

Traumatic Brachial Plexus Injury: A Clinicoepidemiological Cross-Sectional Analysis

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Abstract

Introduction Brachial plexus injuries (BPIs) are extremely debilitating and disabling conditions, resulting in a permanently neurologically impaired limb. Various factors like knowledge about the problem and its possible management, timely referral, accessibility to higher medical centers, patient affordability, and coronavirus disease 2019 in recent times have played major roles in the timing of patients presenting for BPI treatment.

Aims and Objectives The aim of this study was to assess the demographics in patients with BPI, mode and pattern of injury, neuropathic pain, time taken to report to a tertiary healthcare facility and to compare Naraka's data with that of the current Indian demographic scenario.

Methods A retrospective analysis was conducted between November 2018 and November 2021.

Results We found that males were commonly affected and were within 18 to 40 years of age. Right side was commonly injured with supraclavicular mixed type of injuries occurring frequently. Motor vehicle accidents was found to be the leading cause of BPI with a high association with polytrauma associated injuries. The average time taken by the patients to present to the hospital was found to be 9.6 months.

Conclusion We observed many aspects to be common with those reported in literature such as sex, age, and mechanism of injury. However, the time taken to present to the hospital was found to be longer in our study population. There is also a deviation in our findings with the previously described Naraka's seven 70s.

Keywords

- brachial plexus injury
- epidemiology
- Indian population
- motor vehicle accidents

Introduction

Brachial plexus injuries (BPIs) are extremely debilitating and disabling conditions, resulting in a permanently neurologically impaired limb. Varying degrees of sensory and motor

function loss are present depending on the level and type of injury to the plexus. In an otherwise healthy person, a non-functional limb, hampering the activities of daily living, could have a severe impact on their physical, psychological,^{1,2} and

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financial well-being. BPIs were previously considered to be complicated problems with complex treatment and poor outcomes. The outlook toward the same has now changed with a better understanding of nerve physiology and healing and the advent of microsurgical reconstructive techniques. Although reconstructive modalities may not provide a complete recovery, significant recovery can be achieved with timely surgical intervention and meticulous rehabilitation.

In the scenario of polytrauma, the treatment of life- and limb-threatening injuries takes the front seat. BPIs or peripheral nerve injuries are often masked or identified quite late. Various factors like knowledge about the disease and its possible management, timely referral, accessibility to higher medical centers, patient affordability, and coronavirus disease 2019 (COVID-19) in recent times play major roles in the timing of patients presenting for the treatment of BPI.

Early diagnosis, workup, and treatment planning play a crucial role in the management of such patients.

Motor vehicle accidents (MVAs) are the leading causes of closed injuries to the brachial plexus.³ Although the exact incidence of such injuries is varied in varying parts of the world, with the increased use of motor vehicles, the number of high velocity injuries is very high.^{4–6}

Narakas' "rule of 7 seventies" is very popularly known and widely quoted.⁷

We aim to assess the overall profile of patients with traumatic BPIs presenting to our center, to compare the available demographics with that of the Indian population which would help establish a standardized referral protocol of such patients for their early treatment and rehabilitation.

Methodology

All the data of those patients operated for traumatic brachial plexus palsy, patients attended to during interdepartmental consultations, and those treated in the emergency department from November 2018 to November 2021 were collected from hospital medical records after obtaining institute ethics committee approval. Retrospective observational analysis was done. Demographic details like age, sex, mode of injury, clinical examination findings, and pattern of injury based on clinical assessment; presence of associated injuries and their details; presence of pain at the time of presentation, and the procedures the patient underwent in the primary or secondary stages were recorded. Details of magnetic resonance imaging and electrophysiological studies as mentioned in the records were also collected. Record was also made of the time taken by the patients to present to us since the injury. Data of all such patients fulfilling the inclusion criteria were collected. Statistical analysis of data was done using STATA 14 software version 20. Categorical variables were expressed as frequency and proportions. These categorical variables were compared using the chi-squared test and Fisher's exact test. A *p*-value less than or equal to 0.05 was considered as statistically significant.

Results

A total of 83 eligible patient were recruited in our study. All traumatic BPIs which were either evaluated or operated between November 2018 to November 2021 were included in the study.

We found that the average age of the patients affected by traumatic BPI in this study was 26.9 ± 9.93 (mean $\pm$ standard deviation) years. Patients belonging to the age group between 21 and 40 years were seen to be very commonly affected (**Table 1**). We also found that there was male preponderance of BPI (**Table 2**). The most common etiology for traumatic BPI in this study was MVA accounting for 87.95% ($n = 73$). Two-wheeler-associated MVAs accounted for the highest percentage. ($n = 44$) Other causes are mentioned in **Fig. 1** (**Table 3**). Preponderance of right-sided BPI was also the dominant side.

BPI can be isolated injuries or can be a part of polytrauma. It was found that seven patients in this series had only minor associated injuries in the form of soft tissue lacerations, abrasions or contusions, accounting for 8.43% of all patients; while 30 patients had isolated BPI without any accompanying injuries and 46 (55.42%) patients had BPI as a part of the polytrauma spectrum. Other associated injuries are described in **Table 4**.

Table 1 Age distribution of patients

Age group in years	Percentage (%)	Frequency (n = 83)
1–10	7.23	6
11–20	16.87	14
21–30	43.37	36
31–40	21.69	18
41–50	9.64	8
Above 50	1.20	1

Table 2 Gender distribution of patients with BPI

Sex	Percentage (%)	Frequency (n = 83)
MALE	90.36	75
FEMALE	9.64	8

Table 3 Distribution of the modes of injury and types of MVA

Type of MVA	Percentage (%)	Frequency (n = 73)
Pedestrian	15.06	11
2-Wheeler associated	60.27	44
4-Wheeler associated	1.37	1
Unknown type	21.91	16
Heavy vehicles	1.37	1

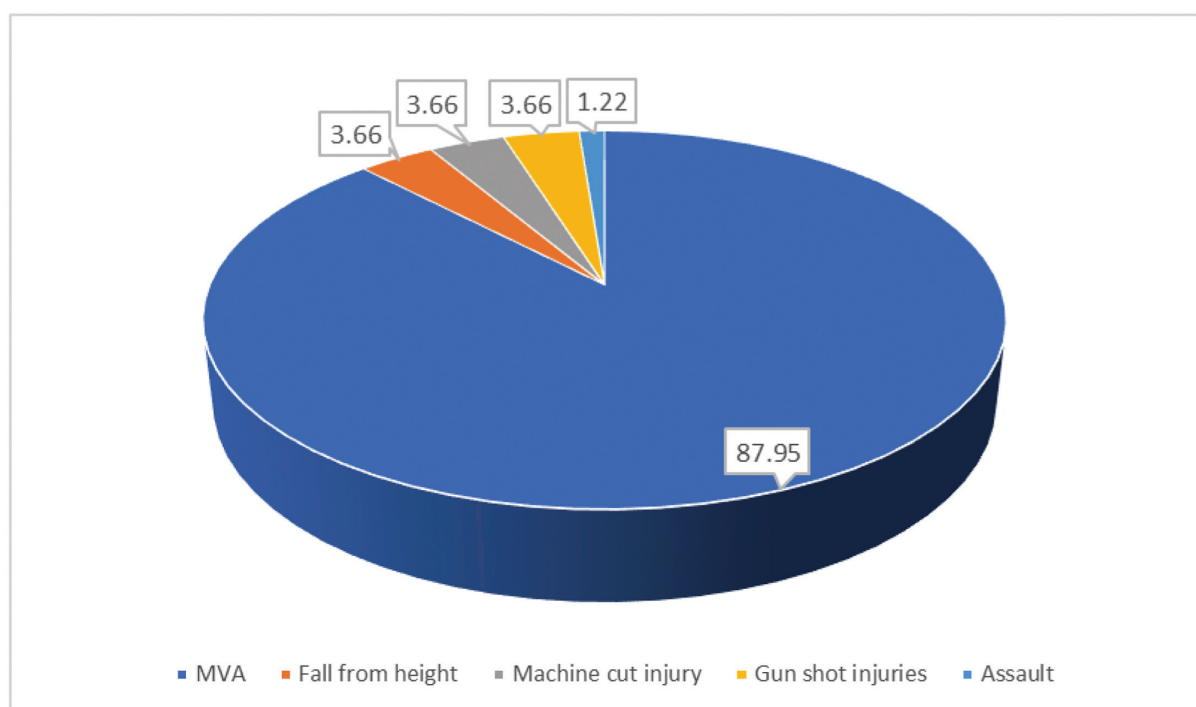


Fig. 1 Percentage distribution of Mode of injury.

Table 4 Distribution of associated injuries

Associated injuries		Percentage (frequency)	Frequency (n = 83)
Minor		8.43	7
Major		55.42	46
	Vascular	6.02	5
	Upper limb long bone and/or flat bone fractures	25.30	21
	Clavicle fracture	12.04	10
	Craniofacial injuries	12.04	10
	Spine injuries	3.61	3
	Solid and hollow viscus injury	2.40	2
	Other long bone fractures	15.66	13
None		36.14	30

Supraclavicular BPI (► **Table 5**) and mixed type of injuries (preganglionic and postganglionic) were the most common (► **Fig. 2**). It was observed that 75.88% of the patients had at least one root avulsion injury.

The patterns of injury to the brachial plexus were also analyzed clinically and radiologically. We found that 22 patients had an upper BPI with involvement of roots C5,

C6; 17 patients had an extended upper BPI with involvement of C5, C6, C7 roots. It was found that 9 patients had a lower and extended lower plexus injury involving C7, C8, and T1 roots. Pan/global BPI affecting 28 patients accounting for 33.73% of all BPIs was the most common. Three patients had a posterior chord involvement (level IV).

Presence or absence of pain at the time of presentation was noted and analyzed. It was seen that seven patients had severe deafferentation pain out of which one patient required surgical intervention.

It was observed that 24 patients were seen immediately after injury within 48 hours in the emergency department; 38 patients reported to the outpatient department within 12 months following injury after an initial treatment at local hospitals. Twenty-one patients presented late, after

Table 5 Site and level of brachial plexus injury distribution

SITE OF INJURY	Percentage (%)	Frequency (N = 83)
Supraclavicular	95.18	79
Infraclavicular	4.81	4

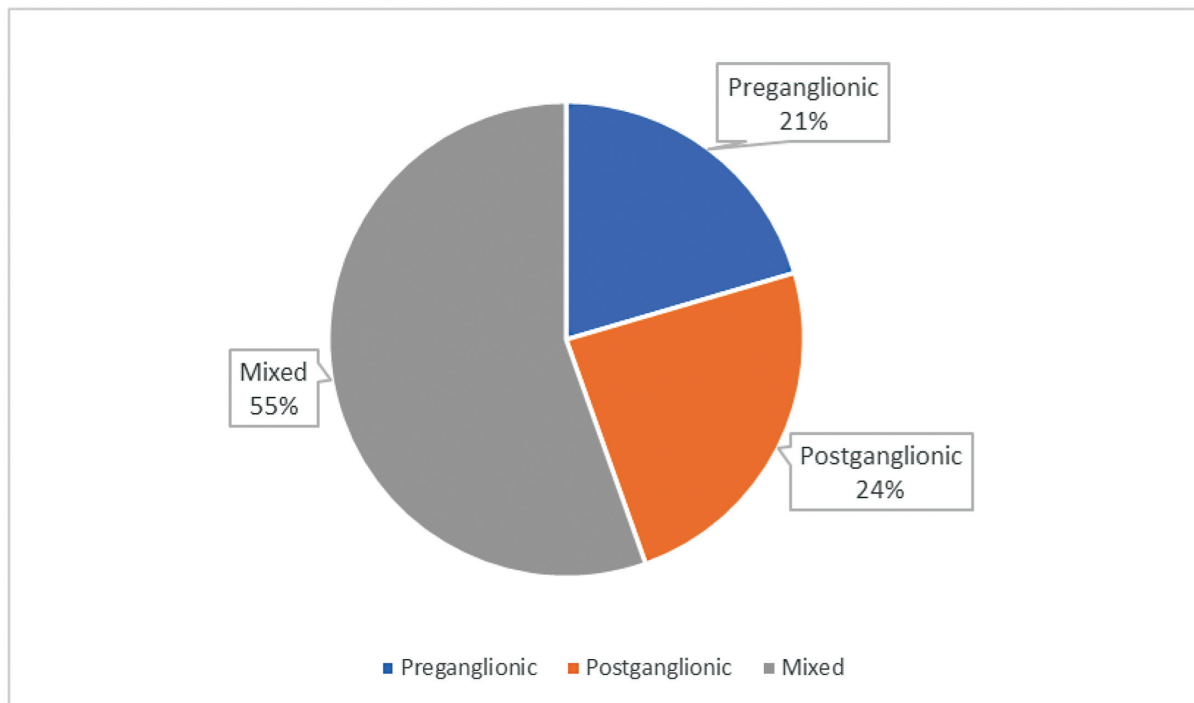


Fig. 2 Percentage distribution of type of injuries.

12 months following injury. Twenty-two patients were lost to follow-up and 48 patients underwent various neurotization procedures like intraplexus and extraplexus nerve transfers; while 13 patients presented late and underwent secondary procedures like trapezius transfers, tendon transfers and free functioning gracilis transfer, bipolar LD muscle transfers. The average time of presentation of patients with BPI to our center was 9.6 months.

Discussion

Epidemiological analysis of BPIs following trauma in literature is sparse. There is a vast regional variation all over the world in the epidemiological profile of such patients owing to the difference in infrastructure, economic status, lifestyle, and accessibility to healthcare services. The number of studies explaining the epidemiology of BPI in an Indian population is even fewer.⁴

MVA has been found to be the commonest causative factor for BPI in our study series. Patients presenting with traumatic BPI MVA after being involved in MVA was 87.95% following which they noticed an inability to move the affected upper limb to varying degrees depending upon the level of injury. A total of 60% of these MVA-associated injuries involved the patients being on a two-wheeler vehicle. The commonest types of motorcycle accidents were head on collisions, pillion rider fall, skid and fall or fall after striking the road barricades/dividers. This is in line with the findings of Kaiser et al who found that the incidence of motorcycle associated injuries in their study population was 67%.⁸ In another study, Kaiser et al have shown that MVA is responsible for 80.7%; with motorcycle accidents accounting for 63.2% of BPI.⁹ Sabapathy from the

Southern part of India found that 94% of the BPIs were due to MVAs and 90% of these MVAs were associated with two wheelers which is quite larger than that found in this study.⁴ Flores et al noted a 57% incidence of motorcycle associated BPIs.¹⁰ Goldie and Coates in their study in 1992 had found that accidents accounted for 65.3% of the BPIs and the referral rate of such patients to higher centers was 29.1%.¹¹

Young male patients within the age group 21 to 40 years were found to be majorly affected in this study. The average age of the patients affected by BPI was found to be 26 years. Males affected by BPI were 90.36% compared with only a 9.64% of females. Sami et al also have found the highest incidence of traumatic BPIs in young male patients in the age group of 16–46 years with an average age of 25 years.¹² A similar average age of 28.38 years was seen in their patient population by Faglioni.¹³ Martin observed that 89.15% of the patients with BPI were males in his study population.¹⁴ This pattern of higher prevalence of BPI in males has been observed by Cho as well.¹⁵ The reason for this higher incidence in the younger male population could be due to their active involvement in occupational and sports activities. Higher use of motorcycle vehicles for commutation could be an indicator of the socioeconomic status of the general population, thus being such an important causative factor of BPI.

Only six of the total 83 patients were found to have an open type of injury in our patients. Sabapathy also had only two open injuries out of a large number of 304 patients.⁴ This finding has an important bearing on the timing of brachial plexus surgeries, as open injuries are an indication for immediate exploration, while closed injuries are observed for spontaneous recovery. Open injuries are obvious at the time of presentation, thus are associated with early

intervention and better prognosis. In a large case series study of 1019 patients done over a period of 30 years including patients with brachial plexus lesions due to thoracic outlet syndrome, Kim from Louisiana have reported an incidence of seven percent of open lacerations to the brachial plexus.¹⁶ This finding is consistent with that in literature. Closed BPIs are the predominantly present as compared with open.

It was observed that 52.2% of our patients had BPI as a part of the polytrauma spectrum, of which, 6.05% had an associated vascular injury, 25.30% had an ipsilateral upper limb long bone and (or) scapular fracture and 12.04% had clavicle fractures. The remaining patients had other severe injuries of the head, spine, pelvic fractures, lower limb fractures and visceral organs requiring admission. Sabapathy observed that 57% of their patients of BPI were associated with polytrauma.⁴ Kaiser et al have found 55% patients to have upper limb fractures, 43% with spinal injuries and 25% with scapula, rib and clavicle fractures.¹⁷ A study from China has demonstrated the incidence of BPI with other associated injuries in 83.53%; with spinal cord injuries in 14.31%, brain injuries in 76.27% and upper limb fractures in 65.31%.¹⁸ With injury to the brachial plexus, injury to the subclavian-axillary artery vascular axis also is a possibility due to its vicinity to the plexus. Similar vascular injuries were found in 6% of our patients. In their series of 520 patients, Songchaeren has found a similar incidence of 5.6% of associated vascular damage.⁵ Johnson et al in their study of association of BPI with vascular injuries, found that 32.2% of the patients had both BPI and an associated vascular injury.¹⁹ Huang observed that 21% of the BPI occurred in association with vascular injuries, which is higher than the number observed by us. In their study, incidence of vascular injuries was very high when associated with other upper extremity fractures.²⁰ We observed that in this series vascular injuries were commonly associated with ipsilateral limb soft tissue injuries and bony fractures involving the scapula, clavicle, humerus, radius and ulna. This shows that the severity of accidental injuries is directly proportional to the velocity of the accident. Higher the velocity, greater is the injury sustained and higher is the incidence of BPI due to the greater force of dissociation between the neck and the shoulder.

Supraclavicular injuries were seen in 95.18% of our patients and 75.9% of the patients had at least one root avulsion. It was found that 96.70% of the patients had supraclavicular injuries with 89% having at least 1 root avulsion in Sabapathy's series. Terzis observed at least 1 root avulsion in 55% of their patients with BPI which is far less than that observed in our patients.²¹ In a study by Moiyadi, 98% of the patients had supraclavicular injuries of which 84% had root avulsion injuries.²² Midha had found that BPIs were predominantly seen in young and middle-aged male patients. MVAs were found to be the most common mode of injury in their study resulting in as high as 62% of the supraclavicular injuries requiring early surgical intervention.⁶ Our findings are similar to that found in literature.

The commonest pattern of injury found in our study was a pan BPI accounting for 33.73% followed by an upper BPI involving C5-C6 roots in 26.51%. Upper extended palsy was

seen in 20.48% of the patients. However, Sulaiman has observed that majority of the patients in his group had involvement of C5, C6, C7 roots followed by pan brachial plexus palsy.^{23,24} Complete plexus palsy was noted in 45% of the study population by Bertelli and 24% had a C5, C6 pattern involvement. The lower plexus involvement was also found to be similar as in our study.²⁵ Bhandari in their series of only upper BPI, observed a higher incidence of C5, C6 injury as compared with C5, C6, C7 pattern as seen in this study.²⁶ A higher involvement of the upper brachial plexus could be due to the high impact injury to the shoulder and the resultant vector of injury causing the upper plexus roots to injure.

Right sided BPI, which also happens to be the dominant side was the most commonly seen in this study group. A possible reason for this could be attributed to right-handed driving in our country. Since the most common cause of BPIs is road traffic associated, collisions would lead to the driver being thrown off the motorcycle to strike the road divider present on the right side.²⁷

Exploration and neurotization for an injured brachial plexus is a very time sensitive procedure. "Time is muscle," is a popular saying amongst the brachial plexus surgeons. The average time to surgery following BPI is 9.6 months in this study. The average time to exploration of closed injuries was reported to be 11.5 months by Rorabeck.²⁸ The average time to surgical intervention was four months in Chuang's study of intercostal nerve to musculocutaneous nerve transfer which was mainly for root avulsion injuries.²⁹ Ochiai have also described an average time till surgery to be 3.4 months.³⁰ The slightly longer time of surgery in this study could be due to the poor awareness of the people, major associated injuries (due to which BPI is often missed) and remote peripheral centers with regards to the condition and its treatment possibilities. This stresses the importance of spreading awareness about BPI to the masses, primary care physicians and emergency specialists for time appropriate referral to centers offering specialized services for the same. Another very important contributing factor to the delayed presentation of patients in the last three years could also be due to the ongoing COVID-19 pandemic which had grossly restricted the movements of the public.

In the study series by Zhou, 54.5% of the patients had neuropathic pain post trauma to the brachial plexus.³¹ Only 8.4% of our patients had intractable pain at the time of presentation. However, a post operative follow up of the presence or absence of pain could not be included in this study.

On comparison of our study findings with the rule of seven 70s as described by Narakas,⁷ 87% of the traumatic BPIs were due to MVAs, of which 60% was associated with motorcycles. It was observed that 52.2% had multiple associated injuries, 95.18% were supraclavicular lesions. One root avulsion was present in 75.9% at least; of these 12.6% involved avulsion of lower root. Pain was present in 8.4% overall, pain was not seen in any patients with avulsion of lower roots. Naraka had described this rule in 1985 after a study which was eighteen years long and based in Switzerland. This rule however, cannot be uniformly applied today to all parts of

the world as there a vast variation in population, types of vehicles in use, causes of injuries and patterns of injury as seen above.

These type of studies in various parts of India would help in establishing a BPI registry, referral protocols, policy development for early management of the patients affected with BPI. The quality of life and knowledge of such patients could be improved by setting up BPI awareness weeks, BPI patients' support groups and brachial plexus networks. The United Brachial Plexus Network, a non-profit organization in the West, aims at educating the masses about prevention and treatment, at the same time offering support to the families of those affected.³² We need many such networks in India which are easily accessible to the masses in remote regions.

This study is not without limitations. The limitation of this study is the small sample size. Owing to COVID-19 and restrictions to in-person follow up visits, only 83 patients overall could be analyzed. We also could not include the post-operative outcomes following surgery in whom surgical intervention was done. An evaluation of the quality of life of these patients also could not be done as it was a retrospective study.

In conclusion, BPI is most commonly seen in young adult males and in relation to MVA, especially with motorcycles. In this study, it was observed that the average time of presentation to a healthcare facility was 9.6 months which is quite delayed considering the time sensitive nature of the injury. Proper traffic control systems and strict regulations for road safety need to be developed and implemented along with innovations of body suits that could protect the patients from such devastating injuries to the limbs. Early evaluation of such patients as well as an early surgical decision is mandatory to expect good outcomes of function. The remote peripheral centers of the country are often the first point of contact of such accident victims. Hence, development of systems to educate the primary healthcare providers to improve their knowledge about BPI and the possible available treatment options along with stress on the importance of "time" with the help of proper referral systems would help in the improving the quality of lives of patients affected by BPI.

Statement

This study has been conducted after institutional ethical board approval

Contribution Statement

All authors have contributed equally to the development of the manuscript. Dr. Maneesh Singhal has been responsible for the conceptualization of the idea and final approval, Dr. Shruthi Chandrasekar and Dr. Ramesh Vaidyanathan have been actively involved in the writing of the manuscript. Dr. Shashank Chauhan have been involved in data analysis and composition of the manuscript. Dr. Shivangi Saha and Dr. Suvashis Dash have been involved in editing and proof reading of the manuscript.

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Conflicting of Interests

None declared.

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