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ORIGINAL ARTICLE - PERIPHERAL NERVES

Traumatic brachial plexus injury: a study of 510 surgical cases from multicenter services in Guangxi, China

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Abstract

Background Traumatic brachial plexus injuries are severe lesions, and the incidence of these injuries has been increasing in recent years.

Methods The clinical data of 510 operated patients with brachial plexus injury recruited from 74 hospitals in Guangxi from 2004 to 2016 were retrospectively studied.

Results Our study included 447 males and 63 females, with an average age of 29.04 years. Traffic accidents were the most common cause of injury (64.71%), especially motorcycle accidents. Closed injuries accounted for 88.24% of cases, and 83.53% of patients had associated injuries, the most common of which were fractures (76.27%). The preoperative predictive value of root injury of MRI and CT was 74.71% and 71.28%, respectively. 44.71% of patients underwent an initial operation within 6 months after the trauma. Regarding the surgery, neurolysis alone, brachial plexus reconstruction, and free functioning gracilis graft accounted for 16.67%, 75.50%, and 4.51%, respectively. A total of 415 patients were followed up with an average time of 47.95 (25–68) months, and anxiety or depression were found among 81.20% of them. Two hundred seventy-six patients suffered from nerve pain, with mild pain present in 67.03% of patients. Additionally, 347 patients were followed up for more than 3 years, 76.81% of patients with C5-C6 injury recovery to useful function, and the procedure of neurolysis alone demonstrated the best efficacy (79.45%).

Conclusions Brachial plexus injury is still a challenging trauma for surgeons, and traffic accidents are the dominant cause. Timely and effective surgery is important for functional limb recovery.

Keywords Brachial plexus · Nerve injury · Nerve transfer · Clinical outcome · Epidemiology

Abbreviations

BPI	Brachial plexus injury
BP	Brachial plexus
MRI	Magnetic resonance imaging
CT	Computed tomography
VAS	Visual analog scale
LSUMC	Louisiana State University Medical Center
NAP	Nerve action potential

Introduction

Traumatic brachial plexus injury (BPI) is regarded as one of the most devastating lesions of the upper limb and causes tremendous loss to affected individuals, their families, and society. In 1970, surgeons were pessimistic about the therapy for BPI because of the poor outcome, and only conservative treatment was generally recommended. Fortunately, with the advances in micro-neurosurgery over the last few decades, surgery as an important treatment has significantly changed the outcomes of BPI [8, 15, 26]. Jain et al. [15] noted that 57% of patients in India were able to return to their jobs, on average 8.6 months after the trauma. Dubuisson and Kline [8] also reported that 78% of patients with open injury and 58% of patients with closed injury restored useful function after surgery, and the authors noted a few important points regarding the management of BPI, such as the necessity of classifying the severities of each brachial plexus (BP) element, determining the indication as well as best time

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for surgery, and determining the best strategy for surgeries by applying intraoperative electrophysiology. Since the 1980s, the number of patients has been increasing because of the improvement in emergency management and the application of helmets, and the severity of lesions in the vessels as well as nerves has become greater in recent years [25]. The technological refinements in the preoperative assessment and repair of nerve injuries impelled us to perform a retrospective study on the epidemiology, clinical management, and outcome of 510 successive patients with BPI.

Materials and methods

This study recruited 510 consecutive operated patients with BPI between January 2004 and December 2016 from 33 tertiary hospitals, 39 secondary hospitals, and 2 primary hospitals. Diagnosis was confirmed by clinical features, radiological assessment (magnetic resonance imaging [MRI], computed tomography [CT], plain radiography, and angiography), and electrophysiology studies (sensory nerve action potentials, electromyoneurography). The collected data included gender, age, address, occupation, injury mechanism, associated injuries, and results of the preoperative evaluation. Additionally, the time elapsed from injury to BP surgery, the surgical procedures applied, and the intraoperative finding of avulsion, rupture, or scar of all BP elements were also recorded. Regarding the topography, we classified BPI into supraclavicular and infraclavicular lesions and assorted them according to the affected roots. After surgery, we followed up patients through the outpatient department or by phone or mail to investigate the psychological state of patients and used the visual analog scale (VAS) to evaluate the degree of limb pain, utilizing the grading system of Louisiana State University Medical Center (LSUMC) to evaluate the function of the upper limb. In brief, in accordance with the LSUMC system, individual muscle-level progressed from 0 (no contraction) to 5 (movement against the greatest resistance), and the presentation of paralytic muscles at that time indicated the degree of injury. Successful results were defined as the achievement of grade 3 or higher [18]. We attempted to contact all the patients or their families; although only 415 patients participated in the follow-up, they constituted a sufficiently representative group in which to assess overall posttreatment status. All treatments included in the study were performed under the direction of my hospital to ensure that the data were of good quality.

Results

Epidemiology

Among the cases, 447 males and 63 females were included, and the male:female ratio was 7.10:1.00. The average age of the subjects was 29.04 (1–73) years. Subjects aged between 20 and 39 years accounted for 59.41% of all cases (Fig. 1), and rural residents accounted for 77.65% of cases. Most of the subjects were laborers (34.90%), farm workers (17.25%), or unemployed (17.45%). Patients with medium to low incomes or no income accounted for 88.04% of the sample. Regarding education level, 73.33% of the patients had a secondary education.

Among the causes of BPI (Table 1), the majority of injuries were attributed to traffic accidents (64.71%), falls (16.08%), and machine traction (7.84%). Among the traffic accidents, 71.52% involved motorcycles and 14.24% involved electric scooters.

Preoperative status

95.88% of the patients first visited the hospital within 24 h after injury, and 70.78% of the patients were transferred to different hospitals at least once. Many patients did not timely receive surgical treatment, and 44.71% of all cases underwent an initial operation within 6 months after the trauma (Fig. 2).

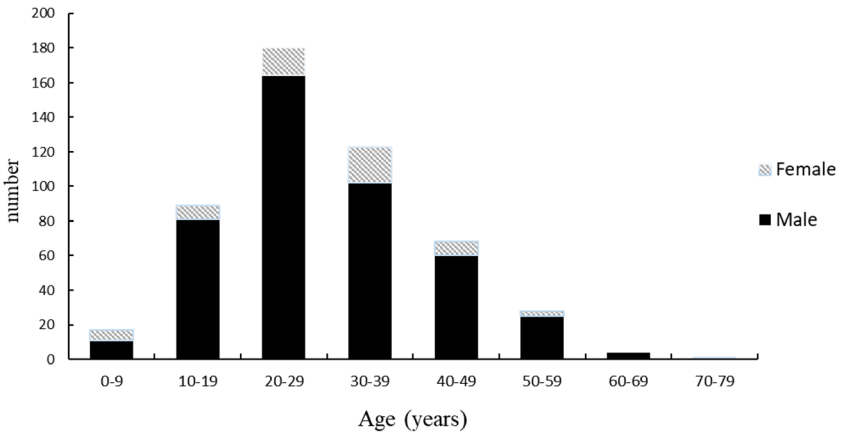

Fig. 1 Histogram of the distribution of patients' ages

Table 1 Causes of brachial plexus injury

Mechanism	No. of patients	Ratio (%)
Traffic accidents		
Motorcycle	236	46.27%
Electric scooter	47	9.22%
Car	24	4.71%
Other	23	4.51%
Falls	82	16.08%
Machine traction	40	7.84%
Hit by falling object	30	5.88%
Sharp injury	16	3.14%
Operative iatrogenic injury	7	1.37%
Gunshot wound	5	0.98%
Total	510	100.00%

Closed injury accounted for 88.24% of cases. 51.60% of the patients had left-sided injuries, 44.26% had right-sided injuries, and one patient was affected on both sides. In addition, 83.53% of the patients had associated injuries, with fractures and brain or spinal cord injuries accounting for 76.27% and 14.31%, respectively (Table 2). Upper limb fractures accounted for 65.31% of all fractures (Table 3). Horner's sign was present in 158 patients, and trapezius, hemidiaphragm palsy, and alar scapula were present in 105, 30, and 22 patients, respectively.

Regarding the preoperative examination, 283 patients underwent MRI scans, 195 patients underwent CT scans, and 427 patients underwent electrophysiological studies. The preoperative predictive value of root injury (at least one root abnormality) of MRI and CT was 74.71% and 71.28%, respectively. Electrophysiological studies diagnosed 56.21% of preganglionically injured roots.

Operation

Supraclavicular BPI was the most common injury type (Table 4), and the percentages of patients with C5-T1, C5-C7, and C5-C6 injuries were 42.66%, 18.00%, and 13.50%, respectively. Additionally, the nerve damage was often more severe in the supraclavicular area (Table 5), and scar was the major intraoperative finding, which was often extensive. In most cases, scar was combined with a traumatic neuroma in the continuity of BP elements. Regarding root avulsion, C7-T1 nerve roots were more likely to be avulsed than C5-C6 nerve roots, especially the C7 nerve root ($n = 210$).

Necrolysis alone was performed in 86 patients (Table 6) because all the elements were found in continuity and transmitted a nerve action potential (NAP). Direct end-to-end suturing was performed in 14 patients, with the following distribution: C5-C6 ($n = 3$), C5-C7 ($n = 2$), C7-T1 ($n = 1$), and median nerve, radial nerve, or axillary nerve ($n = 8$). Nerve grafting alone was performed in 31 patients and included the median nerve, musculocutaneous nerve, axillary nerve as well as radial nerve ($n = 10$), the superior trunk to the posterior and anterior branches ($n = 19$), C7 to the middle trunk ($n = 1$), and the medial cord to the median nerve ($n = 1$).

Nerve transfer alone ($n = 256$) or combined with grafting ($n = 84$) was performed using C5 to the posterior division of the superior trunk ($n = 51$), superior trunk ($n = 44$), anterior and posterior divisions of the superior trunk ($n = 37$), or posterior cord ($n = 24$); C6 to the anterior division of the superior trunk ($n = 48$) or superior trunk ($n = 65$); homolateral C7 to the inferior trunk ($n = 41$), superior trunk ($n = 32$), or anterior or posterior divisions of the superior trunk ($n = 6$); C8 or T1 to the inferior trunk ($n = 40$) or anterior divisions of the inferior trunk ($n = 16$); accessory nerve to the suprascapular nerve ($n = 301$); phrenic nerve to the musculocutaneous nerve or anterior division of the superior trunk ($n = 77$), medial cord/median nerve ($n = 27$), or ulnar nerve ($n = 3$); partial ulnar nerve to the musculocutaneous nerve ($n = 33$); intercostal nerve to the musculocutaneous nerve ($n = 25$), medial cord/median nerve ($n = 4$), ulnar nerve ($n = 2$), or thoracodorsal or radial nerve ($n = 6$); and brachial triceps branches of the radial nerve to the axillary nerve ($n = 25$). In some cases, we performed the contralateral C7 nerve transfer, i.e., transferred a pedicled ulnar nerve to contralateral C7 in the first stage and coapted it to the target nerve in the second stage ($n = 90$);

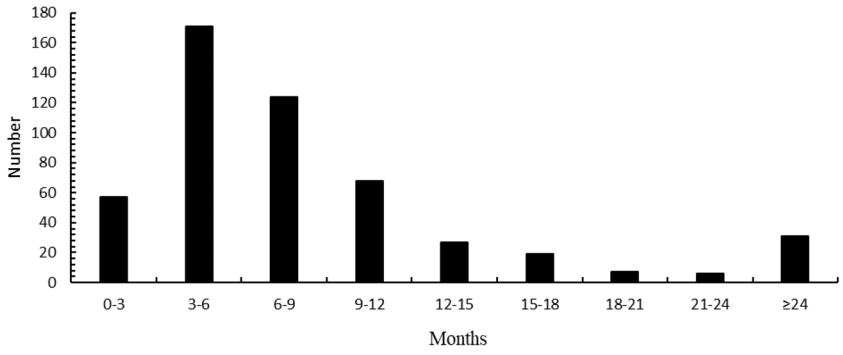

Fig. 2 Histogram of intervals between trauma and first surgery

Table 2 Associated injuries

Injury	No. of patients
Fractures	389
Brain or spinal cord injury	73
Great vessel injury	54
Thoracic injury (excluding fractures)	22
Muscle injury or ischemic muscle spasm	21
Abdominal trauma	3

additionally, transferring of contralateral C7 to the superior or inferior trunk was performed ($n = 25$). Nerve grafting was performed in 115 patients. The grafts were harvested from sural nerves ($n = 65$), the superficial branch of the radial nerve ($n = 48$), the medial cutaneous nerve of the forearm ($n = 32$), and the ulnar nerve ($n = 9$). The average number of nerve grafts was 6.24 grafts per patient, and the average length was 5.32 cm.

Follow-up survey

A total of 415 patients participated in the follow-up survey, and they were followed for an average of 47.95 (25–68) months. The reasons for missing follow-ups included change of address or phone number ($n = 66$), refusal to participate ($n = 27$), and death ($n = 2$). Two hundred seventy-six patients suffered from nerve pain, with 67.03% reporting mild pain (1–3), 23.91% reporting moderate pain (4–6), and 9.06% reporting severe pain (7–10). Anxiety or depression was found in 81.20% of the patients.

Three hundred forty-seven patients were followed up for more than 3 years, and patients with isolated infraclavicular lesions often exhibited better outcomes (82.86%). The successful recovery (i.e., to grade 3 or better) rates of patients with C5-C6, C5-C7, and C5-T1 lesions were 76.81%, 58.70%, and 48.21%, respectively. Regarding the operative procedures, the optimal efficiency was achieved with neurolysis (79.45%), and the outcomes of neurotization with or without grafting are shown in Table 7. Free-functioning gracilis graft as a complex procedure had a success rate of 68.18% in 22 patients. Tendon transfer yielded a good recovery in 10 of 11 patients.

Table 3 Fractures associated with brachial plexus injury

Position	No. of patients
Bones of the upper limb	337
Bones of the lower limb	77
Ribs	62
Skull	29
Spine	25
Pelvis	5

Table 4 The distribution of paralysis (511 brachial plexuses)

Pattern of paralysis	No. of patients	Ratio (%)
C5-C6	69	13.50%
C5-C6-C7	92	18.00%
C7-C8-T1	33	6.46%
C8-T1	12	2.35%
C5-T1	218	42.66%
Cord/cord branch (infraclavicular)	35	6.85%
Supraclavicular and infraclavicular	52	10.18%
Total	511	100.00%

Discussion

Epidemiology

In our study, patients were mainly males, and most were young or middle-aged individuals with low income and education levels who came from rural areas, possibly because they are more frequently exposed to relevant risk factors than other individuals. The percentage of patients who were between 10 and 19 years old was higher than that in the study by Dubuisson and Kline [8], indicating that supervision of and safety education for minors should be improved. In addition, 64.71% of BPI cases were due to traffic accidents, and the highest incidence was attributed to motorcycle accidents (71.52%). This result was similar to that in other studies, but the contribution of traffic accidents to BPI varies between studies [8, 15, 27]. The difference in epidemiological characteristics of these authors' studies may be due to the different lifestyle and social conditions in the different regions.

Table 5 Surgical finding of brachial plexus injuries (511 brachial plexuses)

Location	No. of patients			
	Avulsion	Rupture	Scar/neuroma in continuity	Scar/atrophy in continuity
Roots				
C5	96	3	168	16
C6	145	4	134	10
C7	210	7	76	4
C8	141		55	1
T1	128		47	1
Trunks				
Upper		11	120	9
Middle		7	63	5
Lower			81	
Cord or cord to nerve (infraclavicular)		6	70	11

Table 6 Operative procedures

Surgery	No. of patients
Neurolysis only	85
Direct brachial plexus reconstruction	
End-to-end suture	14
Nerve grafting	31
Direct brachial plexus reconstruction with neurotization	84
Neurotization only	256
Tendon transfer	12
Pedicled lattismus dorsi	5
Free functioning gracilis	23

Open injuries were less frequent than closed injuries, which were frequently caused by sharp injuries and iatrogenic injuries. Closed injuries were often caused by traffic accidents, falls, and industrial injuries. Fractures were the predominant injuries associated with BPI and were most common in the upper extremity long bones and the shoulder girdle bone, in accordance with the study by Terzis et al. [32]; however, they reported a higher percentage of vascular injuries (28%) than that found in this study (11%). This result may indicate that the injuries sustained in our patients could be due to lower-velocity impacts compared with those suffered by patients in the West. It is notable that most of the patients in the aforementioned studies and in our study underwent surgery later, usually because of delayed referral [8, 15, 32]. Previous studies demonstrated that delayed diagnosis of peripheral nerve injury in patients with trauma and loss of awareness occurred in as many as 30% of the patients, and missed diagnosis occurred in 1–10% of patients with severe traumatic brain injury [30]. This result suggests that for patients with suspected BPI, a thorough history-taking, physical examination, and set of imaging studies should be performed early to obtain an accurate diagnosis.

Preoperative status

Regarding preoperative examinations, cervical myelography has been an effective technique to identify root lesions in BPI for a long time; however, it was gradually replaced by CT, which can provide better resolution of nerve root status [1]. MRI is a novel technique for examination of BPI and has become increasingly more popular because of its noninvasive nature and ability to provide detail information on the postganglionic plexus [1]. Doi et al. [7] presented the specificity and sensitivity of MRI for detecting root avulsion as 81.3% and 92.9%, respectively. Electrodiagnostic studies are also effective in preoperative assessment and intraoperative management, but the results are not accurate in the early stage of injury because the development of signs of muscle denervation could be revealed approximately 10–21 days after the injury [12].

The time between trauma and surgery is a relevant prognostic factor. Timely and effective surgery can not only yield better functional outcomes but can also relieve limb pain and help patients return to work as soon as possible [17, 22]. Emergency surgery is required for open injuries of BP [5]. If closed injuries are combined with preganglionic avulsion or postganglionic nerve rupture, the surgery should be performed as soon as possible or no later than 2–3 weeks post trauma [13]. In the case of good nerve continuity, if patients associated with fractures or other acute injuries, the acute injuries should be treated first, followed by 3 months of conservative treatment. If no or poor recovery is observed, surgery should be performed no later than 6 months post trauma due to the occurrence of pathological changes caused by denervation [5, 13]. Most authors

Table 7 Number of patients recovering to grade 3 or better after brachial plexus surgery (> 3 years of follow-up)

Type of operative procedure	No. of patients (%)					
	C5-C6	C5-C7	C5-T1	Cord/nerve	Supraclavicular and infraclavicular	Total
Neurolysis only	11 of 14	10 of 13	20 of 26	13 of 14	4 of 6	58 of 73 (79.45%)
Nerve suture	2 of 3	1 of 2	0 of 0	4 of 6	1 of 2	8 of 13 (61.54%)
Nerve grafting with or without neurotization	12 of 14	11 of 18	29 of 52	7 of 9	6 of 12	65 of 106 (61.32%)
Nerve transfer alone	23 of 33	26 of 52	45 of 127	3 of 4	10 of 28	107 of 243 (44.03%)
Tendon transfer	2 of 2	3 of 3	3 of 4	1 of 1	1of 1	10 of 11 (90.91%)
Pedicled lattismus dorsi	3 of 3	0 of 0	0 of 0	1 of 1	0 of 0	4 of 4 (100.00%)
Free functioning gracilis	0 of 0	3 of 4	11 of 15	0 of 0	1 of 3	15 of 22 (68.18%)
	53 of 69 (76.81%)	54 of 92 (58.70%)	108 of 224 (48.21%)	29 of 35 (82.86%)	23 of 52 (44.23%)	

agree with these recommendations [3, 13, 19, 22]. However, Magalon et al. [21] disagreed, and they stated that exploration should be carried out within 1 week post injury because it is less complex, and a relatively short graft can be applied. However, we believe that early exploration would expose some patients to unnecessary operations.

Adverse prognostic factors included Horner's sign, alar scapula, and weakness of the rhomboid muscle due to dorsal scapular nerve palsy, which can indicate a preganglionic root avulsion. Horner's sign has been shown to be a good predictor of T1 avulsion or T1 neuroma [19]. It is also worth noting that alar scapula is often not present in cases of total BPI because of local myodynamia was in balance.

Surgery

Supraclavicular lesions were more frequent in our series than in previous studies, occurring in 77.91% of the cases. Brophy and Wolfe [3] found that supraclavicular lesions tend to be more severe, which is consistent with our results. Supraclavicular and infraclavicular lesions were always severe and were often caused by traction of machine belts with tremendous traumatic force and complicated mechanisms. C5-C7 lesions were more frequent than C8-T1 lesions, but C7-T1 roots were more prone to be avulsed than C5-C6 roots, which are related to the anatomy of the BP and the injury mechanism of head and shoulder separation. The number of root avulsions in our study was greater than that found in Dubuisson's and Kline study [8], which may be due to the greater number of high-energy trauma events, including traffic accidents and falls.

The significance of intraoperative NAP recording is emphasized by the neurolysis percentage of 16.67%, which was diagnosed based on positive recordings in our study: the neuroma in continuous BP elements was dissected, while other elements were left alone because they conducted a NAP. We do not agree with internal neurolysis as a primary treatment approach as others do; instead, we perform this approach when a split repair is indicated [24].

In 75.49% of our patients, we repaired all or part of the BP found transected, or more likely after the resection of a nonconducting neuroma. Many surgeons attempt to reconstruct damaged BP and even use long grafts and/or the neurotization procedure for patients with serious damage. We and others support the use of neurotization with the utilization of regional nerves, such as the accessory nerve, because the advantage of anatomic proximity allows direct suturing to a BP distal element such as the suprascapular nerve. Furthermore, transfer of the accessory nerve to the suprascapular nerve yielded good outcomes, with an average shoulder abduction of 40–72° after surgery [9]. Regarding C5-C7 avulsion in which C8-T1 and thus hand function were undamaged, we are used to transfer the partial ulnar nerve to the musculocutaneous nerve because this operation is easy, not associated with severe complications, and provides good outcomes of elbow flexion [16]; in addition, the accessory nerve is transferred to the suprascapular nerve. Although procedures of phrenic nerve or intercostal neurotization are complex, they are good donor nerve options [4]. Liu et al. [20] reported the efficiency of intercostal nerve or phrenic nerve transfers for elbow flexion as 70% and 83%, respectively, and no pulmonary complications occurred in the patients after surgery. When the selections of other donor nerves are limited, we utilized contralateral C7 nerve transfer, especially for the treatment of total BP preganglionic avulsion. Contralateral C7 included the availability of 17,000–40,000 axons comprising sensory and motor fibers that can be a useful method for reconstructing motor and sensory function, without enduringly impairing the function of upper limb on the normal side [23, 29].

The optimal surgical procedure is made by electrophysiological examinations after the BP is exposed [12]. Our operation is according to the following principles: direct anastomosis of two ends is preferred; if the defect is too large to be anastomosed without tension directly, nerve grafting should be performed. We perform direct intraplexal repair when there is a sufficient number of proximal roots. If necessary, we expose the nerve root close to the intraforaminal level and often utilize the sural nerve, superficial branch of the radial nerve, and the medial cutaneous nerve of forearm grafts. Direct repair of nerve elements provides better results than neurotization, which is the second treatment option we consider when the number of nerve root is inadequate [8]. Although sensate prehensile hand function is probably the most needed function for patients, restoration of elbow flexion and shoulder abduction is prioritized due to the greater chance for success [19].

After 12–18 months post trauma, the nerve regenerative capacity is greatly reduced [31]. Additionally, degeneration and fibrosis of muscle cells result in poor efficacy [10]. Thus, muscle functional reconstruction should be considered for patients who have no recovery after 18-month post-injury [14]. Free-functional muscle transfers import both healthy muscle and fresh nerve transfer into the elbow area, thus resetting the clock for denervation intervals and allowing motor nerve fibers to have sufficient time to reach their original targets [11]. Hoang et al. [14] also reported that nerve transfers directed at imported free functional muscle can achieve better recovery of elbow flexion than those directed at muscular targets that had been atrophied for 1 year or more. We often use free functioning gracilis to reconstruct elbow flexion, with the intercostal nerve and phrenic nerve often chosen as donor nerves [19]. However, surgeries such as tendon transfer or pedicled lattismus dorsi were considered as a priority because of the high risk of muscle grafting.

Follow-up

Our surgical results are in accordance with those reported by other authors [26, 32]. Regarding supraclavicular lesions,

patients with C5-C6 injuries often recover better than patients with other types of BPI. Among the patients with infraclavicular lesions, a good recovery was achieved in 82.86%. Isolated neurolysis yields a successful outcome in 79.45% of cases. BP reconstruction combined with nerve grafts achieved a good outcome in 61.32% of patients, and nerve transfer was satisfactory in 44.03% of patients. Thus, these operative techniques seem to play a pivotal role in BP reconstruction and enable lots of patients to recover a useful limb [8].

64.64% of the follow-up patients had chronic neuropathic pain, 44.93% of whom reported mild pain, and spontaneous causalgia was the most common type. Neuropathic pain was more commonly found in patients with more severe BPI, and moderate to severe pain was mainly found in patients with complete BP injuries [6]. Currently, drugs and surgery are not effective long-term remedies [2, 28], and neuropathic pain seems to be more difficult to treat than BPI. In addition, anxiety was reported in 84.31% of the patients, possibly due to long-term impairment of limb function, chronic pain, job loss, and poor physical appearance. Chronic pain and bad psychological conditions seriously affect limb recovery and quality of life of patients, needing to be solved [26].

Conclusion

This study demonstrated that the epidemiology of BPI has not significantly changed over the past 10 years. Injuries occurred most frequently in young males due to traffic accidents, especially motorcycle accidents. BPI is often associated with injuries, and correct diagnosis should be made early, with BP surgery performed at the appropriate time. MRI as an effective preoperative examination should be more widely used. Regarding intraoperative findings, scar was associated with a neuroma in continuous nerves in most cases, which was often more severe in the supraclavicular area. Nerve grafts and neurotization procedures were important for repairing the BP. In the follow-up, surgical results confirmed that an aggressive surgical approach, combined with the use of these therapeutic methods, remains appropriate. Chronic neuropathic pain and an unhealthy psychological state are common after BPI, needing more attention.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Research involving human participants and/or animals Not applicable.

Ethical approval First Affiliated Hospital of Guangxi Medical University Ethical Review Committee, 2018 (KY-E-047).

Informed consent Informed consent was obtained from all individual participants included in the study.

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Comments

The authors report an impressive series of 510 patients with brachial plexus injuries operated on over a period of 12 years. The authors were able to collect follow-up data on 415 patients followed for more than two years. The authors use a number of techniques to repair the brachial plexus. A minority of patients could be treated with simple neurolysis. The majority of patients had either nerve grafts or nerve transfers. A few patients had tendon transfers. Their technical results were very impressive. It should be noted that despite the excellent technical results, 2/3 of the patients reported persistent pain and more than 80% of the patients reported persistent anxiety and depression. These findings indicate that despite surgical advances, we have a long way to go in treating patients with significant brachial plexus injuries.

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An interesting epidemiological study of hospital admitted and treated brachial plexus injuries in China.

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