avoid iatrogenic injury of the deep branch of radial nerve by thoroughly understanding the anatomical features involved in the approach. Based on the details of surgery in the Thompson approach, we found that anatomical factors easily lead to iatrogenic injury of the deep branch of radial nerve, but these factors have not yet been described by current surgery literatures, as presented in the Thompson approach. We observed and analyzed anatomical features of the deep branch of radial nerve via autopsy and the anatomical relationship between the deep branch of radial nerve and forearm extensor during the approach. Based on these anatomical features, obviously irrational descriptions of Thompson approach method are found in current surgery literature. Based on this new understanding, we proposed countermeasures to avoid iatrogenic injury of the deep branch of radial nerve that occur during the Thompson approach.

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MATERIAL AND METHOD

Specimen. A total of 48 adult cadaver specimens used in teaching were fixed by formalin (including 35 males and 13 females; 96 sides). This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Beijing General Hospital of PLA. Written informed consent was obtained from all participants.

Treatment by the Thompson approach. In the Thompson approach (Tabor *et al*.), the skin and hypodermis of the forearm are incised from the external epicondyle of the humerus to the middle of wrist and are dissected and stretched to both sides. The clearing of the interspace between the extensor digitorum and extensor carpi radialis brevis and the position where the interspace starts to become clear helps with identification during the Thompson approach. The position where abductor pollicis longus and extensor pollicis brevis emerged superficially from the deep surface of the extensor digitorum to a neutral position is observed and measured. The extensor digitorum at the distal end of the forearm is cut off, detached, and strained to the proximal end. The lentor situation of extensor digitorum and extensor carpi radialis brevis in proximal segments of the forearm is monitored. The lentor extent of the two top parts at the distal part of humeroradial joint line is measured using a Vernier caliper (precision 0.1 mm). The positional relationship between the point where the deep branch of radial nerve leaves the inferior margin of supinator and extensor digitorum and the extensor carpi radialis brevis is observed. The distance from the point where the deep branch of the radial nerve left the supinator to the humeroradial joint line is calculated. The horizontal distance from the point where the deep branch of the radial nerve leaves the supinator to the ulnar margin of extensor carpi radialis brevis is also calculated. From the distal end to proximal end, the extensor indicis part of the extensor digitorum is separated from other parts. The clearing of the boundary and the lentor situation of the two parts in the proximal segments of the forearm are both observed. The lentor extent of the two parts at the distal section of the humeroradial joint line is measured, and the deep muscles of the forearm extensor are thoroughly exposed. The course of the deep branch of the radial nerve to the distal end is observed at the anteroposterior (AP) and the lateral (LAT) sides of the radius; this course is the line from the external epicondyle of the humerus to the styloid process apex of the radius. The supinator from the distal end to the proximal end is longitudinally incised in a neutral position of forearm rotation until the deep branch of the radial nerve is exposed. The distance from the position of the deep branch of radial nerve to the humeroradial joint line is measured.

Statistical analysis. All measured data are entered into SPSS 16.0 software to obtain the mean value and standard deviation (SD) and to record the maximumand minimum values.

RESULTS

Interspace between extensor digitorum and extensor carpi radialis brevis. The interspace between the extensor digitorum and extensor carpi radialis brevis is unclear at the middle segments and proximal parts, but gradually becomes evident at the distal forearm parts. Meanwhile, abductor pollicis longus and extensor pollicis brevis emerged superficially from the interspace between extensor digitorum and extensor carpi radialis brevis at the 1/3 juncture of the middle and distal forearm segments. These structures are easily identified because of the significantly bulged muscle belly, which resulted from the obviously inclined course orientation spanning across extensor carpi radialis longus and extensor carpi radialis brevis (Fig. 1). The lentor of extensor digitorum and extensor carpi radialis brevis at proximal forearm segments is achieved at the level on which the deep branch of radial nerve left the supinator. The lentor became more compact when the humeroradial joint is approached closely. Identification is difficult even when the tendinous lentor is achieved if the boundary of both parts is unclear. The lentor extent is 7.1 ± 2.1 (5.6 - 9.4) cm at the distal part of the humeroradial joint. The distal end of the lentor exceeded the point where the deep branch of radial nerve left the supinator (Fig. 2).

Positional relationship between the deep branch of radial nerve and the interspace between extensor digitorum and extensor carpi radialis brevis. The points where the deep branch of radial nerve left the inferior margin of supinator are all located in the deep surface of the extensor digitorum. The distance from these points to the humeroradial joint line is 6.13 ± 1.76 (4.68 - 8.12) cm, whereas the horizontal distance from the points to the ulnar margin of extensor carpi radialis brevis is 1.3 ± 0.3 (0.9 - 1.9) cm (Fig. 2).

Distribution of the deep branch of radial nerve after leaving the supinator. Muscular branches are derived from the deep branch of radial nerve after leaving the supinator, and these branches are presented as “duck claws”, which are distributed on the deep surfaces of the superficial layers of forearm extensors, such as extensor digitorum, extensor digiti minimi, and extensor carpi ulnaris. These branches dominate the aforementioned superficial muscles as the trunk became attenuated and continuously descended to the superficial surface of deep forearm muscles and to the surface of deep muscular facials (Fig. 3).

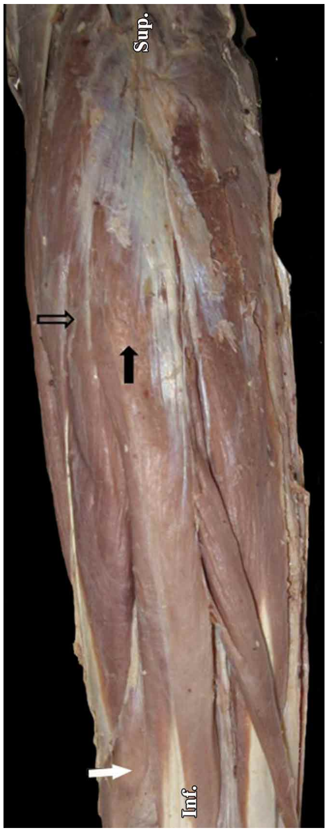

Fig. 1. Dorsal view of the forearm and the interspace between extensor digitorum and extensor carpi radialis brevis are unclear at middle segments and proximal parts of forearm, but gradually became evident at the distal parts of forearm; whereas abductor pollicis longus and extensor pollicis brevis emerged superficially from the interspace between extensor digitorum and extensor carpi radialis brevis at the 1/3 juncture of the middle and distal segments of forearm, thereby indicating extensor carpi radialis brevis and extensor digitorum and abductor pollicis longus.

Fig. 2. The anatomy of the middle and proximal segments of the forearm during the Thompson approach showed the tendinous lentor of extensor carpi radialis brevis and extensor digitorum, and the distal end of the lentor exceeded the point where the deep branch of radial nerve left the supinator, thereby showing the distance from the deep branch of radial nerve to the extensor carpi radialis brevis at the level wherein the deep branch of radial nerve left the supinator.

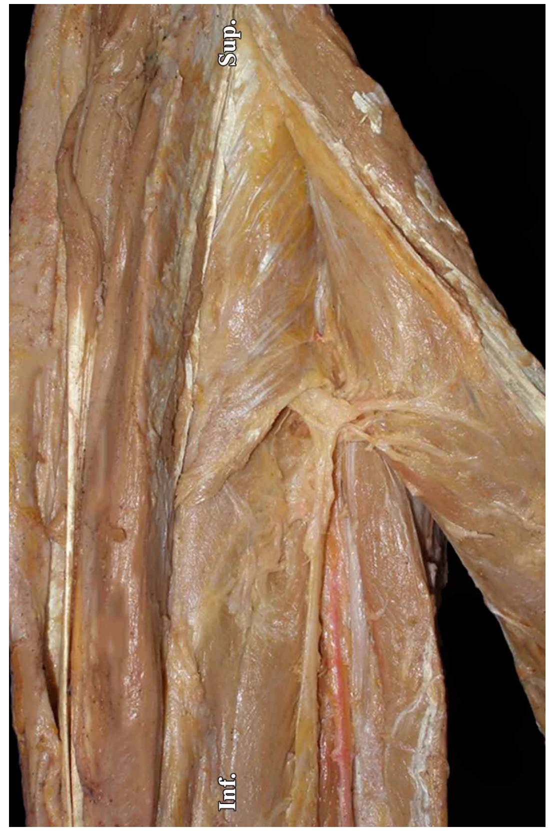

Fig. 3. Anatomy of the deep branch of radial nerve after it leaves the supinator.

Fig. 4. The deep branch of radial nerve after the supinator is dissected showed the distance from the deep branch of radial nerve to humeroradial joint at the AP and LAT sides of the radius.

Distance from the deep branch of the radial nerve to the humeroradial joint line at the lateral side of the radius in a neutral position of forearm rotation. The distance from the deep branch of the radial nerve to the humeroradial joint line at the AP and LAT side of radius in a neutral position of forearm rotation is 3.2 ± 0.6 (2.5 - 3.9) mm (Fig. 4).

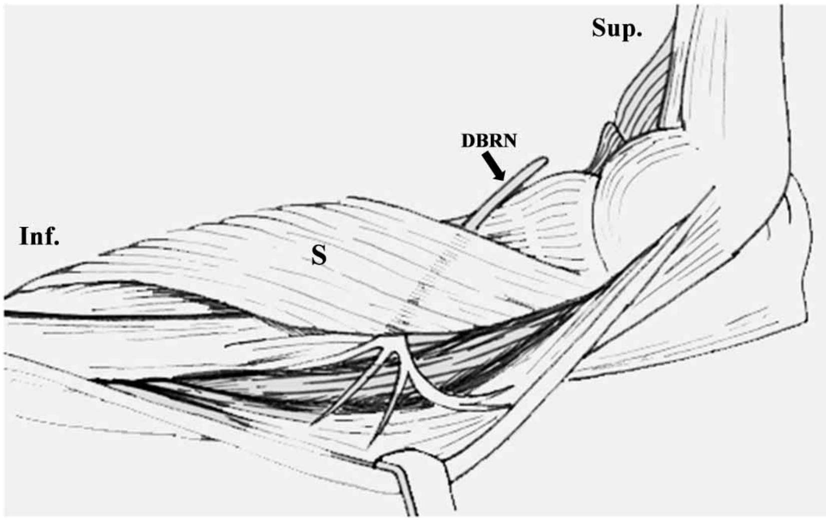

Fig. 5. The relationship between different positions where the supinator (S) is dissected and the deep branch of radial nerve (DBRN). The more the dissection approaches the dorsal side, the greater the risk on the deep branch of radial nerve.

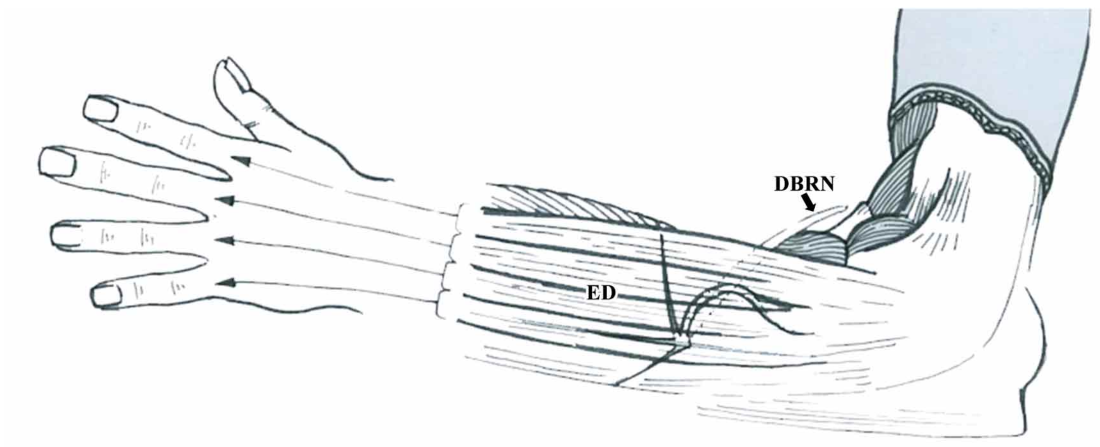

Fig. 6. Influence resulted from the false entrance of incision to the extensor digitorum (ED) on muscular branches of the deep branch of radial nerve (DBRN) sent to extensor digitorum.

DISCUSSION

The question is how to reduce and prevent from iatrogenic injury of the deep branch of radial nerve in the Thompson approach at the middle and proximal segments of the forearm in terms of surgery methodology. Answering this question starts with the following three aspects: 1) the anatomical features of the deep branch of radial nerve and position relationship between the deep branch of radial nerve and other structures of forearm; 2) the clinical features of iatrogenic injury of the deep branch of the radial nerve; and 3) the technical details of the traditional Thompson approach. The disadvantages based on the two aforementioned points are investigated.

The risk of injuring the deep branch of radial nerve in the Thompson approach is primarily attributed to complicated anatomy. 1) A part of the supinator muscles has to be cut off to expose the middle and upper segments of the radius because the natural anatomical interface from the middle and proximal segments of forearm directly reaching the radius is absent in the Thompson approach. The deep branch of the radial nerve is possibly injured when the supinator is inevitably dissected along the trunk of radius, under the premise that the supinator is not cut apart to expose the deep branch of radial nerve because it travels obliquely between the deep and superficial layer of the supinator at an angle nearly greater than 30° to the trunk of radius (Kim *et al*., 2006). 2) Branches depicted as "duck claws" soon arise from the deep branch of the radial nerve after leaving the supinator, in which stretch injuries easily occur because of the very complicated anatomical relationship between these delicate branches and forearm extensor.

Injuries on the deep branch of radial nerve result from the abovementioned first anatomical feature and are injuries of the nerve trunk because only the muscular branch of the supinator is derived from the deep branch of the radial nerve in the supinator. This type of injuries is valued by surgical doctors and easily attracts attention, because it is primarily represented as a functional impairment of thumb and finger extension, thereby reducing wrist extension force. The prevention methods for these injuries are based on the anatomical features of the Thompson approach. These methods have been described in previous works on surgery, as follows. The position of cutting off the supinator needs to be as far from its endpoint as possible because increasing the position to the endpoint would result in a higher position of the deep branch of the radial nerve. Nevertheless, the deep branch of the radial nerve travels obliquely across the radius to reach the dorsal side of the forearm and the position where it enters the supinator is located at the slight exterior of the radial neck anterior. If the dissection line of the supinator is not at the interior of the position where the deep branch of radial nerve enters the supinator, the deep branch of the radial nerve may still be injured when the supinator is dissected in an upward direction. The later the dissection line is for the supinator, the shorter the extent allowed for the dissection of the supinator (Fig. 5). Therefore, based on the anatomical relationship between the trunk of deep branch of the radial nerve and the supinator, the corresponding countermeasures to avoid injuries of the deep branch of radial nerve in the supinator are as follows. 1) The deep branch of radial nerve will not be injured if the dissection position of the supinator is located on the midline of the radial neck at supinator position. 2) Because of the obstruction of the extensor carpi radialis muscle, increasing proximity of the supinator to the proximal end, the more difficult it is to cut off. In addition, it is impossible to dissect the supinator at the anterior center of the proximal end of the radius when the proximal end of extensor carpi radialis muscle is not removed. In the actual surgical operation, surgeons can only place the removal position of the supinator as far to its endpoint as possible. Therefore, considerable risk is present when the supinator is detached toward the proximal end. A process that can be used to reduce the risk of an injury of the deep branch of radial nerve when supinator is cut off is as follows. The distance from the deep branch of radial nerve to the humeroradial joint line at the AP and LAT side of radius needs to be about 3.2 mm. Thus, the dissection of the deep branch of radial nerve by mistake can be avoided if the severance of the supinator at the elbow-joint exterior is equal to or less than 3.5 cm from the inferior of the humeroradial joint line. As the interior approaches the dissection line of the supinator, the extent allowed for the supinator to be dissected increases in length. According to examples in literature, the risk involved in the dissection of the supinator is reduced because of the shift of the deep branch of radial nerve toward the ulnar side when the forearm is pronating; however, the quantitative observation results on the radius shift when the forearm is pronating are inconsistent (Kocher, 1911; Kaplan, 1941; Davies & Laird, 1948; Capener, 1966; Strachan & Ellis, 1971; Mekhail *et al*., 1995; Mekhail *et al*., 1996; Strauch *et al*., 1996). Moreover, the operability is low when surgeries are performed. Safety can be improved by performing body surface localization of the deep branch of the radial nerve. The head and neck of the radius are initially palpated to ensure that the position where the deep branch of radial nerve enters the supinator is located at a slight exterior of the radial head and neck. This position is anterior to the point where the deep branch of radial nerve leaves out of supinator is located at about 6 cm from the inferior of the humeroradial joint line and about 0.5 - 1.0 cm from the ulnar side of the line between the external epicondyle of the humerus and Lister nodules. Consequently, the line between the two positions is the surface projection of the deep branch of the radial nerve (Catalano *et al*.). Various research studies have proposed that the nerve is exposed along the nerve course from where the deep branch of radial nerve leaves out of the supinator to the proximal end of supinator. Afterward, protection for the deep branch of radial nerve under direct vision is provided to avoid injury on the deep branch of radial nerve (Thompson, 1918; Spinner, 1978; Prasartritha *et al*., 1993; Urch *et al*., 2015). However, most surgeons do not deliberately expose the deep branch of the radial nerve in the supinator. Such operation increases surgical workload and easily causes stretch injury of the exposed deep branch of radial nerve because of the loss of protection from muscles.

Injuries on the deep branch of radial nerve during the Thompson approach are mostly reversible injuries in clinical practice, which is why they should be regarded as stretch injuries instead of an acute one. No final conclusion has been reached on what site the stretch injury is at and how it occurs. The site of stretch injury plays an important role in preventing radial nerve injury if a key cause is presented and disclosed. The distance from the points where the deep branch of radial nerve leaves the supinator to the humeroradial joint line is about 6cm, and all points are located in the deep surface of the extensor digitorum, ulnar side of the interspace between extensor digitorum and extensor carpi radialis brevis. Moreover, these points are very close to the radial margin of extensor digitorum, which is only 1.0 - 2.0 cm. Branches are soon sent to be distributed in the deep surface of superficial extensors of the forearm, such as the extensor digitorum, by the deep branch of radial nerve after leaving the supinator. Pull injury, or an injury directly caused by a retractor, is easily developed in different muscular branches of the deep branch of the radial nerve in forearm superficial extensors if the extensor digitorum is separated and stretched at 6 cm, which is close to the distal side of the humeroradial joint line, because these muscular branches are delicate. The anatomical feature of the deep branch of radial nerve is presumed to be the cause of the most common injury of the deep branch of radial nerve during the Thompson approach. The “Horn sign” is the representative form of the nerve injury. This is a specific sign that paralysis is present in the middle and ring fingers, but not in the index finger, because of the presence of another extensor indicis proprius. This hypothesis is supported by seven cases of isolated paralysis of extensor digitorum in the Thompson approach (Spinner *et al*., 1998). However, the anatomical feature of the deep branch of radial nerve is not sufficiently valued by surgeons. The description of standard operative procedure with the Thompson approach in current classical surgery monographs is as follows. The normal interspace between the extensor digitorum and extensor carpi radialis brevis is dissociated and stretched toward both sides, i.e., from the extensor carpi radialis brevis to the radial side and from the extensor digitorum to the ulnar side to the expose supinator, respectively (Canale & Beaty, 2008). A pull injury in sub-branches of the deep branch of radial nerve is easily developed during the stretching of the extensor digitorum to the ulnar side in the middle and proximal segments of the forearm. Based on the aforementioned analysis, prevention and reduction methods for the injury of the deep branch of radial nerve in the Thompson approach in the middle and proximal segments of the forearm are proposed in the study. After the interspace between the extensor digitorum and extensor carpi radialis brevis is dissociated to reach the supinator, the extensor digitorum should not be pulled to the ulnar side to avoid stretching of different muscular branches of the deep branch of radial nerve in the deep surface of the extensor digitorum. Instead, only dissociation and stretching of the extensor carpi radialis brevis to the radial side should be performed. After cutting off the extensor carpi radialis brevis and detaching from the bone surface near the endpoint of the supinator, it should be pulled with the extensor digitorum toward the ulnar side to protect different muscular branches of the deep branch of the radial nerve against pulling and injury, which are directly caused by a retractor, using the supinator. Nevertheless, the pulling force should be controlled to prevent stretch injury of the radial nerve’s trunk.

Theoretically, another form of injury on the deep branch of the radial nerve is easily ignored and might occur during the Thompson approach. Branches presented as “duck claws” soon emerge from the deep branch of radial nerve after leaving the supinator to be distributed to the deep surface of superficial extensors of the forearm as extensor digitorum, extensor digiti minimi, and extensor carpi ulnaris. These muscular branches nearly travel transversally. If the interspace between the extensor digitorum and extensor carpi radialis brevis is not accurately entered, and the extensor digitorum is entered by mistake, the muscular branches in the radial side of extensor digitorum at the falsely entered interspace must be cut off (Fig. 6). Potentiality should be fully present because of the anatomical feature of extensors in proximal segments of the forearm. At the level in which the deep branch of radial nerve leaves the supinator, the relative margins of extensor digitorum and extensor carpi radialis brevis overlap. In addition, the lentor of extensor digitorum and extensor carpi radialis brevis at proximal segments of forearm is achieved, and the average lentor extent is about 7 cm at the distal part of the humeroradial joint. Therefore, identifying the interspace between extensor digitorum and extensor carpi radialis brevis at proximal segments, as well as the proximal and middle segments of forearm, is difficult. Comparatively, the lentor part of extensor indicis and middle finger extensor is about 6 cm at the inferior of the humeroradial joint, where the interspace between these two parts is often more significant than that between extensor digitorum and extensor carpi radialis brevis (Spinner *et al*., 1998). Therefore, anatomy contributes to the possibility that the interspace between the parts of extensor indicis and middle finger extensor for extensor digitorum is entered by mistake in the Thompson approach, thereby resulting in the paralysis of extensor indicis of the extensors. Such situations are rarely seen in clinical practice because of the presence of extensor indicis proprius dominated by continued sub-branches of the deep branch of radial nerve after leaving the supinator. Actions performed by the extensor indicis could still be completed after injury of the “duck claws” of the sub-branches from the deep branch of the radial nerve. The force would merely be weakened, and thus, such injury is often ignored. To prevent this situation, the interspace between extensors and extensor carpi radialis brevis is gradually cleared at the distal part of the middle segments of forearm. Thus, the proper extension of skin incision to the middle and distal segments of the forearm in the Thompson approach is beneficial for the successful entrance to the interspace between extensor digitorum and extensor carpi radialis brevis. Abductor pollicis longus and extensor pollicis brevis could be regarded as reliable markers of normal interspace between extensor digitorum and extensor carpi radialis brevis.

SHAN, J.; WANG, C.; REN, D. & JIANG, H. Factores anatómicos/contramedidas en/contra la lesión atrogénica del ramo profundo del nervio radial en el abordaje de Thompson a través de los segmentos medio y proximal del antebrazo. *Int. J.Morphol., 35(1)*:92-98, 2017.

RESUMEN: El objetivo de este estudio fue investigar los factores anatómicos que provocan la lesión iatrogénica del ramo profundo del nervio radial durante el abordaje de Thompson y proponer las contramedidas correspondientes. El abordaje de Thompson se utilizó para medir la distancia horizontal / longitudinal desde la posición en que el ramo profundo del nervio radial sale del músculo supinador hasta el margen ulnar del músculo extensor radial corto del carpo a nivel de la línea articular humeroradial. Las mediciones se obtuvieron utilizando 48 especímenes de cadáveres adultos, que se usaron en la enseñanza. Se observó la situación de los músculos extensor de los dedos y del extensor radial corto del carpo en los segmentos proximales del antebrazo y se midió la distancia desde el ramo profundo del nervio radial hasta la línea articular humeroradial en el margen lateral del radio en posición neutra de rotación del antebrazo. La distancia horizontal desde el punto en que el ramo profundo del nervio radial sale del margen inferior del músculo supinador hasta el margen ulnar del músculo extensor radial corto del carpo fue 1,3 ± 0,3 cm. La distancia a la línea articular humeroradial fue de 61,3 ± 17,6 mm. La distancia entre el músculo extensor de los dedos y el músculo extensor radial corto del carpo en la parte distal de la articulación humeroradial fue de 7,1 ± 2,1 cm. La distancia desde el ramo profundo del nervio radial a la línea articular humeroradial en el lado lateral del radio fue de 3,2 ± 0,6 mm. Se observan factores anatómicos en la lesión iatrogénica del ramo profundo del nervio radial durante el abordaje de Thompson. El estiramiento del extensor de los dedos antes de la disección del músculo supinador es peligroso.

PALABRAS CLAVE: Abordaje de Thompson; Rama profunda del nervio radial; Anatomía.

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