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Upper Extremity Entrapment Neuropathy

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Abstract

Entrapment neuropathy is a condition characterized by motor, sensory and autonomic deficits that occur as a result of compression of the peripheral nerve at certain points along its anatomical course for different reasons. Although each peripheral nerve has anatomical or compression-appropriate areas, this can occur at any point along the course of the nerve. Entrapment neuropathies usually occur in areas where the nerve passes through a channel consisting of bone and fibrous tissue. External and internal factors play a role in the etiology of entrapment neuropathies. Among the factors that cause neuropathy, anatomical variations, trauma, metabolic diseases, tumors, synovitis and vitamin B6 deficiency are the most common ones.

Keywords: Nerve entrapment, upper extremity, neuropathy, compression, Carpal tunnel syndrome, Cubital tunnel syndrome, Cervical rib syndrome, Thoracic outlet syndrome, Guyon syndrome, Pronator syndrome, Anterior interosseus syndrome, Posterior interosseus syndrome, Suprascapular nerve compression syndrome, Keralgia paresthetica, Spiral groove syndrome, Quadrilateral space syndrome, Musculocutaneous nerve compression syndrome

1. Introduction

Entrapment neuropathy, impingement syndrome or compression neuropathy are clinical conditions that develop due to compression of peripheral nerves in various narrow spaces or tunnels along their anatomical course due to different reasons such as trauma, anomaly, tumor, metabolic disease [1–5]. “Entrapment”, “Compression” or similar terms are used to indicate that the onset of the problem is not caused by the nerves, but that it develops secondary to external mechanical effects [6]. While some neuropathies are common, some are rare [3].

In general, these neuropathies are thought to occur in actively working young/middle-aged individuals (between the ages of 25 and 40), especially in predisposing professions or having a history of certain medical conditions, and in individuals between the ages of 40 and 60 (due to hormonal factors) [3, 4]. In order to diagnose entrapment neuropathy, the patient’s clinical history and examination are very important. However, it can sometimes be difficult to diagnose only by clinical history and examination. At this stage, it may be necessary to using imaging techniques. Electrophysiological studies (including electromyography and nerve conduction studies) are the gold standard in detecting the presence of lesions and determining the location of impingement neuropathies and nerve damage [7–9].

After the impingement, a series of symptoms such as pain, change or loss of sensation, motor dysfunction and muscle atrophy are usually observed. The severity of the problem is directly proportional to the duration of exposure to compression, its shape, severity and size [1, 10]. Pain and loss of strength are the most common symptoms of entrapment neuropathies. Medical conditions such as rheumatoid arthritis, diabetes, pregnancy, and acromegaly may cause entrapment neuropathy to present a more rapid and severe clinical picture [6].

In this study, the definitions of entrapment neuropathies observed in the upper limb, their impingement levels, causes and clinical conditions that may be seen due to impingement were reviewed.

2. Upper extremity entrapment neuropathy

Entrapment neuropathies can occur in both the upper and lower limbs [3]. Entrapment neuropathies of the upper limbs are quite common. Among these, the most common is Carpal tunnel syndrome, then Cubital tunnel syndrome and then ulnar neuropathies [11, 12]. Although anatomical distributions of symptoms differ, these neuropathies contain a similar pathophysiology and treatment [13]. The nerves that innervate the upper extremity originate from the brachial plexus. The brachial plexus begins to form in the posterior cervical triangle and from here extends to the axilla where peripheral nerves are formed that will innervate the upper extremity [14]. After the peripheral nerves responsible for upper extremity innervation leave the brachial plexus, they first lie in the arm region and then in the forearm region. As the nerves course from the arm area to the forearm, they pass through relatively stable structures such as tunnels at the level of the elbow joint. These tunnels are affected by swelling in various clinical conditions such as kidney failure, diabetes, thyroid disease, or a fracture in the area, and cause compression of the travelling nerve. This situation affects the microvascular blood flow, leading to focal ischemia of the nerve. These pathophysiological processes manifest as pain, paresis, loss of sensation and muscle weakness in the areas where the nerve is distributed in the patient [13].

2.1 Etiology

External and internal factors play a role in the etiology of entrapment neuropathies. Anatomical features of the path in which the peripheral nerve travels, the movement pattern of the region where the nerve is compressed, some systemic and local diseases (rheumatoid arthritis, myxedema, acromegaly, synovitis, tenosynovitis, etc.), trauma, space-occupying lesions, incorrectly applied splints, corsets, casts and crutches external are within the factors. However, diabetes mellitus, uremia, avitaminosis and alcoholism are internal factors [5, 15].

2.2 Pathophysiology

Nerve entrapment can be acute or chronic. Acute nerve compression is the development of acute and sensory-motor paralysis in the innervation area as a result of irritation with external pressure where the peripheral nerve is superficial [1]. Chronic compression occurs when the nerve passes through a fibro-osseous canal and is continuously subjected to microtrauma and distortion. According to the Seddon's classification, chronic nerve entrapment is divided into 3 subgroups as neuropraxia, axonotmesis and neurometesis. Neuropraxia is the mildest form characterized by myelin sheath injury or ischemia in which axon and connective tissue are preserved. Improvement occurs within weeks and months. Axonotmesis is

more severe than neuropraxia. There is injury to the axon itself. Although it takes a long time, nerve regeneration is possible. However, there is no complete recovery in patients. Neurometosis is the most severe of them and involves the complete disruption of the axon, which is unlikely to heal [1, 16, 17].

2.3 Clinical symptoms

In entrapment neuropathies, clinical symptoms range from sensory abnormalities to pain, paresthesia, and motor paralysis. Sensory problems and pain are common symptoms in the early stages. Motor dysfunctions may occur in later [6].

2.4 Brachial plexus and upper extremity innervation

The brachial plexus is formed by the ventral primary rami of C5, C6, C7 and C8, and nearly all of the ventral primary ramus from T1. The rami pass between the scalenus anterior muscle and the scalenus medius muscle and reach the posterior triangle of the neck. The rami from C7 and C8 are larger than those from C5 and T1. Before the main nerves of the upper limb are formed, a complex branch exchange occurs between the ventral branches C5-T1. Trunks, divisions and cords of brachial plexus are formed with complex branch exchange. The upper trunk is formed by C5 and C6. The middle trunk is the continuation of C7. The lower trunk is formed by C8 and T1. Trunks are divided into anterior and posterior branches after a short course. These are called anterior and posterior divisions. The anterior and posterior divisions of the trunks form cords by performing a number of combinations among themselves. The posterior divisions of the three trunks unite and form the posterior cord behind the axillary artery. The anterior divisions of the superior and medium trunks unite and form the lateral cord. The anterior division of the inferior trunk forms the medial cord. The cords divide into terminal branches. Terminal branches of lateral cord are musculocutaneous nerve and lateral root of median nerve. Terminal branches of posterior cord are axillary nerve and radial nerve. Terminal branches of medial cord are ulnar nerve and medial root of median nerve (**Figure 1**) [16].

Figure 1.
Brachial plexus formation, roots, trunks, divisions and cords of the brachial plexus.

2.5 Basic entrapment neuropathies of the upper limbs

2.5.1 Compression neuropathies in the neck area

2.5.1.1 Cervical rib syndrome

Anatomy: The cervical rib is the accessory or extra rib originating from the 7th cervical vertebra. It can be found bilaterally or unilaterally and in varying sizes. The cervical rib is usually asymptomatic and is noticed incidentally on chest X-rays. Sometimes it can be palpated like a mass during the deep palpation of the supraclavicular region on physical examination. When it compresses the brachial plexus or subclavian vessels, it causes thoracic outlet syndrome or brachial plexopathy. This syndrome often causes pain in the hands when raising the arms (**Figure 2**) [18–20].

Description: It is a clinical congenital condition characterized by sensory and motor losses in the hand as a result of compression of the cervical rib or the C7 transverse extension to the C8 and T1 roots of the brachial plexus [18–20].

Causes: The accessory or extra rib originating from the 7th cervical vertebra.

Clinical features: Generally, there is a loss of sensation in the inner surface of the forearm and the last two fingers (ring and little fingers). Tingling and numbness could be in patients forearm and hand ulnar part. Pain in the upper extremity, atrophy of the intrinsic muscles of the hand, and vasomotor changes may occur. Cervical ribs may be associated with a weak pulse from the radial region, especially when the arm is abducted [20].

2.5.1.2 Thoracic outlet syndrome (TOS)

Anatomy: The thoracic outlet formed by the clavicle and the first rib is an anatomical region in the lower part of the neck through which important neurovascular structures. The thoracic outlet contains 3 spaces, called the interscalene triangle, costoclavicular space, and subcoracoid space, where neurovascular structures can

Figure 2.
The schematic drawing of close relationship between cervical rib and brachial plexus.

be compressed. The first anatomical stenosis encountered while the neurovascular bundle moves from the lower part of the neck towards the axillary region and the proximal part of the arm is an interscalene triangle. This triangle is bordered anteriorly by the anterior scalene muscle, posteriorly by the middle scalene muscle and inferiorly by the medial surface of the first rib. Brachial plexus and subclavian artery are located in this triangle. The 2nd and 3rd anatomical stenosis regions are the costoclavicular space, and the subcoracoid space. The middle third of the clavicle from the anterior, the first rib from the posteromedial and the upper border of the scapula from the posterolateral form the borders of costoclavicular triangle. The third space is the subcoracoid space under the coracoid process. The brachial plexus or its branches can be compressed in one of these spaces (**Figure 3**) [21, 22].

Description: Thoracic outlet syndrome is a condition that compression of the neurovascular bundle (brachial plexus and subclavian vessels) exiting the thoracic outlet [1, 21].

Causes: The compression that causes the syndrome can occur due to various anomalies of the bone and soft tissues. Bony abnormalities include the abnormal protrusion of the first rib or clavicle, the presence of a cervical rib, improper union or nonunion of the bone after fracture, or bone healing with excess callus

Figure 3.
The schematic drawing of entrapment sites (interscalene triangle, costoclavicular space, subcoracoid space) of the brachial plexus in the thoracic outlet syndrome.

tissue and retrosternal dislocation of the clavicle. Soft tissue anomalies include such as the presence of a fibrous band in the interscalene triangle, the presence of accessory neck muscles (minimus scalene muscle), anterior scalene hypertrophy, variations in scalene muscles and soft tissue tumors such as a Pancoast's tumor [1, 21]. It has been reported that congenital or post-traumatic malformations can cause compression, as well as due to occupational disease or due to excessive use in athletes who frequently perform overhead and throwing activities [23, 24]. Repeated overhead use by athletes engaged in this sport leads to loss of stability of the shoulder girdle and hypertrophy of the scalene muscles and pectoralis minor muscle. As a result, compression may occur in neurovascular structures in the region [25].

Clinical features: Neurogenic TOS involve include paresthesia, numbness,, and weakness radiating from the neck region and shoulder and extending into the arm and hand. TOS can cause paresthesia in a wide area. Symptoms can be seen unilateral or bilateral. Pain is felt especially over the trapezius muscle [1, 9, 24].

2.5.2 Impingement syndromes around the shoulder

2.5.2.1 Suprascapular nerve compression syndrome

Anatomy: The suprascapular nerve is a peripheral nerve with motor and sensory fibers that originates from the C5-C6 nerve roots and leaves the upper trunk of the brachial plexus. After passing through the posterior cervical triangle, it runs laterally, deep to trapezius and omohyoid, and enters the supraspinous fossa through the suprascapular notch, which is a fibro-osseous tunnel bridged by the transverse scapular ligament. The suprascapular nerve gives off two branches in the suprascapular fossa. One of these branches is distributed to the supraspinatus muscle, the other to the upper aspect of the shoulder joint. The nerve passes through the lateral part of the scapular spine and reaches the spino-glenoid notch. It reaches the infraspinatus fossa by passing through this notch. It supplies the infraspinatus muscle and posterior aspect of the glenohumeral joint (**Figure 4**) [8, 16, 26].

Description: This clinical condition is characterized by the suprascapular nerve compression at the suprascapular notch or at the spino-glenoid notch [26].

Causes: Different pathologies play a role in the compression of the suprascapular nerve at the suprascapular notch and/or spino-glenoid notch. The reasons causing compression are grouped in 2 subgroups, primary and secondary. Primary reason is dynamic entrapment of the nerve. Causes such as space occupying lesions (neoplasm, ganglion cyst, ossified scapular ligament), traumatic conditions (scapula fractures, shoulder dislocation, massive cuff tear, distractive trauma, penetrating trauma), post traumatic disorders (hematomas, heterotopic ossification, hypertirroidisim) and systematic disorder are classified as secondary. In addition, hormonal alterations or iatrogenic conditions (arthroscopic tear cuff repair, Latarjet procedure) can also cause suprascapular neuropathy [8, 26, 27]. If suprascapular nerve entrapment occurs around the suprascapular notch, both supraspinatus and infraspinatus muscles; if the spino-glenoid occurs around the notch, only the infraspinatus muscle is affected [8]. Shoulder pain associated with suprascapular neuropathy is seen as secondary to trauma in people involved in sports, and repetitive stretching of the nerve, especially in overhead volleyball players, baseball players, basketball players and dancers, is shown as an etiological factor [26].

Clinical features: When the suprascapular nerve is entrapped at the suprascapular notch, both supraspinatus and infraspinatus muscles may undergo denervation. When the nerve is compressed at the spino-glenoid notch, denervation is limited to the infraspinatus muscle [8, 26]. Suprascapular neuropathy presents with

Figure 4.
 The schematic drawing of entrapment sites in suprascapular nerve compression syndrome (entrapment sites are shown with a black arrow. A: The suprascapular notch, B: The spino-glenoid notch. SSN: Suprascapular nerve, SS: Supraspinatus muscle, IS: Infraspinatus muscle).

dull and poorly localized pain, often localized lateral and posterior to the shoulder. Patients have difficulty in raising the arm. Particularly the shoulder external rotation and abduction is weakened on the affected side and is often confused with cervical disc pathologies. If the impingement is in the suprascapular notch, the pain is more pronounced and the clinical noisier. Pain can spread to the neck and anterior rib cage wall. In addition, the suprascapular nerve is a purely motor nerve. So, no sensory loss is observed [8, 26–28].

2.5.2.2 Axillary nerve compression neuropathy (Quadrilateral space syndrome-QSS)

Anatomy: The quadrilateral space (QS) (**Figure 5**) is a space in the posterior aspect of the shoulder and bordered medially by the the long head of the triceps, laterally by the medial edge of the surgical neck of the humerus and inferiorly by the teres major and latissimus dorsi muscles and superiorly by the the teres minor muscle or the glenohumeral capsule. The QS contains the posterior circumflex humeral artery and the axillary nerve. Axillary nerve originates from the posterior

Figure 5.
The schematic drawing of entrapment site (quadrilateral space) in axillary nerve compression neuropathy AN: Axillary nerve, Tm: Teres minor muscle, Tr: Long head of the triceps, TM: Teres major muscle, H: Humerus, D: Deltoid muscle).

cord of the brachial plexus (C5-C6). It then runs along the inferolateral edge of the subscapular muscle and curves downward from the glenohumeral joint capsule to reach the OS. It divides into anterior and posterior branches in the space. The anterior branch curves together with the posterior circumflex artery around the humeral neck and reaches the deltoid muscle. At the acromion level, the nerve gives branches to supply the anterior deltoid and cutaneous branches that spread over the skin covering the deltoid muscle. The posterior branch innervates the teres minor and the posterior deltoid muscle and gives off branches to the skin over the distal part of the deltoid and the upper part of the long head of triceps [8, 16, 26, 29, 30].

Description: Quadrilateral space syndrome or axillar nerve compression neuropathy is a condition characterized by compression of the posterior humeral circumflex artery and axillary nerve in the quadrilateral space while the shoulder is in abduction and external rotation [29, 30].

Causes: Fractures of the upper limb, improper use of crutches, casts, fibrous bands, or inferior (from 9 to 7 o'clock positions) paraglenoid cysts may cause stretching injuries or stenosis of the quadrilateral space and OS contents may be compressed in QS. As a result, axillary neuropathy develops due to compression. Fibrous bands are the most common cause of compression in the QS. Also, space-occupying lesions in the QS (paralabral cyts, bony fracture fragments, benign tumors), venous dilation and muscle hypertrophy have been implicated cause of cases of QSS [8, 26, 29, 30].

Clinical features: The patient has poorly localized lateral and posterior shoulder pain and weakness, which is exacerbated by abduction and external rotation of the arm. Generally, pain becomes evident at night, after overhead activities and in the late phase of throwing. In a non dermatomal distribution, paresthesias of the affected arm may be seen. Minimal axillary nerve sensory defect can be detected [8, 26, 30, 31]. QSS is difficult to diagnose because it shows similar characteristics to the symptoms of rotator cuff pathology or other shoulder joint-related abnormalities [8].

2.5.3 Impingement syndromes in the arm and forearm

2.5.3.1 Supracondylar process syndrome

Anatomy: The supracondylar process is a beak-shaped bone spur located on the anteromedial face of the distal part of the humerus. This congenital variation does not cause any symptoms in many people. It is located approximately 4 to 8 cm above

Figure 6.
The schematic drawing of median nerve between the Struthers ligament and the bony prominence (supracondylar process) in the distal humerus.

the medial epicondyle. The Struther's ligament, a fibrous band, is stretched between the tip of this bone spur and the medial epicondyle. The Struther's ligament, a fibrous band, is stretched between the tip of this bone spur and the medial epicondyle. The neurovascular structures that are most compressed in this entrapment site are the median nerve and the brachial artery (**Figure 6**) [32, 33].

Description: It is a condition characterized by the compression of the median nerve between the Struther's ligament and the bony prominence in the distal humerus [32–34].

Causes: Congenital bone spur in beak-shaped form located in the distal part of the humerus called the supracondylar process [32, 33].

Figure 7.
The schematic drawing of musculocutaneous nerve and lateral cutaneous nerve of the forearm.

Clinical features: Symptoms are vascular and neuronal. Vascular compression symptoms are related to the brachial artery. Ischemic pain, forearm claudication and cyanosis may be seen. Pain, muscle wasting and numbness of the affected hand are symptoms that can be seen in nerve compression. Heavy manual work, repetitive activities and during flexion and pronation of the forearm may cause an increase in symptoms [34]. Prolonged median nerve compression may cause weakness and atrophy in some patients. Paresthesia and numbness may be seen at extension of the elbow [35].

2.5.3.2 Musculocutaneous nerve compression neuropathy

Anatomy: The musculocutaneous nerve originates from the lateral cord of the brachial plexus (C5–7), opposite the lower border of pectoralis minor. As the name suggests, it is a complex nerve. It innervates the biceps, coracobrachialis and brachialis muscles. It superficializes near the lateral edge of the bicipital aponeurosis and continues in the distal part of the forearm under the name of lateral antebrachial cutaneous nerve. It receives the sensation of the lateral part of the forearm [16, 36–42]. It contains only motor fibers above the elbow and only sensory fibers below the elbow (**Figure 7**) [16, 42].

Description: It is characterized by compression of the musculocutaneous nerve while travelling within the coracobrachialis muscle or at the point-where the lateral antebrachial cutaneous branch separating from the nerve is superficialized [9, 17, 38].

Causes: Musculocutaneous nerve entrapment is less common than others. Impingement usually occurs after trauma. Factors such as weightlifting, ball sport (throwing etc.), football, sleep, rowing, remote control sports (such as model airplane flying), prolonged repetitive forceful contracture of the elbow flexors such as following prolonged windsurfing, playing recreational basketball, humeral fractures, osteochondroma of the humerus, shoulder surgery, anterior shoulder subluxation, vigorous upper extremity exercise, coracoid process transfer are recommended foretiology of musculocutaneous nerve compression [7, 9, 36, 37, 39–41].

Clinical features: Compression of the musculocutaneous nerve causes wasting and weakness in the muscles innervated by the nerve. Patients may have dysesthesia on the lateral aspect of the forearm. Lateral cutaneous nerve (LACN) may be injured in situations such as venipuncture, cut-down procedure, compression. LACN is a purely sensory nerve. However, patients affected by LACN complain of pain rather than paresthesia. Symptoms caused by compression of the LACN may mimic other syndromes that cause elbow pain, such as lateral epicondylitis and radial tunnel [9, 36, 41].

2.5.3.3 Proximal radial nerve compression neuropathy (Spiral groove syndrome)

Anatomy: The radial nerve originates from the posterior cord of the brachial plexus and innervates the muscles of the extensor compartments of the upper extremity. After passing the axilla, the radial nerve winds closely around the posterolateral aspect of the humeral shaft and descends along the spiral groove between the heads of the triceps muscle. The radial nerve innervates brachioradialis, extensor carpi radialis, and supinator muscles and skin overlying the posterior upper arm (posterior cutaneous nerve of the arm and lower lateral cutaneous nerve of the arm) [1, 7–9, 16, 26, 36]. Then, the radial nerve reaches the anterior compartment of the arm by piercing the septum approximately 10 to 12 cm above the lateral epicondyle and gives off superficial and deep branches [7].

Description: It is a condition characterized by compression of the radial nerve as it passes between the heads of the triceps muscle in the spiral groove (**Figure 8**) or a fibrous arch of the lateral head of the triceps muscle [7, 9].

Causes: During the course of the nerve in the spiral groove, its close relationship with the humerus and Intermuscular septum leaves the nerve vulnerable to impacts from outside. Humerus fractures, external compression (arm rest on the edge of the chair during unconsciousness from anesthesia, drugs abuse (alcohol), or during profound sleep-Saturday night syndrome, crutches use), long tourniquet application, professions that require repeated use of the triceps muscle, deep intramuscular injections of the arm are common causes of nerve compression [9, 26]. The most common cause of radial nerve compression in the axilla is improper use of crutches. Radial nerve compression neuropathy in the spiral groove. It is often referred to as “Saturday night paralysis”. The reason for this name is the radial nerve compression caused by long-term unconsciousness of alcoholics [7–9, 35, 42].

Figure 8.
The schematic drawing of the course of the proximal radial nerve in the spiral groove (n.:nerve, m.:musculus).

Figure 9.
“Wrist drop deformity” caused by compression of the radial nerve.

Clinical features: Loss of sensation and pain occur at the sensory dermatome of radial nerve where lateral of the elbow, the dorsal of the forearm and the dorso-radial of the hand in the slight compression of the radial nerve. The pain is further exacerbated by elbow extension, forearm flexion, and wrist flexion in the position where traction is exerted on the nerve. Pain that increases with resistant extension of the middle finger is an important finding of radial nerve entrapment neuropathy. As the pressure on the nerve gets longer, motor losses begin to occur. At this level, the triceps muscle is intact, there is paralysis in the supinator and brachioradialis muscles; However, since the biceps muscle with musculocutaneous nerve innervation is active, elbow flexion and supination movement are not restricted. There is paralysis in wrist extensors, finger extensors, thumb abductor and extensor. Therefore, this condition resulting from proximal radial nerve compression syndrome is called “Wrist drop deformity” (**Figure 9**) [7, 9, 26, 42, 43].

2.5.4 Impingement syndromes in the elbow

2.5.4.1 Cubital tunnel syndrome (ulnar neuropathy)

Anatomy: The ulnar nerve originates from roots C8 to T1 via the medial cord of the brachial plexus. It runs along the posterior aspect of the humerus on the arm, and the medial epicondyle pierces the intermuscular septum approximately 8 cm above it. It enters the posterior compartment of the forearm. The nerve passes under the arcade of Struther’s in the presence of the Struther’s ligament. At the level of the elbow, the ulnar nerve passes through a fibro-osseous channel called the cubital tunnel that is bordered by the olecranon, medial epicondyle and Osborne ligament. A fascial structure between the olecranon and the medial epicondyle known as the cubital tunnel retinaculum (CTR) formed the roof of the cubital tunnel (**Figure 10**). The nerve then passes under the arcuate ligament formed by aponeurosis of flexor carpi ulnaris muscle and reaches the forearm. The ulnar nerve reaches the elbow joint level without giving any motor or sensory branches.

Figure 10.

The schematic drawing of cubital tunnel (a:Artery, n:Nerve, m:Muscle, med.Epi: Medial epicondyle, flex:Flexor, FCU: Flexor carpi ulnaris, Olec:Olecranon).

When it passes between the two heads of the flexor carpi ulnaris muscle, it gives motor branches to the flexor carpi ulnaris muscle [1, 7, 8, 9, 16].

Description: Cubital tunnel syndrome is the second most common impingement syndrome after carpal tunnel syndrome [26]. Due to its anatomical features, the ulnar nerve is most frequently compressed in the elbow area, where it is most susceptible to local compression and trauma. Posner [44] defined the 5 potential compression area in the elbow. These are the arcade of Struthers, the medial intermuscular septum, the cubital tunnel, retroepicondylar groove, and the flexor pronator aponeurosis. Although the term cubital tunnel syndrome refers to a specific anatomic point, compression neuropathy may be also outside the cubital tunnel. Cubital tunnel syndrome is a condition characterized by the compression of the ulnar nerve in the region of the elbow joint [45].

Causes: There are many reasons that can cause the development of ulnar neuropathy. Compression of the nerve in condylar groove, cubitus valgus, elbow fractures, osteoarthritis with medial osteophytes, and space occupying soft-tissue lesions, ganglia, and accessory muscles (eg, anconeus epitrochlearis muscle) are the most important known reasons [8, 9, 26, 45].

Clinical features: The complaint is generally in the form of pain radiating to the medial of the forearm, sensory abnormalities in the dorsal and palmar aspects of the hand, and motor weakness in the intrinsic muscles of the hand. In advanced stages, claw hand deformity(hyperextension of the metacarpophalangeal joints of the 4th and 5th fingers, flexion of the proximal and distal interphalangeal joints by the effect of extrinsic flexors) may occur. The little finger may also remain in a slightly abducted position (Wartenberg's sign) [8, 9, 26, 42].

2.5.5 Impingement syndromes in the forearm

2.5.5.1 Anterior interosseous (AIN) syndrome (Kiloh-Nevin syndrome)

Anatomy: The anterior interosseous nerve (AIN) originates from the median nerve. It is the terminal motor branch of the median nerve (**Figure 11**). After separating from the median nerve in the anterior part of the cubital fossa, it extends

Figure 11.
 The schematic drawing of anterior interosseus nerve between the pronator teres muscle heads.

on the forearm towards the wrist with the interosseous branch of the ulnar artery that accompanies it on the anterior face of the antebrachial membran. It courses between the muscle bellies of the flexor pollicis longus and flexor digitorum profundus at the forearm. The nerve innervates the flexor pollicis longus, radial part of the flexor digitorum profundus, the pronator quadratus muscles and middle and index fingers [1, 16, 24, 46–48].

Description: It is a condition characterized by compression of the anterior interosseous branch of the median nerve the proximal forearm [8].

Causes: There are many factors that may cause anterior interosseous nerve syndrome to occur. Causes may be spontaneous or traumatic. Supracondylar fractures, penetrating injuries, cast fixation, puncture of vein, internal fixation for fractures are considered within traumatic causes. Presence of supracondylar bony, compression of the nerve during the passage between two heads of pronator teres muscle, brachial plexus neuritis and hematoma and mass-induced nerve compression are spontaneous causative factors. The tendinous margin of the deep head of the pronator teres muscle is the most common site of AIN entrapment [8, 26, 46, 48].

Clinical features: The most obvious symptoms of AIN are pain and muscle weakness in the volar forearm, particularly at night, and difficulty in handwriting and pinching movements with the fingers. Symptoms may be increased by supination and extension. Motor dysfunction can be seen in AIN. Especially, patients complain that weakness in their thumb and index finger. Patients cannot make the

Figure 12.
Hand posture in anterior interosseous syndrome.

“OK” sign (**Figure 12**). Due to the Martin-Gruber anastomosis, paralysis may also occur in the intrinsic muscles of the hand [1, 8, 9, 26, 46, 48].

2.5.5.2 Pronator teres syndrome

Anatomy: The median nerve originates from the medial (C8 and T1) and lateral cords (C5 through C7) of the brachial plexus. At the elbow level, from medial to lateral, are the median nerve, brachial artery and the biceps tendon. The median nerve courses anterior to the brachialis muscle and deep to the Lacertus fibrosus. The nerve then courses between the superficial (humeral) and deep (ulnar) heads of the pronator teres muscle in the proximal third of the forearm and exits the cubital fossa (**Figure 13**) [16, 26, 49].

Description: It is a condition characterized by compression of the median nerve between the two heads of the pronator teres muscle or the pressure of the fibrous bands [8].

Causes: The nerve may be compressed due to thickened bicipital aponeurosis, Struther’s ligament, the arch of the flexor digitorum superficialis, as well as the hypertrophic pronator teres muscle, aberrant median artery, crossing branch of the radial artery, or soft tissue mass [8, 9, 49].

Clinical features: With resistant wrist flexion and forearm pronation, symptoms increase. The pain is localized to the medial of the forearm. Paresthesia and sensory problems are seen in the first three fingers of the hand, which is the dermatome area of the median nerve. In addition, weakness may occur in the intrinsic and extrinsic muscles of the hand innervated by the median nerve [8, 9, 49].

2.5.5.3 Posterior interosseous nerve (PIN) syndrome (Supinator syndrome)

Anatomy: The radial nerve originates from the posterior cord of the brachial plexus and innervates the muscles of the extensor compartments of the upper extremity. After the course of the radial nerve in the arm, the nerve reaches the anterior compartment of the arm by piercing the septum approximately 10 to 12 cm above the lateral epicondyle and gives off superficial and deep branches (**Figure 14**) [1, 4, 7]. The deep branch (posterior interosseous nerve-PIN) of the radial nerve first wraps around the radial neck and then travels within the radial tunnel. The radial tunnel is bordered medially by brachialis and biceps tendon and laterally by extensor carpi radialis longus and brevis. The PIN then passes below the superficial layer of supinator (which is known as the arcade of Frohse) and innervates supinator as

Figure 13.
The schematic drawing of median nerve between the pronator teres muscle heads.

well as wrist and finger extensors. The superficial branch of the radial nerve runs along the radial artery in the forearm. It passes over the first extensor compartment at the wrist and disperses on the back of the hand [1, 8].

Description: Posterior interosseous nerve syndrome is a condition characterized by compression of the nerve in the proximal forearm, anterior to the elbow capsule, under the Frohse archade, approaching the arch, or within the supinator muscle [1, 8, 9].

Causes: In some professions such as athletes and violinists, excessive use of the arm, use of crutches, repetitive pronation-supination movement, fractures of the radial head, soft tissue tumors such as ganglion and lipoma, septic arthritis, synovial chondromatosis, or rheumatoid synovitis are the causes of posterior interosseous nerve syndrome [4, 9, 26, 35].

Figure 14.
The schematic drawing of the course of the radial nerve and its superficial and deep branches.

Clinical features: In PIN syndrome, wrist extensors are intact because the innervation of these muscles is at the level of the elbow joint. In PIN syndrome, paralysis develops in finger extensors, thumb extensors and abductors. There is no sensory deficit. In clinical examination, it may be mistaken for lateral epicondylitis. In lateral epicondylitis syndrome, there is pain that concentrates on the lateral epicondyle and increases with resistant extension of the wrist. In PIN syndrome, the pain is exacerbated by the resistant extension of the third finger and radiates to the lateral side of the arm. Also, resistant supination movement causes pain [1, 8, 26, 50].

2.5.5.4 Superficial cutaneous radial nerve compression (*Keralgia paresthetica*- Wartenberg syndrome)

Anatomy: The superficial branch of the radial nerve, after separating from the radial nerve, extends distally along the radial side of the forearm deep in the brachioradialis muscle (**Figure 15**). It is superficial by piercing the fascia between the brachioradialis and extensor carpi radialis longus muscle tendons approximately 8–9 cm above the radial styloid [51, 52].

Figure 15.
 The schematic drawing of the course of the superficial branch of the radial nerve in the forearm.

Description: It is a condition characterized by the compression of the superficial sensory branch of the radial nerve at the level of the wrist [1, 8, 50, 52].

Causes: Distal radius fractures, penetrating injuries, a tight watch strap or hand cuffs, a tight cast or splint, repetitive exercise (e.g. rowing), iatrogenic injury, lipoma and bony spurs are important factors causing nerve compression [1, 51, 52].

Clinical features: Patients usually complain of pain and numbness on the dorsal and lateral side of the hand. It is a pure sensory nerve so there is no motor deficits [1].

2.5.6 Impingement syndromes in the wrist

2.5.6.1 Carpal tunnel syndrome (CTS)

Anatomy: The median nerve passes between the two heads of the pronator teres muscle and reaches the forearm. In the forearm, nerve gives off branches that innervate the palmaris longus muscle, the flexor carpi radialis muscle and the flexor digitorum superficialis muscle. The palmar cutaneous branch separates from the median nerve approximately 5 cm proximal to the wrist fold. At the wrist level, the median nerve is located on the ulnar side of the flexor carpi radialis tendon and passes through the carpal tunnel [1, 16]. Carpal tunnel is lined by transverse carpal ligaments on the volar side and carpal bones on the dorsal side. In addition to the median nerve, two tendons for the 2nd, 3rd, 4th, 5th fingers (flexor digitorum superficialis and profundus) and one for the thumb (flexor pollicis longus) pass through the carpal tunnel. A total of 9 separate flexor tendon median nerves pass through the tunnel together (**Figure 16**). As the nerve passes through the carpal tunnel, it gives off motor branches that innervate the lateral two lumbricals, opponens pollicis, abductor pollicis brevis, flexor pollicis brevis muscles. Also, it provides sensory innervation of the palmar face of the radial 3,5 fingers [1, 8, 9, 35].

Description: Carpal tunnel syndrome is the most common peripheral nerve entrapment of the upper extremity. It is the compression of the median nerve under the carpal transverse ligament at the wrist level [8, 35].

Causes: Obesity, female gender, concomitant diseases (such as diabetes, pregnancy, rheumatoid arthritis, hypothyroidism, connective tissue diseases, pre-existing median mononeuropathy), repetitive wrist movements, mass lesions (eg, ganglion, lipoma, neurofibroma, fibro lipomatous hamartoma genetic predisposition and use of aromatase inhibitors are among the important causes of carpal

Figure 16.
The schematic drawing of the carpal tunnel and its elements.

tunnel syndrome. Also, carpal tunnel syndrome is associated with professions that require prolonged use of hand-held vibrating hand tools and long and repeated wrist flexion and extension [1, 8, 35, 53].

Clinical features: The first complaint of patients with CTS is the numbness and tingling spreading to the first three fingers of the hand, and the burning and pain sensation in the wrist. This complaint is especially aggravated at night. It has been reported that complaints were reduced by waving the hand. As the motor fibers begin to be affected over time, atrophy begins to occur in the lumbrical muscles of the 2nd and 3rd fingers, and the patient's hand weakness, incompetence (dropping something from the hand, inability to do fine hand skills) begins to develop [1, 8, 35, 53].

2.5.6.2 Guyon's duct syndrome (Ulnar tunnel syndrome)

Anatomy: After the ulnar nerve passes through the anterior part of the forearm, it comes to the wrist through the Guyon canal, a fibro-osseous tunnel located between the os pisiforme and the anchor of the os hamatum (**Figure 17**) [7, 8, 54]. The roof of the Guyon canal consists of the palmar fascia and the palmaris brevis muscle. There are pisiform and hamate bones around this canal. As the ulnar nerve passes through the Guyon canal, it divides into superficial and deep branches. After the superficial part of the nerve branches into the palmaris brevis muscle, it gives the sensory branches innervating ulnar side of the palm of the hand and all surface of the 4th finger and 5th finger. Deep part of the nerve gives branches to the hypothenar muscles. Subsequently, the deep part gives all the interosseous and branches innervating the 3rd and 4th lumbrical muscles. It ends by giving the terminal branches to the adductor pollicis and flexor pollicis brevis [16, 55].

Figure 17.
 The schematic drawing of the Guyon canal and ulnar nerve course inside the Guyon canal.

Description: It is characterized by compression of the ulnar nerve in the Guyon canal [1].

Causes: Using of tools, bicycle, handlebars (cyclist's palsy), crutches, using wheelchairs and work machines, osteophyte, arthritis, synovitis, ganglion, fibrous bands, subluxation of the ulnar nerve over the medial epicondyle, the presence of the Struthers arch and anconeus internus muscle, presence of os hamuli proprium, presence of an accessory abductor digiti minimi muscle and accessory or reversed palmaris longus muscle, hypertrophic flexor carpi ulnaris muscle are factors that can cause compression [1, 7, 8, 35, 55].

Clinical features: Sensory loss occurs on the palmar-ulnar side of the little finger and ring finger. Weakness and atrophy can be seen in the intrinsic muscles of the hand innervated by the ulnar nerve. Disruption of the balance between the intrinsic and extrinsic muscles of the hand causes the physiological arcs of the hand to collapse and classic claw hand deformity occurs. Froment and Wartenberg findings are positive [1, 8, 35, 55].

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