Observational Study

Medicine

OPEN

Epidemiology of upper extremity peripheral nerve injury in South Korea, 2008 to 2018

Sung Jae Kim, MD, PhD[a], Young Min Kwon, MSc[a], Sang Min Ahn, MD[b], Jang Hoon Lee, MBBS[b], Chang-Hun Lee, MD, PhD[b,*]

Abstract

Peripheral nerve injuries (PNIs) in the upper extremities is an important medical problem, causing significant morbidity at a relatively young age. The epidemiology of PNI in South Korea has not been comprehensively evaluated. The purpose of our study was to examine the incidence of upper extremity PNI in South Korea based on an analysis of nationwide data and to investigate the association between PNI and patients' demographic characteristics. Patient claims data from the Health Insurance Review and Assessment Service from 2008 to 2018 were collected. Demographic characteristics, such as the age, sex, region, admission route, length of hospital stay, healthcare facility level, and cost were evaluated. Annual incidence, body sites affected, damaged nerves, accompanying injuries, and surgical procedures were analyzed. Annual incidence trends, injured anatomical area, seasonal injury trends, and injury trend according to sex were also evaluated. A total of 57,209 cases were identified during the study period. Mean age was 39.7 ± 16.3 years. Of these cases, 51,651 (90.28%) were surgically treated. About 79% of accompanying injuries occurred in the hand area (hand lacerations, 69.5%; fractures or joint dislocations of the hands, 6.86%; crushing injuries of the hands, 2.67%). Overall, injuries to the digital nerve showed the greatest frequency (62.7%). In the upper arm and forearm, the ulnar nerve was most frequently injured; however, in the hand, radial nerve injuries were most common. The annual incidence rate per 100,000 persons decreased from 10.67 in 2008 to 7.88 in 2018. The annual incidence decreased by 0.98 times per year. PNI occurred 33.91 times more frequently in the finger than in the upper arm, and there were 1.16 times more PNIs in the summer and 2.14 times more in men. We investigated the incidence trend and epidemiologic characteristics of upper extremity peripheral nerve injury in South Korea from 2008 to 2018. A decreasing tendency of annual incidence was observed from 2013 onwards. Finger and digital nerve were most commonly injured, and the incidence of PNI was higher in the summer and in men.

Abbreviations: CI = confidence interval, HIRA = health insurance review and assessment service, NHIS = national health insurance service, PNI = peripheral nerve injury.

Keywords: epidemiology, peripheral nerve injury

1. Introduction

Peripheral nerve injury (PNI) in the upper extremities is a serious health problem, causing significant morbidity to patients at a relatively young age.[1,2] Given the high rate of neuropathic pain, functional deficits, and overall reduced quality of life following traumatic neuropathy, a detailed assessment of extremity PNI is essential to provide health practitioners and officials with accurate information for patient care and resource allocation.[3,4]

Epidemiologic trends of upper extremity PNI, including characteristics such as incidence, age, sex, and associated diagnoses have been reported in trauma patients in other countries. The mean incidence of upper extremity PNI in the United States in 2014 was 16.9 per 100,000 persons[5]; in Sweden, the incidence was 13. 9 per 100,000 person-years between 1998 and 2006.[6] PNI represented 3.3% of cases of severe trauma with upper extremity involvement in a German trauma multicenter database between 2002 and 2015.[7] Some retrospective studies also attempted to describe the epidemiology of PNI. McAllister et al[8] reported the frequency distributions of the levels and causes of PNI of 813 patients in the United Kingdom between 1982 and 1991. Ciaramitaro et al[9] reported the epidemiologic findings and quality of life of 158 PNI patients in Italy. Kouyoumdjian et al[10] reported the injury pattern and cause of 1124 PNI patients in Brazil between 1989 and 2014. However, there is no recent

SJK and YMK contributed equally to this work.

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (no. 2020R1A2C2101353) and the research fund of Hanyang University (HY-202000000000506).

The authors have no conflicts of interest to disclose.

The data that support the findings of this study are available from a third party, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from the authors upon reasonable request and with permission of the third party.

Supplemental Digital Content is available for this article.

[a] Department of Orthopaedic Surgery, Dongtan Sacred Hospital, Hallym University College of Medicine, Hwaseong, Korea, [b] Department of Orthopaedic Surgery, Hanyang University College of Medicine, Seoul, Korea.

** Correspondence: Chang-Hun Lee, Department of Orthopaedic Surgery, Hanyang University College of Medicine, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Korea (e-mail: drlch79@hanyang.ac.kr).*

How to cite this article: Kim SJ, Kwon YM, Ahn SM, Lee JH, Lee C-H. Epidemiology of upper extremity peripheral nerve injury in South Korea, 2008 to 2018. Medicine 2022;101:48(XXX).

Received: 14 March 2022 / Received in final form: 12 October 2022 / Accepted: 13 October 2022

http://dx.doi.org/10.1097/MD.0000000000031655

study that evaluated the epidemiology of PNI based on an entire population database over a long period of time.

The incidence of trauma, epidemiological features, and injury mechanisms and patterns may vary among countries due to different socioeconomic factors and laws.[7] Therefore, data from overseas need to be interpreted in a societal context. The incidence of PNI in South Korea has not been comprehensively evaluated, requiring independent observational research to investigate the trend of PNI. The purpose of our study was to examine the incidence of PNI in South Korea based on an analysis of nationwide data between 2008 and 2018and to investigate the association between PNI and patients' demographic characteristics.

2. Methods

2.1. Data source

Patient claims data of the Health Insurance Review and Assessment Service (HIRA) was collected. The HIRA database contains data from the National Health Insurance Service (NHIS), which covers the entire South Korean population. It was not necessary to achieve informed consent because the database was anonymized. The study was approved by the Institutional Review Board (IRB) of our institute (IRB. no 2020-10-022).

2.2. Subject definition

Patient claims data was searched using the main disease code according to the International Classification of Diseases-10 version. The patient's diagnostic codes and the relevant surgical procedure codes we used are listed in Tables S1 and S2 (Supplemental Digital Content, http://links.lww.com/MD/H876, which summarizes the diagnostic codes and surgical procedure codes).

The demographic characteristics of all patients, such as age, sex, region, admission route, length of hospital stay, healthcare facility level, and cost were investigated. Region was defined using a dichotomous scale of rural versus urban. Admission route was also defined using a dichotomous scale of emergency visit versus outpatient visit. Healthcare facility level was classified as: a "clinic," an institution with less than 30 beds; a "hospital," between 30 and 99 beds; a "general hospital," more than 100 beds; and a "tertiary hospital," more than 500 beds and 20 specialized departments.

2.3. Data processing

Incidence per 100,000 person-years was calculated based upon the epidemiologic data from the "Statistics Korea" website (http://www.kosis.kr). Injured anatomical areas were divided into upper arm, forearm, hands, and fingers. The damaged nerves were classified into the axillary nerves, musculoskeletal nerves, ulnar nerves, medial nerves, radial nerves, and the digital nerves according to the diagnostic code. Accompanying injuries were investigated using the additional diagnostic code assigned in admission claims data (Table S3, Supplemental Digital Content, http://links.lww.com/MD/H877, which shows the accompanying injuries). Surgical procedures performed in each case were also investigated with procedure code assigned in admission claims data. The seasonal incidence trend was also addressed. The seasons were defined as spring (March–May), summer (June–August), autumn (September–November), and winter (December–February).

2.4. Statistical analysis

Descriptive statistics were used to analyze the demographic data of all included patients. Trends in healthcare facility level, of injured anatomical area, and of damaged nerve were analyzed. The surgical trends according to damaged nerve and to injured anatomical area were analyzed. Incidence according to age was also analyzed. Age was scaled into 10-year intervals for analysis.

Statistical analysis was carried out using quasi-Poisson model instead of Poisson model because of overdispersion. A test for overdispersion was conducted with qcc package from R packages. We investigated the incidence rate ratios and 95% confidence intervals (95% CI) using the multivariate quasi-Poisson regression model for injured parts (upper arm/forearm/hand and wrist/finger). Subjects with injured upper arm were consider as reference group. 95% CI and *P*-values were presented to provide measurement of the likelihood that the differences were found due to just chance. The model was adjusted for injured anatomical area, seasonal injury trends, injury trend according to the sex and for annual incidence trends (as continuous variable).

Data analysis was conducted by using SAS Enterprise Guide V.7.1 (SAS Institute) and Statistical analysis, especially quasi-Poisson regression, was performed using R packages version *R*-4.0.0.

3. Results

Demographic data of all patients are summarized in Table 1. A total of 57,209 cases were identified during the study period. Among the total cases, 51,651 cases (90.28%) were surgically treated. Mean age was 39.7 ± 16.3 years. Patients aged between 40 to 49 years showed the highest incidence (12,697 cases, 22.26%, Fig. 1). Figure 2 illustrates the annual incidence trends excluding the cases with work-related PNI. The incidence rate per 100,000 persons decreased from 10.67 in 2008 to 7.88 in 2018. The annual incidence decreased 0.98-fold (95% CI, 0.97–0.99; $P = .036$) per year.

Table 1

Demographic characteristics of the patients with peripheral nerve injury between 2008 and 2018.

Number of peripheral nerve injuries	57,209
Age (yr)	39.7 ± 16.3 (1–97)
Sex (male: female)	39,578: 17,631 (69.2%: 30.8%)
Admission route*	14,572: 41,287 (26.1%: 73.9%)
Hospital stay (d)	13.4 ± 8.15 (0–297)
Place of occurrence (urban/rural)	55,991/1218 (97.9%/2.1%)

Results are given with mean, standard deviation, range.
*Admission route (emergency visit: outpatient visit).

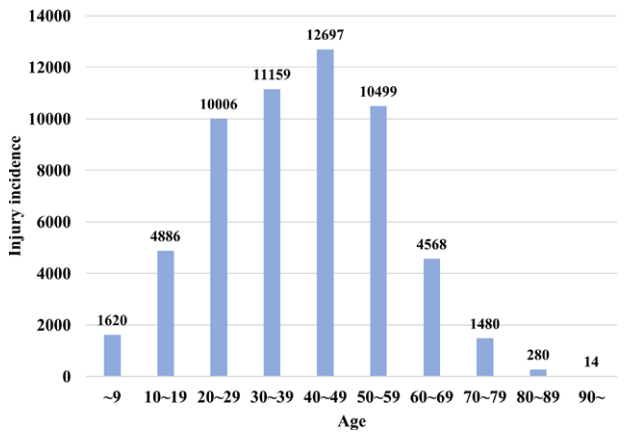

Figure 1. Injury incidence according to age.

Analysis of the anatomical area of injury showed that more than half of injuries occurred in the fingers (53.6%). And the hand and wrist (26.6%), forearm (16.7%), and upper arm (3.1%) appeared in order. Overall, digital nerve injuries were the most common (62.7%, Table 2). In the upper arm, the ulnar nerve was most frequently involved (46.7%), followed by the radial nerve (30.4%). The forearm area exhibited a similar trend to the upper arm area (ulnar nerve, 37.9%; radial nerve, 35.7%). In the hand and wrist except finger, injuries to the radial nerve showed the greatest frequency (37.9%). Among the identified accompanying injuries (Table 3), 79% of all accompanying injuries occurred in the hand area (hand lacerations, 69.5%; fractures or joint dislocations of the hands, 6.86%; crushing injuries of the hands, 2.67%). Lacerations of the forearm also occurred at a high frequency (14.81%). About two-thirds of patients (60.1%) were treated in a "hospital"-level healthcare facility (Fig. 3). Trends in overall surgical procedures are listed in Table 4. Nerve graft procedures were only performed in 0.6% (362 cases) during the study period. Surgical trends according to the specific damaged nerve and the injured anatomical area are depicted in Figure S1 (Supplemental Digital Content, http://links.lww.com/MD/H878, which illustrates the surgical trends). The average cost for the treatment of a PNI was about $1150, and there were only minor variations in the management cost according to the healthcare facility level or region (Fig. 4).

The results of quasi-Poisson regression analyses are summarized in Table 5. The incidence rate was 33.91 times higher in the fingers than the upper arm (95% CI = 31.47–36.57, $P < .001$), and 4.33 times higher in the forearm than the upper arm (95% CI = 4.02–4.66, $P < .001$). In terms of seasonal incidence trends, the incidence rate was highest in summer and lowest in winter. In terms of sex differences in injury incidence, a 2.14-fold higher incidence was observed among men compared to women (95% CI = 2.13–2.15, $P < .001$).

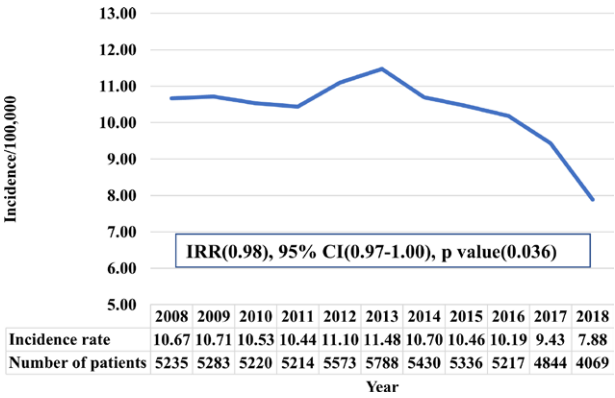

Figure 2. Annual incidence trend of peripheral nerve injury.

Table 2

Nerve injury trends according to the anatomical area.

	Number	Percent
Total		
Digital nerve	30,678	62.7
Radial nerve	6639	13.6
Ulnar nerve	6463	13.2
Median nerve	4971	10.2
Axillary nerve	116	0.2
Musculocutaneous nerve	55	0.1
Upper arm		
Ulnar nerve	633	46.7
Radial nerve	412	30.4
Median nerve	139	10.3
Axillary nerve	116	8.6
Musculocutaneous nerve	55	4.1
Forearm		
Ulnar nerve	2907	37.9
Radial nerve	2739	35.7
Median nerve	2028	26.4
Hand and Wrist except finger		
Radial nerve	3488	37.9
Ulnar nerve	2923	31.7
Median nerve	2804	30.4

Patients with unclear injury area were excluded.

4. Discussion

The overall annual incidence of upper extremity PNI in South Korea decreased from 10.67 to 7.88 per 100,000 persons

Table 3

List of accompanying injuries.

Accompanying injury	Frequency	Percent
Injury of cranial nerves	4	0.01
Laceration of neck	85	0.14
Fracture or dislocation of neck	395	0.66
Laceration of shoulder	1202	2.02
Fracture or dislocation of shoulder	919	1.54
Crushing injury or amputation of shoulder	8	0.01
Laceration of forearm	8827	14.81
Fracture or dislocation of forearm	667	1.12
Crushing injury or amputation of forearm	103	0.17
Laceration of hands	41412	69.50
Fracture or dislocation of hands	4087	6.86
Crushing injury or amputation of hands	1590	2.67
Injuries involving multiple body regions	171	0.29
Burns	44	0.07
Frostbite	1	0.00
Sequelae of injuries of upper limb	73	0.12

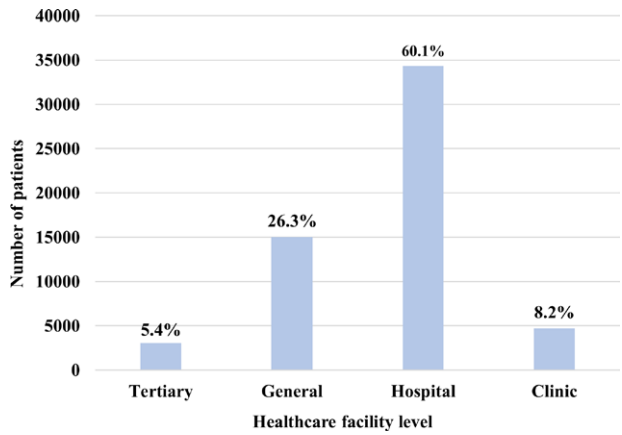

Figure 3. Healthcare facility level and management of peripheral nerve injury.

Table 4

Frequency of surgical procedures.

Procedure name	Frequency
Neuroplasty	3878 (6.8%)
Neurorrhaphy	47,411 (82.9%)
Nerve graft (<4 cm)	240 (0.4%)
Nerve graft (>4 cm)	122 (0.2%)
Non-surgery	5558 (9.7%)

between 2008 and 2018. Our results reflect well-known characteristics of the patient population with upper extremity PNI: that the condition is more common in young men and is usually associated with trauma. The incidence of PNI in urban areas was higher than that in rural areas. Interestingly, many patients with PNI visited outpatient clinics rather than emergency rooms for treatment. A gradual decline in the number of upper extremity injury cases and related surgical procedures was observed.

PNI was observed more commonly in the finger and hand rather than in the forearm and upper arm. The digital nerve was the most involved nerve. The data from the HIRA database indicate that the most common PNI was to the digital nerve followed by the radial, ulnar, and median nerves. In the upper arm and forearm, injuries to the ulnar nerve showed the greatest injury frequency; however, in the hand and wrist, the radial nerve was most frequently affected. The frequency of injured nerve was not consistent with previous studies. Asplund et al from Sweden and McAllister et al[6,8] from the United Kingdom reported that proper and common distal nerve injury was the most common type of PNI, followed by median, ulnar, radial, and musculocutaneous nerve injury. Ciaramitaro et al[9] from Italy, Noble et al[11] from Canada, and Selecki et al[12] from Australia documented the most common nerves associated with upper-limb trauma to be radial, ulnar, and median nerves in order of frequency. Lad et al[13] from the United States reported that ulnar nerve injury was most common.

Men were 2.14-fold more likely to sustain an upper extremity PNI, and the predominance was observed throughout all injury parts. Previous studies have also supported this male predominance in upper extremity injuries.[5–14] The average age of injury in our study was 39.7 years, which is in line with previous research that found the peak age of incidence to be around the fourth decade of life.[5,7,9,10,14] A study by Giustini et al,[15] however, reported 2 peaks, the first occurring around age 12 years and the second around age 38 years. The incidence of PNI was higher in the summer. Hot and humid conditions dominate during summer in South Korea, with an average temperature of 23 to 36°C and an average humidity of 80 percent. Hot and humid environments cause lack of concentration and decreased safety consciousness, which may account for the increase in the incidence of PNI.

The average treatment cost of an upper extremity nerve injury was approximately $1200, which is significantly lower than the cost in other countries. The NHIS nearly covers the entire population of South Korea and manages the cost of treatment materials and surgery. Although it is a potential cause of conflicts between the government and the clinicians, it has the effect of reducing the average cost for medical treatment. In the United States, the average cost of an upper extremity nerve injury was $47,004.[14] In Germany, hospital reimbursement of around €3000 were reported to treat PNI in the upper extremity.[16] Tapp et al[5] advocated that the high cost of treatment intensifies the significant monetary burden already placed on patients with nerve injuries due to physical dysfunction. Although medical costs incurred immediately after the injury were found to be lower in South Korea than in other countries, we were not able to evaluate the long-term costs. Bergmeister et al[16] outlined the significant burden of indirect costs, such as the value of lost productivity related to work absences and decreased capacity to work.

Another insight provided in this research is the stability of operative interventions. In total, 82.8% of PNIs was managed with neurorrhaphy. Neurorrhaphy is the gold standard treatment for acute PNI,[17] and this finding indicated good access to the healthcare system in times of urgency or emergency. The average length of stay in the hospital and low mortality rate also suggest that patient management was uncomplicated. However, despite the development of new surgical procedures and techniques during the study period, especially nerve allograft, no increase in the utilization of such procedures was identified. The NHIS has the advantage of providing a certain level of affordable treatment to many patients with good accessibility, but it is an obstacle to the introduction of new technologies. In South Korea, the introduction of new surgical products for nerve repair, including off-the-shelf conduits and acellular nerve allografts, has been delayed; the frequency of nerve grafting for PNI was low (0.6%) during the study period. The use of nerve grafts is expected to increase in the future.

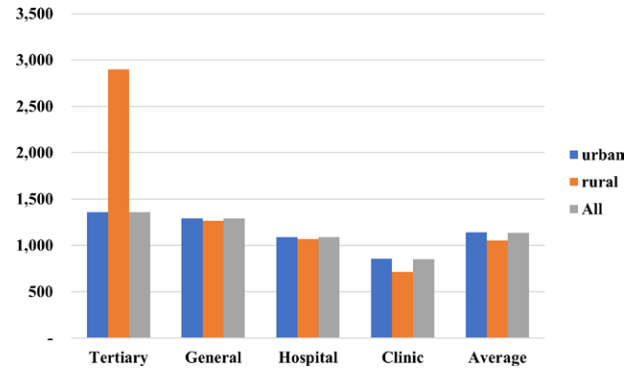

Figure 4. Management cost of peripheral nerve injury. The won-dollar exchange rate is assumed to be 1130 won per dollar.

Table 5

IRR and 95% CI for quasi-Poisson regression.

	N	IRR	95% CI	*P* value
By injured location				
Upper arm	1783	1.00	–	
Forearm	9528	4.33	4.02–4.66	<.001
Hand and Wrist	15,197	6.78	6.31–7.29	<.001
Finger	30,678	33.91	31.47–36.54	<.001
By season				
Autumn	14,527	1.00	–	
Spring	13,722	0.95	0.92–0.98	<.001
Summer	17,005	1.16	1.13–1.20	<.001
Winter	11,932	0.83	0.80–0.86	<.001
By gender				
Female	17,623	1.00	–	
Male	39,563	2.14	2.12–2.16	<.001

Patients whose specific injury area could not be identified were excluded in the analysis.

CI = confidence interval, IRR = incidence rate ratio, N = *number of patients with peripheral nerve injury,* the number of patients.

Overall, despite increases in diagnostic codes and the Korean population, there was a minor, but statistically significant decrease in the incidence of upper extremity PNI from 2013 to 2018. In particular, the decline is more pronounced from 2016 to 2018. There are several possible explanations for this finding. One possibility is a decrease in overall traumatic injuries due to government management. The National Injury Fact Book in Korea documented a gradual decrease in standardized incidence rate of traumatic injuries from 2015. The incidence of the traumatic injuries from violence, work-related injury, and traffic accident has gradually decreased. Another possibility is the increase of individual awareness to a potential safety accident. In 2013, South Korea's GDP per capita exceeded $30,000 for the first time. The increase in individual income has heightened public awareness of personal life and welfare, including safety. The occurrence of PNI may decrease as individual lifestyles and working conditions that avoid excessive work become more widespread throughout society. We hope to continue to observe a decline in the number of patients diagnosed with upper extremity PNIs.

There are a few limitations to this research. First, we could not analyze the cause of PNI. Information other than demographic data, diagnosis code, procedure code, and cost are not included in the NHIS database. The investigation on the cause of injury might reveal more meaningful epidemiological findings for PNI and provide more insight on measures to lower the incidence of PNI. *Second, there is a possibility of misclassification bias. This is because the healthcare provider has determined the disease code, and HIRA only cares about the adequacy analysis of treatment and cost. However, detection bias is not considered because healthcare providers must provide medical history and image studies to HIRA to receive treatment costs for nerve damage from NHIS.* Third, we did not find a significant factor that can account for the consecutive decrease in the annual incidence from 2013 to 2018. The discovery of a cause-effect relationship could help PNI prevention efforts worldwide. Also, an entire population-based epidemiological study of PNI might support the results of previous studies with smaller sample sizes and show the differences between countries.

We investigated the incidence trend and epidemiologic characteristics of upper extremity PNI for the entire South Korean population from 2008 to 2018. A decreasing tendency of annual incidence was observed from 2013 onwards. The fingers and digital nerve were the most common area and nerve injured, and the incidence of PNI was higher in the summer and in men. *It is expected that the incidence of PNI can be efficiently reduced if preventive activities are carried out considering the epidemiological properties of PNI.* A follow-up study is needed to observe epidemiologic trends in the incidence of PNI and to evaluate the cause of these trends.

Author contributions

Conceptualization: Chang-Hun Lee.
Data curation: Sung Jae Kim.
Formal analysis: Young Min Kwon.
Funding acquisition: Chang-Hun Lee, Sung Jae Kim.
Investigation: Sung Jae Kim, Young Min Kwon.
Writing – original draft: Sung Jae Kim, Young Min Kwon, Chang-Hun Lee.
Writing – review & editing: Sang Min Ahn, Jang Hoon Lee.

References

[1] Robinson LR. Traumatic injury to peripheral nerves. Muscle Nerve. 2000;23:863–73.
[2] Wang ML, Rivlin M, Graham JG, et al. Peripheral nerve injury, scarring, and recovery. Connect Tissue Res. 2019;60:3–9.
[3] Foster CH, Karsy M, Jensen MR, et al. Trends and cost-analysis of lower extremity nerve injury using the national inpatient sample. Neurosurgery. 2019;85:250–6.
[4] Padovano WM, Dengler J, Patterson MM, et al. Incidence of nerve injury after extremity trauma in the United States. Hand. 2020;21:1558944720963895.
[5] Tapp M, Wenzinger E, Tarabishy S, et al. The epidemiology of upper extremity nerve injuries and associated cost in the US emergency departments. Ann Plast Surg. 2019;83:676–80.
[6] Asplund M, Nilsson M, Jacobsson A, et al. Incidence of traumatic peripheral nerve injuries and amputations in Sweden between 1998 and 2006. Neuroepidemiology. 2009;32:217–28.
[7] Huckhagel T, Nüchtern J, Regelsberger J, et al. Nerve injury in severe trauma with upper extremity involvement: evaluation of 49,382 patients from the TraumaRegister DGU® between 2002 and 2015. Scand J Trauma Resusc Emerg Med. 2018;26:76.
[8] McAllister RM, Gilbert SE, Calder JS, et al. The epidemiology and management of upper limb peripheral nerve injuries in modern practice. J Hand Surg Br. 1996;21:4–13.
[9] Ciaramitaro P, Mondelli M, Logullo F, et al. Italian Network for Traumatic Neuropathies. Traumatic peripheral nerve injuries: epidemiological findings, neuropathic pain and quality of life in 158 patients. J Peripher Nerv Syst. 2010;15:120–7.
[10] Kouyoumdjian JA, Graça CR, Ferreira VFM. Peripheral nerve injuries: a retrospective survey of 1124 cases. Neurol India. 2017;65:551–5.
[11] Noble J, Munro CA, Prasad VS, et al. Analysis of upper and lower extremity peripheral nerve injuries in a population of patients with multiple injuries. J Trauma. 1998;45:116–22.
[12] Selecki BR, Ring IT, Simpson DA, et al. Trauma to the central and peripheral nervous systems. Part II: a statistical profile of surgical treatment New South Wales 1977. Aust N Z J Surg. 1982;52:111–6.
[13] Lad SP, Nathan JK, Schubert RD, et al. Trends in median, ulnar, radial, and brachioplexus nerve injuries in the United States. Neurosurgery. 2010;66:953–60.
[14] Karsy M, Watkins R, Jensen MR, et al. Trends and cost analysis of upper extremity nerve injury using the National (Nationwide) inpatient sample. World Neurosurg. 2019;123:e488–500.
[15] Giustini M, de Leo A, Leti Acciaro A, et al. Incidence estimates of hand and upper extremity injuries in Italy. Ann Ist Super Sanita. 2015;51:305–12.
[16] Bergmeister KD, Große-Hartlage L, Daeschler SC, et al. Acute and long-term costs of 268 peripheral nerve injuries in the upper extremity. PLoS One. 2020;15:e0229530.
[17] Beris A, Gkiatas I, Gelalis I, et al. Current concepts in peripheral nerve surgery. Eur J Orthop Surg Traumatol. 2019;29:263–9.