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Etiology and mechanisms of ulnar and median forearm nerve injuries

Etiologija i mehanizmi povreda lakatnog i središnjeg nerva podlaktice

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Abstract

Bacgraund/Aim. Most often injuries of brachial plexus and its branches disable the injured from using their arms and/or hands. The aim of this study was to investigate the etiology and mechanisms of median and ulnar forearm nerves injuries. **Methods.** This retrospective cohort study included 99 patients surgically treated in the Clinic of Neurosurgery, Clinical Center of Serbia, from January 1st, 2000 to December 31st, 2010. All data are obtained from the patients' histories. **Results.** The majority of the injured patients were male, 81 (81.8%), while only 18 (18.2%) were females, both mainly with nerve injuries of the distal forearm – 75 (75.6%). Two injury mechanisms were present, transection in 85 patients and traction and contusion in 14 of the patients. The most frequent etiological factor of nerve injuries was cutting, in 61 of the patients. Nerve injuries are often associated with other injuries. In the studied patients there were 22 vascular injuries, 33 muscle and tendon injuries and 20 bone fractures. **Conclusion.** The majority of those patients with peripheral nerve injuries are represented in the working age population, which is a major socioeconomic problem. In our study 66 out of 99 patients were between 17 and 40 years old, in the most productive age. The fact that the majority of patients had nerve injuries of the distal forearm and that they are operated within the first 6 months after injury, promises them good functional prognosis.

Key words:
peripheral nerve injuries; forearm injury; diagnosis; median nerve; ulnar nerve; neurosurgical procedures.

Apstrakt

Uvod/Cilj. Povrede brahijalnog pleksusa i njegovih grana najčešće onemogućavaju povređene da koriste ruke. Cilj rada bio je da se ispitaju etiologija i mehanizmi povreda središnjeg i lakatnog nerva podlaktice. **Metode.** U ovu retrospektivnu kohortnu studiju bilo je uključeno 99 osoba operisanih na Klinici za neurohirurgiju Kliničkog centra Srbije u periodu od 1. januara 2000. do 31. decembra 2010. Svi podaci dobijeni su iz istorija bolesti povređenih. **Rezultati.** Većina povređenih bili su muškarci, 81 (81,1%), dok su samo 18 (18,2%) bile žene. Najveći broj povređenih imao je povrede nerava distalnog dela podlaktice – 75 (75.6%). Bila su zastupljena dva mehanizma povrede, transekcija kod 85 povređenih, a trakcija i kontuzija kod 14 povređenih. Najčešći etiološki faktor povrede nerava bila je posekotina, kod 61 povređenih. Povrede nerava često su bile udružene sa drugim povredama. U našem radu bile su 22 vaskularne povrede, 33 povrede mišića i tetiva i 20 fraktura kostiju. **Zaključak.** Većina pacijenata sa povredama perifernih nerava predstavljaju radno sposobnu populaciju, što predstavlja veliki socioekonomski problem. U našoj studiji 66 od 99 povređenih bili su stari od 17 do 40 godina, u svojim najproduktivnijim godinama. Činjenica da je većina povređenih imala povredu nerava distalnog dela podlaktice i da su operisani u prvih 6 meseci nakon povrede daje dobru prognozu njihove funkcionalne sposobnosti.

Ključne reči:
živci, periferni, povrede; podlaktica, povrede; dijagnoza; n. medianus; n. ulnaris; neurohirurške procedure.

Introduction

The forearm and hand represent complex functional unit of the joints, muscles, tendons, nerves, blood vessels and skin. Proper functioning and good condition of all of these elements is necessary to forearm and hand function to its fullest potential. Most often injuries of brachial plexus and its branches disable patients from using their arm and/or hand. The hand is, along with the brain, the most important organ for the implementation of the tasks of adaptation, research, observation, perception and manipulation, unique to humans [1, 2]. The loss of its function can be a daunting experience, sometimes with serious economic and

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psychological consequences, and not so rarely with consequences of losing the job.

There are numerous ways to classify nerve injuries. However, the most used is classification by Seddon and Sunderland. In 1943 Seddon published his classification, and separated injuries into three categories — neuropraxia, axonotmesis, and neurotmesis – largely based on the scale of injury from microscopic to macroscopic [3]. In 1951, Sunderland [4] expanded upon this idea, subdividing neurotmesis into three additional grades. The Seddon classification is useful to understand the anatomic basis for injury, while the Sunderland classification adds information useful for prognosis and treatment strategies.

Sunderland I degree (neuropraxia)

Macroscopically nerve is intact, but histopathologically there may be segmental demyelination with continuity of the axon. Tinel's sign is negative, because there is no Wallerian degeneration. Nerve conduction is slower but electromioneurographic (EMNG) findings are normal. Spontaneous recovery is complete, and it usually occurs in few minutes to few weeks, three months at the longest [3–6].

Sunderland II degree (axonotmesis)

The axon and myelin sheet are damaged. There is Wallerian degeneration distally and regeneration. Tinel's sign is therefore positive, and it progresses distally. Endoneurium remains intact. Neurological exam shows total motor and sensory deficit, and EMNG registers fibrillations 2–3 weeks after injury, and after that denervation. Complete recovery can be expected [3–6].

Sunderland III degree

There is an injury to the axon, myelin and endoneurium but not the perineurium. In this type of injury the axon regenerates through scar changes of endoneurium tissue, which causes loss of some axons. Recovery is variable and incomplete, and it is accompanied by a certain degree of mismatch [3–5].

Sunderland IV degree

Continuity of the nerve in this type of nerve injuries is maintained by the epineurium, while there is an injury of axon, myelin, endoneurium and perineurium. Wallerian degeneration occurs distally from the injury. Spontaneous recovery is not possible [3–5]. Surgery is usually performed 3 months after injury (period in which previous three degrees of injury would recover).

Sunderland V degree (neurotmesis)

There is a complete transection of the nerve. Usual cause of injury is laceration, spontaneous recovery is not possible [3–6].

In the year 1988 Mackinon and Dellon added VI degree of injury to this classification. It is the combination of previous types of injuries, and it is characterized by neuroma in continuity. In accordance with this, the degree of recovery is different, and it can be complete (I and II degree), partial (III degree) or absent (IV and V degree) [5, 7].

Peripheral nerve injuries result in significant changes of proximal and distal nerve segments. Those changes are usually classified as morphological, biochemical and functional [7]. There are different mechanisms of peripheral nerve injuries [7]: Laceration (transection); Stretching (traction) and contusion; Ischemia and compression; Electric, thermal and radiation injury; Injection injury.

Approximately 30% of peripheral nerve injuries are lacerations. Traction and contusion injuries are also quite frequent and they usually occur combined with fractures and joint dislocations [7].

This paper focuses on ulnar and median nerve injuries. Traumatic isolated ulnar nerve injuries result in functional loss of ring and little finger flexion, thumb adduction and also interosseal muscles palsy. During examination Froment's sign can be seen.

Isolated median nerve injuries result in the loss of pronation of forearm, flexion of the wrist, index finger, middle finger and distal phalanx of the thumb; and also abduction and opposition of the thumb. Hypoesthesia of the first three fingers can be seen. During examination, thenar muscles atrophy can be seen.

The level of forearm nerve injuries can roughly be divided into high or low, referring to the distance of the lesion to the sensory and motor end organs. Surgical repair of high lesions generally have poorer outcome than low lesions [8, 9]. In high lesions, axons have to bridge a larger distance to the end organ than in lower lesion. Factors that influence outcome of nerve injury repair and healing are described in many studies [10–17]. They are often divided into intrinsic and extrinsic factors. Intrinsic factors can not be influenced by medical treatment, and they include age of patient [13], level and severity of injury [14, 16], nerve tissue loss [13], associated injuries [14, 15] and nerve type [14]. Opposite to them, extrinsic factors are dependent on the quality of treatment: type of repair [10], surgical technique [12], use of microsurgical equipment [17], timing of the surgery [14] and postoperative protocol [11].

The aim of this study was to present etiology and mechanisms of injuries of median and ulnar nerve of the forearm in 99 patients treated in the Clinic of Neurosurgery, Clinical Center of Serbia, from January 1st, 2000 to December 31st, 2010.

Methods

This retrospective cohort study included a total of 99 subjects, who were diagnosed and treated of ulnar and median nerve injuries of the forearm in the Clinic of Neurosurgery, Clinical Center of Serbia from January 1st, 2000 to December 31st, 2010. This study excluded patients with injuries that occurred as result of nerve entrapments, such as cubital and carpal tunnel syndrome, Guyon's canal syndrome or pronator teres syndrome. All the data were obtained from the patients histories. The patients were divided into three groups, dependent on the injured nerve: ulnar nerve group (U group), median nerve group (M group) and median-ulnar nerve group (MU group).

Statistical analysis was performed using statistical package PASW 18. For a description of the parameters of interest we used the methods of descriptive statistics: measures of central tendency (mean value), range, percentages and tabulation.

The study was approved by the relevant Ethics Committee, and it presents a part of the doctoral thesis project.

Results

Demographic characteristics of the patients, the side of injured arm, level, mechanism and etiology of injuries, associated injuries and post-injury period to surgery are shown in Table 1. The majority of injured patients from our series were male – 81 (81.8%), while only 18 (18.2%) were females. Male patients were the majority in all the three groups made according to the injured nerve. Age of patients was comparable in all the three groups, including both the mean age and the range of patients' age, although the widest range was in the U group, because of one 8-year-old patient. In our study, there were 25 ulnar nerve injuries of the left forearm and 21 ulnar nerve injuries of the right forearm. The median nerve was injured almost twice as often in the right than in the left forearm, 19 to 11, respectively. Injuries of both median and ulnar nerves occurred in the left forearm in 15 patients and in the right forearm in 8 patients. In total, occurrence of injuries was comparable between the left and the right forearm, with a slightly higher number of injuries in the left forearm. The majority of the patients had nerve injuries of the distal forearm – 75 (75.6%), of who in 71 cases the mechanism of injury was transection, while in just 4 cases mechanism was traction and contusion. In 24 (24.2%) patients with proximal forearm nerve injuries, mechanism of injury in 14 of them was transection, while in other 10 patients mechanism of injury was traction and contusion (Tables 1 and 2).

Table 1

Demographic data, the side of the injured arm, level, mechanism, associated injuries, and the period between injury and surgery of the studied patients

Parameters	Groups of patients			
	M	U	MU	Total
Number of patients, n (%)	30 (30.3)	46 (46.5)	23 (23.2)	99
Gender, n				
male	29	34	18	81
female	1	12	5	18
Age (years), mean (range)	33 (10–55)	33 (8–56)	36 (17–53)	33 (8–56)
Forearm affected, n				
left	11	25	15	51
right	19	21	8	48
Level of injury, n				
proximal forearm	7	12	5	24
distal forearm	23	34	18	75
Mechanism of injury, n				
transection	28	35	22	85
traction and contusion	2	11	1	14
Etiology of injury, n				
cutting by knife, axe, glass or ceramic	19	25	17	61
injury by circular saw, motor saw or grinder	3	5	2	10
fall	1	9	0	10
gunshot injury	2	2	2	6
car accident	2	4	1	7
unknown	3	1	1	5
Associated injuries, n				
yes	12	18	14	44
no	18	28	9	55
Time between injury and surgery, n				
3 weeks–3 months	12	19	6	37
3 months–6 months	9	18	11	38
6 months–12 months	9	8	5	22
more than 12 months	0	1	1	2

M – median nerve; U – ulnar nerve; MU – median-ulnar nerve.

Table 2

Mechanisms and the etiology of nerve injuries by the level of injery and by the gender

Variable	Level of injury		Gender		Total
	proximal	distal	male	female	
Mechanism of injury, n					
transection	14	71	72	13	85
traction and contusion	10	4	9	5	14
Etiology of injury, n					
cutting by knife, axe, glass or ceramic	10	51	49	12	61
injury by circular saw, motor saw or grinder	0	10	10	0	10
fall	5	5	7	3	10
gunshot injury	5	1	5	1	6
car accident	4	3	7	0	7
unknown	0	5	3	2	5

The most frequent cause of nerve injuries is cutting (by knife, axe, glass or ceramic), and it is four times more frequent in male than in female subjects. This type of injury is dominant in all three groups made according to the injured nerve. Also, it is five times more frequent in the distal than in the proximal region of the forearm. In our study sample there were 10 patients injured by circular saw, motor saw or grinder, and all of them were male with injuries of distal forearm. Gunshot injury was the etiological factor in 6 patients (Tables 1 and 2).

The most frequent type of injury in our study was transection. Out of 85 patients injured in this way, 34 had associated injuries. Although the number of patients in whom mechanism of injury was traction and contusion was significantly lower, out of 14 patients injured in this way, 9 had associated injuries. It should be noted that in our study every patient with gunshot injury had associated injuries (Table 3).

The most common associated vascular injury in the MU group of patients was injury of ulnar artery – in 7 of the cases, while the total number of associated vascular injuries in this group was 16. However, the highest number of bone fractures and muscle and tendon injuries was in the U group. The most common was fracture of the ulna and injury of *flexor digitorum superficialis* muscle and *flexor carpi ulnaris* muscle. The most frequently injured muscle in all the three groups was *flexor digitorum superficialis* muscle (Table 4).

Table 3

Mechanism and cause of nerve injuries according to associated injuries

Variable	Associated injuries (yes/no), n			
	group M	group U	group MU	Total
Mechanism of injury				
transection (n = 85)	10 / 18	11 / 24	13 / 9	34 / 51
traction and contusion (n = 14)	1 / 1	7 / 4	1 / 0	9 / 5
Etiology of injury				
cutting by knife, axe, glass or ceramic (n = 61)	7 / 12	6 / 19	9 / 8	22 / 39
injury by circular saw, motor saw or grinder (n = 10)	1 / 2	3 / 2	1 / 1	5 / 5
fall (n = 10)	0 / 1	4 / 5	0 / 0	4 / 6
gunshot injury (n = 6)	2 / 0	2 / 0	2 / 0	6 / 0
car accident (n = 7)	1 / 1	3 / 1	1 / 0	5 / 2
Unknown (n = 5)	0 / 3	0 / 1	1 / 0	1 / 4
Total	11 / 19	18 / 28	14 / 9	43 / 56

M – median nerve; U – ulnar nerve; MU – median-ulnar nerve.

Table 4

Distribution of associated injuries *per* nerve injuries

Types of associated injuries	Associated injuries, n			
	group M (n = 36)	group U (n = 46)	group MU (n = 23)	Total
Vascular injury				
brachial artery	2		2	4
ulnar artery	1	2	7	10
radial artery			2	2
ulnar vein			2	2
radial vein			1	1
cubital artery	1			1
interosseal artery			1	1
interosseal vein			1	1
Total vascular injuries	4	2	16	22
Bone fractures				
radius	1	4	2	7
ulna	1	5	1	7
humerus		2	1	3
costae*		1 (I–VII)	1 (I–V)	2
clavicula			1	1
Total bone fractures	2	12	6	20
Muscles and tendons				
abductor pollicis longus muscle	1			1
abductor pollicis brevis muscle	1			1
opponens pollicis muscle	1			1
flexor digitorum superficialis muscle	4	4	5	13
flexor digitorum profundus muscle	1	1	2	4
flexor carpi ulnaris muscle		4	4	8
flexor carpi radialis muscle	1			1
flexor pollicis longus muscle	1			1
palmaris longus muscle		1		1
abductor digiti minimi muscle		1		1
flexor digiti minimi brevis muscle		1		1

M – median nerve; U – ulnar nerve; MU – median-ulnar nerve.

***numbers in front the brackets indicate the number of patients with fractures of the ribs, while the number in brackets indicates broken ribs. The sum of serial rib fracture in one person is counted as one associated injury.**

Figure 1 represents the distribution of frequency of the injured patients according to their age. It should be noticed that except for the two children of 8 and 10 years of age, all the injured patients from our study represent the population of working age and that the majority of those patients were 40 years old or younger.

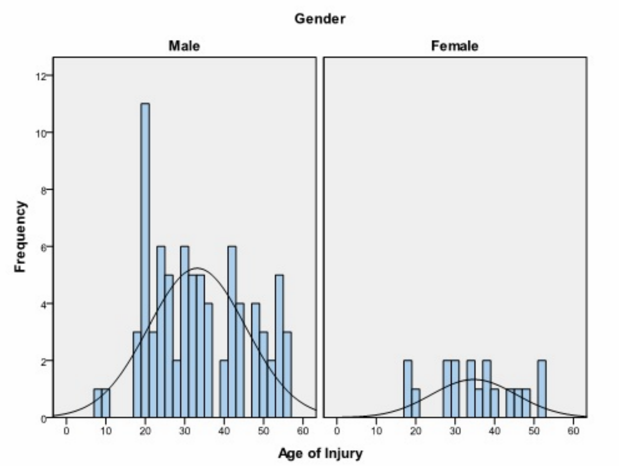

Fig. 1 – Age distribution at the time of getting injured.

Timing of surgery in our population is shown in Table 5. The majority of patients with transection injuries were surgically treated during the first 6 months of the injury, whereas the majority of the patients with traction and contusion injuries were treated between 6 months and one year after the injury.

bone fractures. From 22 vascular injuries, 16 was in MU group, the most common vascular injury was ulnar artery injury – 10 cases, of which 7 are in the MU group. The highest number of associated injuries were injuries of muscles and tendons, 33 of them. The most common were injuries of *flexor digitorum superficialis* muscle – in 13 cases, and they were dominant in all the three groups of patients.

The majority of patients from this study were male, 81 (81.8%). All mechanisms and causes of injuries in our study were predominant in males. If we take in observation that male population more often use knifes, axes, sharp metals, saws, chainsaws and weapons it can give us a possible explanation for a high male sex predomination. There is no significant difference between our results and the results from Galanakos et al. [18] and Ahmed et al. [19], who reported 72% and 89.19% injured males in their studies, respectively. The range of age in our study was from 8 to 56 years, and also except for the two patients who were 8 and 10 years old, all the others were in the working-age population. Our results are also comparable with the results of Ahmed et al. [19] who had reported the range of patients from 25 to 50, and Galanakos et al. [18] who had the range from 15 to 62. In our study we did not have data about professions of injured patients, and their return to work. However, as it can be seen from studies of other authors [20, 21], injuries of forearm nerves can lead to a delayed return to work, reduced productivity, lower functional abilities, loss of job and they can have unwanted social consequences. All of this provides the economic and social importance to this problem, since, most of the injured

Table 5

Distribution of patients according to mechanisms and the etiology of injury and timing of surgery

Parameter	Surgically treated patients (number) timing of surgery			
	3 weeks to 3 months	3–6 months	6–12 months	more than 12 months
Mechanism of injury				
transection	34	34	16	1
traction and contusion	3	4	6	1
Etiology of injury				
cutting by knife, axe, glass or ceramic	30	19	11	1
injury by circular saw, motor saw or grinder	1	7	2	0
fall	2	5	2	1
gunshot injury	2	2	2	0
car accident	1	2	4	0
unknown	1	3	1	0

Discussion

The emphasis of this study was on etiology and mechanisms of forearm median and ulnar nerve injuries. These injuries are the most common peripheral nerve injuries. As it was also shown in some previous studies [18] they are often associated with injuries of surrounding structures, which this already difficult problem makes even harder. Associated vascular injuries compromise wound healing, and also, these injuries have direct effect on peripheral nerve regeneration.

Associated injuries of forearm nerves in our sample are: 22 vascular injuries, 33 muscle and tendon injuries and 20 are working-age people. If we take into observation that 66 out of 99 of our population were the patients in most productive age, between 17 and 40 years, it gives even bigger socioeconomic impact on this problem. These results are consistent with the results of peripheral nerve injuries of other authors cited by Kouyoumdjian [22].

Out of 99 patients in our study, 75 of them had nerve injuries of the distal part of the forearm. Nerve injuries of distal forearm, have better prediction for motor and sensory recovery than injuries of proximal parts of forearm [8, 9, 14, 16]. The reason for better functional recovery in distal nerve injuries is that axons have to bridge a shorter distance to the end organ in comparing to high or proximal nerve injuries. Besides that, proximal nerve injuries of forearm affect bigger number of muscles which causes lower functional abilities of the hand of injured patient. In our study two causes of nerve injuries that led mostly to injuries of the proximal forearm region are gunshot injuries and car accidences. In the majority of cases, these etiological factors are associated with other injuries. All 6 patients with gunshot injury had associated injuries, while out of 7 patients injured in a car accident, 5 had associated injuries. The reason that most of injured patients in our sample had injuries of the distal forearm and that 56 out of 99 patients did not have associated injuries gives good functional prognosis to the majority of them.

The majority of patients with transection injuries were surgically treated within the first 6 months of the injury, whereas the majority of the patients with traction and contusion injuries were treated within 6 months and one year after the injury, as shown in Table 5. Opinions about timing of the surgery are divided among experts in peripheral nerve surgery. Some experts believe that patients with clear nerve transection injuries should be operated urgent [23]. Others, however, believe that it is better to wait 3 weeks, when the process of Wallerian degeneration is over. The majority of surgeons agree that nerve reparation procedure should be executed within the first 6 months after injury, at the latest within a year. After that period of time, results of surgical treatment are poorer. However, in the last years, more and more experts of peripheral nerve surgery advise additional examination for late referrals. The claim is that if there are fibrillations present in the muscle, surgical treatment is indicated even one or more years after injury, and the results are satisfactory [24].

The etiology and mechanism of injury are of the most significant factors in making decision on treatment modality. Timing of the surgery is determined by it, as previously explained. Also, the choice of treatment depends on these factors. In transection injuries, and especially in the cases where injury of the nerve is evident from the moment of injury, surgery will be performed earlier. With this in mind, nerve tissue will not be contracted, so direct suture of the nerve usually can be accomplished. And with this, the chances for full recovery are high. However, in traction and contusion injuries, although continuity of the nerve is macroscopically intact, larger portion of the nerve is affected. Surgery is usually performed between three and six months after injury, and in this period nerve stumps are retracted. During surgery, a particular portion of the nerve is found “empty”, so together with retraction of the nerve stumps, and resection of the damaged nerve, a large defect is present. There is no possibility for direct suture, so nerve grafting or neurotization must be performed. Results of these types of treatment are usually poorer [3].

Conclusion

The etiology and mechanism of injury are of the most significant factors in choosing treatment. Traumatic injury of peripheral nerves is a worldwide problem and can result in a significant disability. Median and ulnar nerves are the two most commonly injured nerves in upper extremity, which occur most in the working age population. In our sample there were two mechanisms of injuries of forearm nerves, transection, and traction and contusion. The dominant cause of injury was a transection with a knife, axe, glass or ceramic. The most common associated injury was injury of the ulnar artery, injury of the *flexor digitorum superficialis* muscle and fracture of the ulna.

The fact that the majority of patients had nerve injuries of the distal forearm and that they are operated within the first months after the injury, gives them good functional prognosis.

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