RBO REVISTA BRASILEIRA DE ORTOPEDIA
www.rbo.org.br

Original article

Clinical aspects of patients with traumatic lesions of the brachial plexus following surgical treatment☆

Frederico Barra de Moraes, Mário Yoshihide Kwae, Ricardo Pereira da Silva, Celmo Celeno Porto, Daniel de Paiva Magalhães, Matheus Veloso Paulino*

Department of Orthopedics and Traumatology, School of Medicine, Universidade Federal de Goiás (UFG), Goiânia, GO, Brazil

ARTICLE INFO

Article history:
Received 24 March 2014
Accepted 23 October 2014
Available online 9 September 2015

Keywords:
Accident prevention
Multiple trauma
Brachial plexus/surgery

ABSTRACT

Objective: To evaluate sociodemographic and clinical aspects of patients undergoing operations due to traumatic lesions of the brachial plexus.
Method: This was a retrospective study in which the medical files of a convenience sample of 48 patients operated between 2000 and 2010 were reviewed. The following were evaluated: (1) range of motion (ROM) of the shoulder, elbow and wrist/hand, in degrees; (2) grade of strength of the shoulder, elbow and wrist/hand; (3) sensitivity; and (4) visual analogue scale (VAS) (from 0 to 10). The Student's *t*, chi-square, Friedman, Wilcoxon and Kruskal–Wallis tests were used ($p < 0.05$).
Results: The patients' mean age was 30.6 years; 60.4% of them had suffered motorcycle accidents and 52.1%, multiple trauma. The mean length of time until surgery was 8.7 months (range: 2–48). Thirty-one patients (64.6%) presented complete rupture of the plexus. The frequent operation was neurosurgery in 39 cases (81.3%). The ROM achieved was ≥30° in 20 patients (41.6%), with a range from 30° to 90° and mean of 73° ($p = 0.001$). Thirteen (27.1%) already had shoulder strength ≥M3 ($p = 0.001$). Twenty-seven patients (56.2%) had elbow flexion ≥80°, with a range from 30° to 160° and mean of 80.6° ($p < 0.001$). Twenty-two had strength ≥M3 ($p < 0.001$). Twenty-two patients (45.8%) had wrist extension ≥30° starting from flexion of 45°, with a range from 30° to 90° and mean of 70° ($p = 0.003$). Twenty-seven (56.3%) presented wrist/hand extension strength ≥M3 ($p = 0.002$). Forty-five (93.8%) had hypoesthesia and three (6.2%) had anesthesia ($p = 0.006$). The initial VAS was 4.5 (range: 1.0–9.0) and the final VAS was 3.0 (range: 1.0–7.0) ($p < 0.001$).
Conclusion: Traumatic lesions of the brachial plexus were more prevalent among young adults (21–40 years), men, people living in urban areas, manual workers and motorcycle accidents, with multiple trauma and total rupture of the plexus. Neurosurgery, with a second procedure consisting of muscle-tendon transfer, was the commonest operation. Surgery for traumatic lesions of the brachial plexus resulted in significant improvement in the ROM and strength of the shoulder, elbow and wrist/hand, improvement of the sensitivity of the limb affected and reduction of the final pain.

☆ Work performed in the Hand and Microsurgery Service, Hospital das Clínicas, Universidade Federal de Goiás (UFG), Goiânia, GO, Brazil.

* *Corresponding author.*
E-mail: frederico_barra@yahoo.com.br (F.B. de Moraes).

http://dx.doi.org/10.1016/j.rboe.2015.08.015

Aspectos clínicos de pacientes com lesão traumática do plexo braquial após tratamento cirúrgico

Palavras-chave:
Prevenção de acidentes
Traumatismo múltiplo
Plexo braquial/cirurgia

RESUMO

Objetivo: Avaliar aspectos sociodemográficos e clínicos de pacientes operados de lesão traumática do plexo braquial (LTPB).

Método: Estudo retrospectivo, revisão de prontuários, amostra de conveniência, 48 pacientes operados entre 2000 e 2010. Avaliados: 1) ADM – em graus, do ombro, cotovelo e punho/mão; 2) grau de força do ombro, cotovelo e punho/mão; 3) sensibilidade; 4) EVA (0 a 10). Testes de *t* de Student, qui-quadrado, Friedman, Wilcoxon e Kruskal–Wallis ($p < 0,05$).

Resultados: Idade de 30,6 anos, 60,4% acidentes motociclísticos. Politraumatismo 52,1%. Tempo até a cirurgia de 8,7 meses (2 a 48). Trinta e um (64,6%) com lesão total do plexo. Cirurgias mais frequentes: neurais em 39 (81,3%). ADM $\geq 30^{\circ}$ do ombro 20 pacientes (41,6%) de 30° a 90°, média 73° ($p = 0,001$); 13 (27,1%) já tinham força no ombro $\geq$ M3 ($p = 0,001$). Cotovelo $\geq 80^{\circ}$ de flexão, 27 pacientes (56,2%) de 30° a 160°, com média de $80,6^{\circ}$ ($p < 0,001$); 22 com força $\geq$ M3 ($p < 0,001$). Extensão do punho $\geq 30^{\circ}$ partindo de 45° de flexão em 22 pacientes (45,8%), de 30° a 90°, média 70° ($p = 0,003$); 27 (56,3%) tinham força de extensão do punho/mão $\geq$ M3 ($p = 0,002$); 45 (93,8%) hipoestesia e três (6,2%) anestesia ($p = 0,006$). EVA inicial 4,5 (1 a 9) e EVA final 3 (1 a 7) ($p < 0,001$).

Conclusão: As LTPB tem maior prevalência em jovens (21–40 anos), homens, urbanos, trabalhadores braçais, acidentes motociclísticos, com politrauma, lesão total do plexo. Cirurgias neurais, seguidas em segundo tempo, pelas transferências miotendíneas. A cirurgia para LTPB mostrou melhoria significativa de ADM e força em ombro, cotovelo e punho/mão, da sensibilidade do membro afetado e diminuição da dor final.

Introduction

Traumatic brachial plexus injuries are debilitating and lead to motor and sensory deficit, pain, functional limitation and significant alterations to patients' quality of life. They are more prevalent among young adults who have suffered high-energy trauma, especially car accidents.[1–3] Diagnosis is difficult and treatment is complex. The incidence of these injuries is 1.3% in multiple-trauma patients and 5% in motorcycle accident victims.[4]

The first descriptions of traumatic brachial plexus injuries came from periods of great wars, caused by wounds that were opened by means of cutting and blunt objects, such that blows or projectiles hitting the shoulder would lead to loss of upper limb movement. The first written report was in the Iliad, written by Homer (9th century B.C.; Trojan War).[5] However, scientific publications only began in the 19th century during the American civil war and, later, in the 20th century, when closed injuries started to become predominant, caused by firearm accidents, explosions and military vehicles, with high-energy trauma.[6]

Surgeries for reconstructing traumatic brachial plexus injuries have the following main objectives: (1) stabilization and external rotation of the shoulder; (2) elbow flexion; (3) wrist and finger flexion; (4) hand sensitivity; (5) thoracobrachial clamp; and (6) pain relief.[2–4] In 1900, Thorburn[7] described the first surgery for treating injuries of the brachial plexus through a technique with direct repair, followed by Harris and Low,[8] who in 1903 proposed neural transfer (neurotization), and by Seddon,[9] who published a correction technique with interposition of neural grafts in 1947. For better functional results from the upper limb, the modern manner of dealing with traumatic brachial plexus injuries includes complex neuromicrosurgical techniques that are performed early (neurolysis, direct neural repairs, neural transfers and nerve grafts); or later on, myotendinous and bone surgery (tendon transfer, free muscle transfers and/or osteotomies with joint arthrodesis), which expanded the possibilities of functional recovery of the injured upper limb.

The objective of the present study was to evaluate the clinical characteristics and functional gain of the upper limb in patients who underwent surgical treatment after traumatic brachial plexus injuries.

Methods

This was a retrospective study conducted through reviewing the medical files of a convenience sample of 48 patients with traumatic brachial plexus injury who were operated consecutively at the Hand and Microsurgery Service between December 2000 and December 2010.

Initially, 68 medical files were found, from which 20 were excluded because they did not present complete data. The main reason for this was discontinuity or interruption of the treatment follow-up. Cases of obstetric or tumor injuries, or lesions due to infection, were excluded. The clinical and sociodemographic characteristics of all 48 patients were evaluated before they underwent surgery.

The clinical characteristics evaluated were: (1) age group; (2) sex; (3) side affected; (4) origin; (5) type of work before the accident; (6) type of accident; (7) interval between traumatic brachial plexus injury and the first appointment at the specialized care service; (8) interval between traumatic brachial plexus injury and the first surgery performed by the specialized team; (9) association with multiple trauma; (10) level of the neural injury (trunks affected), determined through physical examination, electromyography and the initial surgical findings; (11) type of neural injury according to electromyography; (12) types of surgeries performed.

The functional recovery parameters of the upper limb consisted of the pre- and post-surgery clinical examinations, in a standing position. Regarding the overall functional characteristics, the following were evaluated: (1) joint range of motion (ROM), in degrees, of the shoulder, elbow and wrist/hand, measured through manual goniometry; (2) degree of strength of the shoulder, elbow and wrist/hand, measured using the muscle strength scale of the British Medical Council (M0 = absence of activity; M1 = fasciculation; M2 = movement cannot overcome gravity; M3 = movement overcomes gravity; M4 = movement overcomes a resistance force; M5 = normal strength); (3) sensitivity of the injured limb (classified into anesthesia, hypoesthesia and normal); (4) pain, which was recorded on a visual analogue scale (VAS), ranging from 0 to 10, where 0 is the total absence of pain and 10 the worst pain ever reported (0–3 = mild pain; 4–7 = moderate; 8–10 = intense).

The following functional parameters were considered satisfactory (10–21): (1) ROM: shoulder abduction $\geq 30^{\circ}$, elbow flexion $\geq 80^{\circ}$, wrist extension $\geq 30^{\circ}$; (2) strength: shoulder abduction $\geq$ M3, elbow flexion $\geq$ M3, wrist extension $\geq$ M3; (3) sensitivity: hypoesthesia and normal; (4) pain: VAS ≤ 3 or reduction of 50% of the initial value.

The data were gathered and stored in the Excel for Windows software, and were analyzed using statistical software (SPSS version 13.0 for Windows). All samples were evaluated using the Student *t*, chi-square, Friedman and Wilcoxon tests for parametric data and the Kruskal–Wallis test for nonparametric data. The significance level was taken to be $p \leq 0.05$.

Results

Out of the 48 patients with traumatic brachial plexus injuries, only one (2%) was female, and 24 cases (50%) were on the right side. The mean age was 30.6 years (range: 14–59): seven patients (14.6%) were 10–20 years old, 33 (68.8%) were 21–40, and eight (16.7%) were 41–60. Regarding the origin of the patients, 20 (41.7%) were from the state capital, 11 (22.9%) from towns in the region surrounding the state capital, 12 (25%) from elsewhere in the same state and five (10.4%) from other states. Regarding the type of work that the patients were doing before the accident, 16 (33.3%) were unemployed, 18 (37.5%) were laborers and 12 (25%) administrative, among whom six (12.5%) were motorcycle couriers and two (4.2%) were intellectuals.

Regarding the types of accidents (Fig. 1), 29 patients (60.4%) were on motorcycles; 10 (20.8%) were in cars; one (2.1%) was run over; five (10.4%) suffered injuries from weapons, of which two cases (4.2%) were gunshot wounds and three cases (6.2%) were stabbings; one patient (2.1%) suffered an accident at home and two (4.2%) at work. The mean interval between traumatic brachial plexus injuries and the first doctor appointment was 4.2 months (range: 1–17) and until the surgery was 8.7 months (range: 2–48). Eight patients (16.8%) underwent surgery between 1 and 3 months after their injury, 19 (39.3%) between 3 and 6 months, 12 (25%) between 6 and 12 months, and nine (18.9%) more than 12 months after traumatic brachial plexus injury. These were musculoskeletal operations, and not neural, because of the time at which they arrived. Patients in the age group between 21 and 40 years underwent surgery significantly earlier (less than 6 months after injury) than the others ($p = 0.023$).

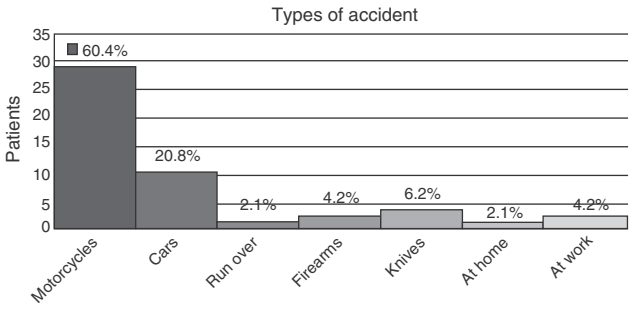

Fig. 1 – Types of accidents suffered by patients with traumatic brachial plexus injury, with highest frequency of motorcycle accidents.

Regarding the presence of multiple trauma, 25 patients (52.1%) presented other forms of trauma in addition to the brachial plexus injury (Table 1).

The complementary examination used for evaluating traumatic brachial plexus injuries was electroneuromyography. Concerning the level of the neural injury (Fig. 2), 31 patients (64.6%) presented total brachial plexus injury: 12 (25%) in the upper trunk, three (6.2%) in the upper and middle trunks, and two (4.2%) in the middle and lower trunks. Regarding the type of neural injury (Fig. 3), 20 (41.6%) presented neurotmesis, 24 (50%) axonotmesis and four (8.4%), neuropraxia, among which 10 (20.8%) were avulsions. The Claude–Bernard–Horner syndrome was found in five patients (10.4%). A significant correlation was observed between the level of neural injury seen on physical examination (trunks affected), electroneuromyography ($p < 0.001$) and the initial surgical finding ($p = 0.003$). In addition, factors such being a laborer ($p = 0.007$) or having a

Table 1 – Trauma associated with brachial plexus injury.

Trauma	No. of patients	(%)
1. Clavicle fracture	11	22%
2. Traumatic brain injury	5	10%
3. Forearm fracture	5	10%
4. Face injury	3	6%
5. Lower-limb fracture	2	4%
6. Upper-limb fracture	2	4%
7. Arterial injury of the shoulder	2	4%
8. Rib fracture	1	2%

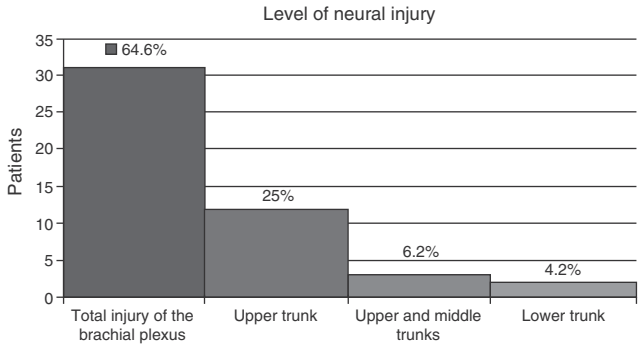

Fig. 2 – Level of neural injury in patients with traumatic brachial plexus injury.

Table 2 – Neural surgical procedures performed on brachial plexus injuries.

Type of neural surgery	No. of patients	(%)
1. Neurolysis and sural grafts	28	58.4
2. Neurotization from the ulnar to the median and musculocutaneous nerves	13	27
3. Neurotization from the accessory to the suprascapular nerve	10	20.8
4. Direct neurorrhaphy of the ulnar	9	187
5. Neurotization from the ulnar to the musculocutaneous nerve	5	10.4
6. Neurotization from the intercostal to the musculocutaneous nerve	4	8.4

motorcycle accident ($p = 0.012$) presented a correlation with total brachial plexus injury.

Regarding the type of surgery performed initially, 39 patients (81.3%) underwent neural surgery (Table 2), seven (14.5%) muscle-tendon transfers (flexor-pronators for the wrist and fingers extensors) and two (4.2%) wrist arthrodesis. A second surgical procedure was performed on 20 patients (41.6%), among which 18 were muscle-tendon transfers, one neurotization and one wrist arthrodesis.

The time until the second surgery varied greatly, from 2 to 60 months after the first procedure. Out of the 18 muscle-tendon transfers performed on this occasion, two were for stabilizing the shoulder, two for finger movement and 14 for elbow flexion.

Regarding the gain of ROM of the shoulder, the following results were observed: 42 patients (87.5%) did not present any movement after the traumatic brachial plexus injury and only six (12.5%) had ROM $\geq 30^\circ$ (stable). After the surgical treatment, 20 patients (41.6%) improved their ROM, and this change was significant ($p = 0.001$). The range was from 30° to 90°, with a mean of 73°, in 14 patients who did not have any ROM and six who already had some ROM and achieved improvements.

Regarding the gain of ROM of the elbow, the following results were observed: 43 patients (89.6%) did not present any motion after traumatic brachial plexus injuries and only five (10.4%) had ROM $\geq 30^\circ$. After the treatment, a gain of elbow flexion $\geq 80^\circ$ occurred in 27 patients (56.2%), with a range from 30° to 160°, with a mean of 80.6° ($p < 0.001$), 22 did not have any ROM and five had some ROM and achieved improvement.

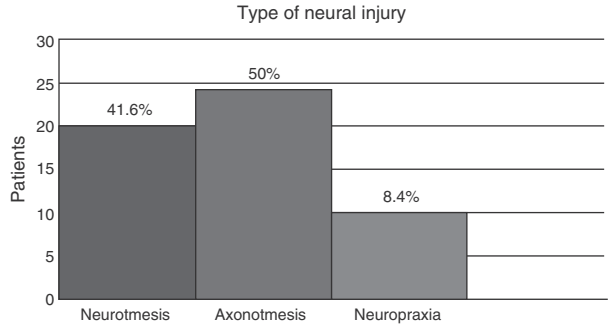

Fig. 3 – Type of neural injury in patients with traumatic brachial plexus injury.

Regarding the gain of ROM of the wrist/hand, the following results were observed: 34 patients (70.8%) presented the wrist/hand in the total flexion position (45°) without active motion after traumatic brachial plexus injury, seven (14.6%) had ROM $\geq 30^\circ$ and seven (14.6%) had total ROM (90°). After treatment, a gain of wrist extension $\geq 30^\circ$ beginning at 45° of flexion occurred in 22 patients (45.8%) and this ranged from 30° to 90°, with a mean of 70° for these patients ($p < 0.001$). There were 13 who did not have any ROM and nine who had some ROM and achieved improvement.

Regarding the gain of shoulder strength, the following results were observed: 42 patients (87.5%) did not present any functional muscle activity after their injury to the plexus, and only six (12.5%) had strength $\geq$ M3. After the surgeries, 13 (27.1%) had strength $\geq$ M3 and six (12.5%) evolved from M0 to M2 (stable shoulder). These changes were significant ($p < 0.001$).

Regarding the gain of elbow strength, the following results were observed: 44 patients (91.6%) did not present any functional muscle activity after traumatic brachial plexus injury, and only four (8.4%) had strength $\geq$ M3. After treatment, 30 patients (62.5%) presented improvements in elbow flexion strength, and 22 achieved strength $\geq$ M3 ($p < 0.001$).

Regarding the gain of wrist/hand strength, the following results were observed: 26 patients (54.2%) did not present any functional muscle activity after traumatic brachial plexus injury, while 22 (45.8%) had strength $\geq$ M3. After the surgeries, 27 (56.3%) had strength $\geq$ M3. These changes were significant ($p = 0.002$).

Regarding sensitivity after the plexus injury, 33 (68.6%) presented hypoesthesia and 15 (31.2%) had anesthesia. After the surgical procedures, 45 (93.8%) presented hypoesthesia and three (6.2%) had anesthesia. This evolution of sensitivity was significant over the course of time ($p = 0.006$). None of the patients recovered normal sensitivity, in comparison with the uninjured side.

Pain after trauma, evaluated through the visual analogue scale (VAS), ranged from 1 to 9, with a mean of 4.5. Nine patients presented mild pain (18.8%), 35 moderate (72.9%) and four intense (8.3%). After the treatment, 24 patients (50%) presented mild pain and 24 (50%) moderate. None of the patients continued to have intense pain. The mean VAS after treatment was 3 (range: 1–7). This reduction of pain was also significant over the course of time ($p < 0.001$).

Discussion

There is great difficulty in diagnosing and treating traumatic brachial plexus injury because it is infrequent and highly complex. Few centers have specialized professionals and material for this type of treatment, either in Brazil or in other countries. The post-surgical functional results are obtained over the long term (usually after 1 or 2 years) and many patients are unable to adhere to rehabilitation due to their precarious socioeconomic conditions.

Difficulties in public services in relation to making clinical diagnoses and providing care in referral centers, difficulty in performing complementary examinations such as electroneuromyography and magnetic resonance imaging, long intervals between accident and surgery, constant need (for many years) to go to the rehabilitation center and functional results below patients' expectations are the most common factors that lead patients to abandon their treatment.[1] In the present study, this could be observed because of the diversified origins of the patients. In addition, the mean interval from the traumatic brachial plexus injury to the first appointment (4.2 months), and until the surgery (8.7 months), worsened the prognosis. Twenty-one patients (43%) underwent surgery more than 6 months after their injury.

Many of our patients were performing low-qualification manual activities before their accidents. Many of these activities demand physical effort, which limits these patients' reintegration into the work market after the accident and compromises their incomes. Many do not even have social security benefits (INSS) or are reassigned to other functions because they are not performing work under a formal contract or are unemployed.[10] Our data show that at the time of the accident, the study population consisted of young unemployed men, laborers or motorcycle couriers. This patient group was unable to return to the work market, and this also leads to losses for society, which has to bear the cost of their early retirement.

According to the Ministry of Health, young people have more motorcycle accidents than the general population.[11] Motorcycle accidents are closely related to traumatic brachial plexus injuries. Several studies have proven this high prevalence of morbidity and mortality. Even in countries where people do not ride motorcycles because the snow does not allow them to do so, accidents involving similar means of transportation such as snowmobiles present high incidence of traumatic brachial plexus injuries.[10–14] Data from the microsurgery service of our institution reveal that between 2004 and 2007, among the 160 patients with traumatic brachial plexus injuries who were treated, approximately 60% of the cases were caused by motorcycle accidents.[1] In the present study, 62% of the patients with traumatic brachial plexus injuries had had motorcycle accidents.

Regarding the clinic characteristics of patients with traumatic brachial plexus injuries, there was a strong association with the presence of multiple trauma in 25 patients (52%), especially clavicle fractures in 11 (22%) and traumatic brain injury (TBI) in five (10%). Several studies in the literature have shown this clinical association, which can hamper the initial diagnosis of traumatic brachial plexus injuries and delay the beginning of proper treatment.[2–4] Many patients are only sent for evaluation of the plexus in referral centers after fractures and multiple trauma have been treated.

Regarding the level of the neural injury, 31 patients (64.5%) presented total brachial plexus injury, which corroborates the data in the literature and transforms traumatic brachial plexus injuries into quite a severe situation that leaves sequelae.[1–4,14–19] The trauma mechanism comprising traction of the brachial plexus in car accidents, due to the high-energy impact, leads to neural injuries of greater severity. This was also confirmed by the electromyography performed on these patients, regarding the type of neural injury: 20 patients (41.6%) presented neurotmesis and 24 (50%) axonotmesis.

Surgeries for treating traumatic brachial plexus injuries can be divided into neural, muscle-tendon and bone. Neural surgeries should preferably be performed not more than 6 months after injury in order to obtain a better prognosis regarding reinnervation. Neural procedures can be intraplexural or extraplexural and are considered to present high complexity.[14–19] In the present study, the initial surgical procedures were most frequently of neural type, which were performed in 39 cases: 28 cases of neurolysis in association with neurorrhaphy with sural grafts; 24 cases of neurotization of which the most common ones were 13 from the ulnar to the median and musculocutaneous nerves and 10 from the accessory to the suprascapular nerves; and nine neurorrhaphy procedures. In the second operation, the procedure most often performed was muscle-tendon, with 18 transfers, of which 14 were for elbow flexion.

Regarding the sensitivity after surgical treatment of traumatic brachial plexus injuries, a significant improvement was observed in 12 patients (25%) who moved from anesthesia to hypoesthesia ($p = 0.006$), although none of them recovered their normal sensitivity, compared with the uninjured side. Post-trauma pain varied in intensity, with an initial mean of 4.5 (range: 1–9) and final of 3 (range: 1–7). This 25% reduction of pain was significant over the course of time ($p < 0.001$). This agrees with the literature, which shows a long-term improvement of pain of 30%, after surgery.[20] Pain may have an impact on the quality of life of these patients, even if they present significant functional gains.[21,22]

Regarding the gain of shoulder strength, only a third of the patients presented abduction $\geq$ M3 after the first surgery, while recovery in approximately two-thirds of the patients has been reported in literatures.[23,24] Regarding the gain of elbow strength, only half of the patients presented flexion $\geq$ M3 by the end of the treatment, while recovery of approximately two thirds of the patients has been reported in literatures.[23–25] These results can be explained by the difficulties and delays in accessing better treatment that exist in third-world countries, with few referral centers for treating traumatic brachial plexus injury.

Physical examination is still the method most used for evaluating post-surgery results from surgical reconstruction of traumatic brachial plexus injuries, but this presents limitations because, from a functional point of view, it cannot express all the magnitude and complexity of this injury.[4,26] Several studies have managed to advance toward more complete criteria for how to evaluate the function of the injured limb, such as through isokinetic measurements of the driving force in individual muscle groups, as well as measurements

through questionnaires and scales such as DASH (Disability of Arm, Shoulder and Hand). In addition, it does not take into consideration an evaluation of the patient himself, which can be performed through instruments such as the McGill, SF-36 and WHOQOL-bref scales, for evaluating quality of life.[27–30]

Conclusion

Traumatic brachial plexus injuries present higher prevalence among young male adults (21–40 years old), individuals living in urban areas and laborers. They are mostly caused by motorcycle accidents and are associated with multiple trauma, with total plexus injury, most frequently comprising neurotmesis or axonotmesis. The most common surgical procedures were neural (neurolysis, neurorrhaphy, grafts and neurotization), followed in a second procedure by muscle-tendon transfers for to achieve gains of elbow flexion.

Surgical treatment of traumatic brachial plexus injuries was effective, with improvements of range of movement and the strength of shoulders, elbows and wrists/hands, along with improvement of the sensitivity of the affected limb and reduction of the final pain.

Conflicts of interest

The authors declare no conflicts of interest.

REFERENCES

1. Traspadine PC. Acidentes de mtocicletas e sua relação com a lesão do plexo braquial. In: Bijos P, Correa JFG, editors. Plexo braquial. Rio de Janeiro: Di Livros; 2011. p. 43–58.
2. Terzis JK, Kostopoulos VK. The surgical treatment of brachial plexus injuries in adults. Plast Reconstr Surg. 2007;119(4):73e–92e.
3. Bijos P. Lesões de plexo braquial. In: Bijos P, Zumiotti AV, Rocha JR, Ferreira MC, editors. Microcirurgia reconstrutiva. São Paulo: Atheneu; 2005. p. 199.
4. Oberlin C. Brachial plexus palsy in adults with radicular lesions, general concepts, diagnostic approach, and results. Chir Main. 2003;22(6):273–84.
5. Homero OM, Nienkotter S. Ilíada. Campinas, SP: Editora Unicamp; 2008.
6. Toffolo L, Silva JB. Lesões traumáticas do plexo braquial no adulto: diagnostico e tratamento. Acta Méd (Porto Alegre). 2010;31:157–64.
7. Thorburn W. Secondary suture of brachial plexus. Br Med J. 1900;1:1073–5.
8. Harris W, Low VW. Importance of accurate muscular analysis in lesions of the brachial plexus and the treatment of Erb's palsy and infantile paralysis of the upper extremity by cross-union of nerve roots. Br Med J. 1903;2:1035–8.
9. Seddon HJ. The use of autogenous grafits for the repair of large gaps in peripheral nerves. Br J Surg. 1947;35(138):151–67.
10. Cavalcante J, Jorge Neto F. O portador de deficiência no mercado formal de trabalho. São Paulo: Atheneu; 2001.
11. Brasil. Análise do Ministério da Saúde revela que os acidentes com motos foram os que mais cresceram no país desde a década de 1990. Disponível em: www.saude.gov.br.
12. Koizumi S. Padrão das lesões nas vítimas de acidentes por motocicletas. Rev Saude Publica. 1992;26(5):306–15.
13. Denatran. Estatística relacionada aos acidentes com vítimas fatais e não fatais entre 2002 e 2006 envolvendo motocicletas. Disponível em: www.denatran.gov.br.
14. Bengtson KA, Spinner RJ, Bishop AT, Kaufman KR, Coleman-Wood K, Kircher MF, et al. Measuring outocomes in adult brachial plexus reconstruction. Hand Clin. 2008;24(4):401–15.
15. Bishop AT. Functioning free-muscle transfer for brachial plexus injury. Hand Clin. 2005;21(1):91–102.
16. Vekris MD, Beris AE, Lykissas MG, Korompilias AV, Vekris AD, Soucacos PN. Restoration of elbow function in severe brachial plexus paralysis via muscle transfers. Injury. 2008;39 Suppl. 3:S15–22.
17. Barrie KA, Steinmann SP, Shin AY, Spinner RJ, Bishop AT. Gracilis free muscle transfer for restoration of function after complete brachial plexus avulsion. Neurosurg Focus. 2004;16(5):E8.
18. Doi K, Hattori Y, Ikeda K, Dhawan V. Significance of shoulder function in the reconstruction of prehension with double free-muscle transfer after complete paralysis of the brachial plexus. Plast Reconstr Surg. 2003;112(6):1596–603.
19. Doi K, Muramatsu K, Hattori Y, Otsuka K, Tan S, Nanda V, et al. Restoration of prehension with the double free muscle technique following complete avulsion of the brachial plexus. Indications and long-term results. J Bone Joint Surg Am. 2000;82(5):652–66.
20. Terzis JK, Vekris MD, Soucacos PN. Outcomes of brachial plexus reconstruction in 204 patients with devastating paralysis. Plast Reconstr Surg. 1999;104(5):1221–40.
21. Kretschmer T, Ihle S, Antoniadis G, Seidel JA, Heinen C, Börm W, et al. Patient satisfaction and disability after brachial plexus surgery. Neurosurgery. 2009;65 4 Suppl.:A189–96.
22. Ciaramitaro P, Mondelli M, Logullo F, Grimaldi S, Battiston B, Sard A, et al. Traumatic peripheral nerve injuries: epidemiological findings, neuropathic pain, and quality of life in 158 patients. J Peripher Nerv Syst. 2010;15(2):120–7.
23. Merrell GA, Barrie KA, Katz DL, Wolfe SW. Results of nerve transfer techniques for restoration of shoulder and elbow function in the context of a meta-analysis of the English literature. J Hand Surg Am. 2001;26(2):303–14.
24. Chuang DC, Lee GW, Hashem F, Wei FC. Restoration of shoulder abduction by nerve transfer in avulsed brachial plexus injury: evaluation of 99 patients with various nerve transfers. Plast Reconstr Surg. 1995;96(1):122–8.
25. Terzis JK, Kostas I. Muscle target responsiveness to 718 intercostal nerve neurotizations in severe posttraumatic brachial plexus lesions. Plast Reconstr Surg. 2008;110:615.
26. Bengtson KA, Spinner RJ, Bishop AT, Kaufman KR, Coleman-Wood K, Kircher MF, et al. Measuring outcomes in adult brachial plexus reconstruction. Hand Clin. 2008;24(4):401–15.
27. Choi PD, Novak CB, Mackinnon SE, Kline DG. Quality of life and functional outcome following brachial plexus injury. J Hand Surg Am. 1997;22(4):605–12.
28. Kitajima I, Doi K, Hattori Y, Takka S, Estrella E. Evaluation of quality of life in brachial plexus injury patients after reconstructive surgery. Hand Surg. 2006;11(3):103–7.
29. Ahmed-Labib M, Golan JD, Jacques L. Functional outcome of brachial plexus reconstruction after trauma. Neurosurgery. 2007;61(5):1016–22.
30. Fleck MP, Louzada S, Xavier M, Chachamovich E, Vieira G, Santos L, et al. Application of the Portuguese version of the abbreviated instrument of quality life WHOQOL-bref. Rev Saude Publica. 2000;34(2):178–83.