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Original Article

Evaluation of the surgical treatment of humeral shaft fractures and comparison between surgical fixation methods☆

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ABSTRACT

Objective: The objective of this study is to analyze the surgical results of humeral shaft fracture treatment and describe its epidemiology.
Methods: Retrospective study that identified all patients treated with surgical fixation of humeral shaft fractures between December of 2014 and June of 2016 in a trauma reference center. All medical records were reviewed in search of epidemiological data referent to the trauma and post-operative results, including radiographic healing of the fracture and related complications.
Results: Fifty-one patients were included, mostly male (78.4%), with an average age of 35.02 years. The most common trauma mechanism was a traffic accident (56.9%) followed by same-level falls (17.6%). No statistically significant difference was found between healing time comparing surgical fixation techniques, including open reduction and internal fixation, minimally invasive technique, intramedullary nailing, and external fixation.
Conclusion: Although each technique has inherent advantages and disadvantages, all fixation methods proved to be adequate options for the surgical treatment of humeral shaft fractures with high rates of healing and low rates of post-operative complications.

☆ Study conducted at Hospital do Trabalhador, Curitiba, PR, Brazil.

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Avaliação das fraturas diafisárias do úmero tratadas cirurgicamente e comparação entre os métodos de fixação cirúrgica

Palavras-chave:
Epidemiologia
Úmero
Fraturas do úmero
Fixação de fratura
Osteossíntese
Fixação intramedular de fraturas
Consolidação da fratura

RESUMO

Objetivo: Descrever o perfil dos pacientes com fraturas diafisárias do úmero, bem como analisar os resultados das diferentes modalidades cirúrgicas.

Método: Estudo retrospectivo baseado na identificação de todos os casos de fraturas diafisárias de úmero submetidas a tratamento cirúrgico entre dezembro de 2014 e junho de 2016 em um serviço de referência em trauma, bem como na análise dos respectivos prontuários, e que buscou dados epidemiológicos referentes ao trauma e resultados pós-operatórios, inclusive tempo de consolidação e complicações relacionadas.

Resultados: Foram incluídos 51 pacientes, dos quais a maioria do sexo masculino (78,4%), com média de 35,02 anos. O mecanismo de trauma mais prevalente foram acidentes de trânsito (56,9%), seguidos de quedas de mesmo nível (17,6%). Não foi encontrada diferença significante entre o tempo de consolidação dos diferentes métodos, inclusive redução aberta e fixação interna com placa e parafusos, técnica minimamente invasiva com placa em ponte, haste intramedular e fixação externa.

Conclusões: Todos os métodos cirúrgicos avaliados mostraram-se adequadas opções para o tratamento cirúrgico das fraturas da diáfise do úmero, ainda que tenham vantagens e desvantagens inerentes a cada técnica, com altas taxas de consolidação e poucas complicações relatadas.

Introduction

Humeral shaft fractures represent up to 3% of all skeletal fractures[1] and approximately 20% of fractures involving the humerus.[2] Its incidence is bimodal, with a first peak near the third decade of life, mainly in men, and a second most prominent peak in women, around the seventh decade.[3]

Classically, the treatment of choice is conservative, but the morbidity and the related complications, as well as lower tolerance of the surgeon and the patient to what is considered an acceptable residual deformity, have led to a greater indication for surgical treatment.[3]

The main surgical methods include plate and screw fixation, including open reduction and minimally invasive techniques, intramedullary nails (IMN), and external fixation; all these methods present high rates of consolidation in the literature.[1]

The usual indications for surgery include exposed fractures, associated neurovascular injury, joint fracture extension, polytrauma, extensive associated soft tissue injury, pathological fractures, and failure of conservative treatment. Relative indications are those regarding obese patients, cases associated with brachial plexus injury and muscular atrophy, and patients who did not adhere to conservative treatment.[1,3]

This study is aimed at performing a retrospective analysis of surgically treated humeral shaft fractures in order to evaluate and compare types of surgical fixation, consolidation rate, main complications, and to draw an epidemiological profile of the patients who underwent this surgery in a large hospital.

Methods

This was a retrospective, observational, and quantitative study, based on the identification of all patients who underwent surgical treatment of humeral shaft fractures from December/2014 to June/2016, based on the procedure code found in the surgical registry book of this medical facility. The study was approved by the Ethics Committee for Human Research under no. 58374316.0.0000.5225 on September 29, 2016.

The hospitalization and outpatient follow-up records of all patients retrieved were analyzed, including the imaging tests performed during this period. Humeral shaft fractures were defined as those in the area between the surgical neck of the humerus and the area immediately above the condyles. The collected data included: age at the trauma, gender, trauma mechanism, side, presence of bone exposure, presence of associated lesions, AO/OTA classification, hospitalization time, intensive care unit (ICU) stay, time to bone consolidation, and complications. Patients with incomplete medical records, pathological fractures, loss to follow-up, or death during the study period were excluded.

After hospital discharge, outpatient follow-up was performed according to the routine of this medical facility, at two weeks, six weeks, three months, six months, and one year postoperatively. Cases with complications or associated lesions returned to the clinic according to the need for follow-up. The minimum follow-up time was six months for patients with bone consolidation, and one year for patients with delayed consolidation or pseudarthrosis.

Table 1 – Epidemiology of 51 cases of humeral shaft fractures included in the study.

	Number	%
Gender		
Male	40	78.4
Female	11	21.6
Age		
Up to 20 years	8	15.7
21–30 years	15	29.4
31–40 years	14	27.4
41–50 years	6	11.8
Over 50 years	8	15.7
Side		
Right	21	41.2
Left	30	58.8
Trauma mechanism		
Traffic accidents	29	56.9
Motorcycle accidents	22	–
Car accidents	5	–
Run-over injury	2	–
Same-level falls	9	17.6
Falls from a height	6	11.8
Firearm injury	6	11.8
Sports trauma	1	1.9
AO classification		
A	34	66.7
B	7	13.7
C	10	19.6

The obtained data were analyzed and compared with those of the literature. Statistical analyzes were performed using the GRAPHPAD PRISM statistical package, considering a level of significance of 5% ($\alpha = 0.05$). The chi-squared test was used to analyze trauma mechanisms; the G test for the relationship of pseudarthrosis and surgical techniques; analysis of variance, for non-parametric data; and the Kruskal–Wallis test, for the association of surgical techniques and different consolidation times.

Results

A total of 66 patients who underwent surgical treatment for humeral shaft fracture in the period studied were retrieved. Of these, 15 were excluded, according to the aforementioned criteria. Of the 51 patients included in the study, 40 (78.4%) were males and 11 (21.6%) were females. The mean age was 35.02 years (range: 15–69), with a younger mean age in males: 32 years, *versus* 46 years in females. The most prevalent side was the left side, accounting for 58.8% of the cases.

The main trauma mechanism observed was traffic accidents, accounting for 29 (56.9%) cases, followed by same-level falls (nine cases, 17.6%), and falls from a height and firearm injuries (six cases each, 11.8%). Finally, one case (1.9%) of fracture after torsional trauma was recorded. Table 1 summarizes the demographic and trauma mechanism data.

According to the AO classification, 34 fractures were classified as A; of these, ten (19.6%) were classified as A1, six (11.8%) as A2, and 18 (35.3%) as A3. Seven other cases were classified as type B, of which four (7.8%) were B1 and three (5.9%) B2; no case of type B3 was observed. Finally, ten cases were classified as C, of which five (9.8%) were classified as C1, one (1.9%) as C2, and four (7.9%) as C3. The patients classified as type C presented the highest mean time of hospitalization, ten days, *versus* seven and six days of types A and B, respectively. Type C patients also presented a higher incidence of other lesions in 70% of cases, in contrast to 47% in type A and 57% in type B, as well as a higher incidence of bone exposure (50% of cases).

Table 2 – Sample sizes, mean, and standard deviation of the consolidation time (in months) of each surgical technique used. The *p*-value is associated with the Kruskal–Wallis test.

Surgical technique	*n*	Mean	Standard deviation	*p*
EF[a]	3	5.7	3.8	0.176
IMN[b]	5	3.0	0.0	
Bridge plating	11	4.3	1.6	
ORIF[c]	26	3.9	2.7	

[a] External fixation.
[b] Intramedullary nail.
[c] Open reduction and internal fixation.

Among the methods used for definitive treatment, the most prevalent was open reduction and internal fixation (ORIF) with plate and screws, performed in 29 (56.9%) cases. With this method, fracture healing was observed at two to 14 months postoperatively (mean: 3.8 months). Three cases of pseudoarthrosis were identified, accounting for 10.3% of the patients who underwent this method of treatment. The second most prevalent method was bridge plating, in 12 cases (23.5%). The mean time of consolidation was 4.8 months, ranging from three to eight months; only one case of pseudoarthrosis was observed (8.3%).

IMNs were used in five cases (9.8%); in all, bone consolidation was observed at three months; no cases of treatment failure were observed in the present sample. Finally, in five cases (9.8%), external fixation (EF) presented a mean consolidation of 5.6 months, ranging from 3 to 10 months. Two cases of pseudoarthrosis were observed, representing 40% of the patients treated with the method. In the statistical analysis, no significant difference was observed between the methods in relation to consolidation time, as shown in Table 2. Fig. 1 presents the distribution of the values (in months) found for each surgical technique.

Regardless of the definitive fixation method, 16 (31.4%) patients underwent external fixation as initial treatment, 13 had bone exposure, two had arterial lesions on the same limb, and one was polytraumatized with multiple fractures. External fixation was not performed in only one patient with an exposed fracture; this case was treated with bridge plating on the same day of emergency admission. In addition to the five patients in whom the EF was the definitive treatment, nine patients were converted to ORIF with plate and screws and two with bridge plating.

Among the patients studied, in 25 (49%) the only lesion identified at admission was the humeral shaft fracture. There were 15 cases of other associated osteoarticular lesions, 14 of nerve lesions, two of vascular lesions, and four of lesions in other systems. The most common nerve injury was that

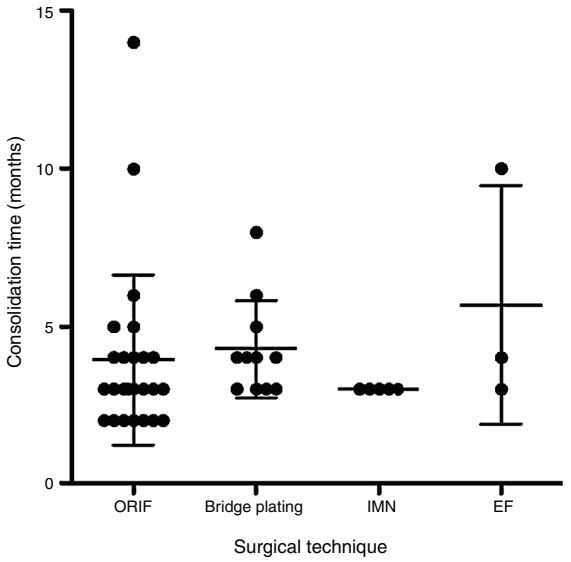

Fig. 1 – Mean and standard deviation of consolidation time (in months) of each surgical technique. No significant differences were observed between the groups ($p = 0.176$).

of the radial nerve, in 11 cases, followed by the ulnar nerve (two cases), and one case of brachial plexus lesion. Only seven cases of radial nerve injury were identified at the time of admission and only three showed complete improvement during outpatient follow-up without the need for a new surgical procedure.

Discussion

The present study identified 51 cases of humeral shaft fractures that underwent surgical treatment. Large population studies show a female predominance in humeral shaft fractures,[4–6] but this tendency is not always confirmed by other studies. Tsai et al.[7] analyzed the epidemiology of humeral shaft fractures over a five-year period in Taiwan and reported a predominance in men in the third decade of life; those authors suggested a correlation with the difference in age distribution among countries where the data were collected. Studies presenting surgical results in smaller samples, such as those by Connolly et al.[8] (53 patients), Kumar et al.[9] (30 patients), and Zogaib et al.[10] (22 patients), are in agreement with the distribution observed in the present study, with a predominance of males between the third and fourth decades of life. A lower mean age and a higher male prevalence may be related to higher-energy trauma and to cases that were not susceptible to conservative treatment.

Regarding the trauma mechanisms, in the present study a higher prevalence of traffic accidents was observed, followed by same-level falls, falls from a height, and firearm injury. This distribution is similar to that found by Tsai et al.,[7] who observed as main trauma mechanisms traffic accidents (63.2%), same-level falls(15.1%), and falls from a height (11.3%). The main difference is the prevalence of firearm injuries, which represented 11.8% of the present sample; in the study by Tsai et al., these injuries were grouped with other trauma mechanisms, accounting for less than 5% of the patients. This divergence may be correlated with socioeconomic factors in the studied locations, suggesting a difference in the urban violence indices.

In the analysis of the mechanism of trauma by gender, a difference was observed in the prevalence of firearm injuries in the male group (15% of cases, *versus* zero cases among female patients). A higher percentage of same-level falls was observed in the female group, with 27.2% of the cases *versus* 15% in the male group. The female patients with humeral fractures by this mechanism had a higher mean age than those of the same gender, 51 years. These data follow the trend observed in the scientific literature, which demonstrates a higher prevalence of same-level falls in women in higher age groups.[4] No statistically significant association of gender and trauma mechanisms was observed in both groups.

Traffic accidents were similar between the groups (57.5% in men and 54.5% in women), although the type of accident was different between the groups. Run-over injuries and motorcycle falls were more frequent in females: 9% and 36.3% *versus* 2.5% and 12.5% in males, respectively. In the male group, 32.5% of the accidents involved a motorcycle collision (against a fixed object or other vehicles), while no cases were found in the female group. Such differences between the genders corroborate the literature data, which show a greater involvement of women in traffic accidents as passengers or pedestrians, while men are mostly involved as drivers.[11]

There is no consensus in the literature regarding the best method of treatment for humeral shaft fractures. Although retrospective studies, such as that by Mahabier et al.,[2] presented similar results between conservative and surgical treatments, a recent systematic review[12] was unable to retrieve randomized controlled trials to evaluate these results.

Similarly, there is no clear definition of the best surgical technique. Most patients are still treated with plate and screws, but IMN and minimally invasive techniques have their place too.[3] The present study corroborates this trend: most patients (56.8%) underwent ORIF with plate fixation. Another possibility for surgical treatment is the use of flexible nails, such as Ender nails, which present good postoperative radiographic and functional results, as recently demonstrated by Godinho et al.,[13] besides the implant being cheaper. However, the authors do not have experience with the use of this material for comparison.

A recent meta-analysis[14] compared the results of surgical treatment with plates and intramedullary nails, demonstrating similar rates of non-consolidation, postoperative infection, and radial nerve injury. The only statistically significant difference observed was of the incidence of delay in consolidation, which was higher in the IMN group. Conversely, a rate of 10.3% of pseudarthrosis was observed in the group that underwent plate fixation in the present study, which was higher than that found in the literature (3%[15]–6%[16]); in turn, no cases of pseudarthrosis were observed in the group that underwent fixation with IMN, possibly due to the sample size. The failure rates of the treatments

were not statistically associated with the different surgical methods.

The minimally invasive technique has also found its place for its minor soft tissue injury during the procedure,[17] despite the concern regarding deformities resulting from an inadequate reduction of the fracture and safety for the radial nerve.[18] In the current study, similar non-consolidation rates were observed between the ORIF with plate and screws group and the bridge plating group (10.3% and 8.9%, respectively), which is in agreement with the literature findings.[17,18] Both groups presented the same number (two) of patients with radial nerve praxia after the procedure that had not been identified on admission. In their meta-analysis, Hu et al.[17] demonstrated a statistically significant difference in radial nerve injury after the procedure, higher in the group of conventional osteosynthesis with ORIF with plate and screws.

The main indication for EFs is temporary stabilization in polytrauma or severe cases; they are not recommended as a definitive method.[1] Nonetheless, Scaglione et al.,[19] evaluated the use of this method as a definitive treatment, achieving a consolidation rate of 97.6% in a mean time of 12 weeks. These data differ from those found in the present study, in which a 40% pseudoarthrosis rate and a mean of 5.6 months until consolidation were observed; however, the present sample was small. Such differences are probably related to the profile of patients in each study, since at this medical facility EFs are only used as definitive treatment in exceptional cases. All patients in the present sample had bone exposure, and only one of them was not classified as polytrauma, despite the fact that the mechanism of injury was of high energy (firearm injury). Both cases of pseudoarthrosis were classified as type C fractures by the AO classification, and the bone exposure was classified as grades 3 A and 3 C of Gustilo and Anderson. In the aforementioned study, only four patients had bone exposure, out of a total sample of 85.

The limitations of the present study were the small number of patients undergoing surgical treatment with IMN and EF, which hindered the comparison between the groups, and the lack of functional evaluation of the affected limb after consolidation. The number of patients excluded from the initially retrieved sample (15) could have contributed to a more significant comparison between the compared surgical groups.

Conclusion

The main surgical treatments for humeral shaft fractures are ORIF with plate and screws, minimally invasive technique with bridge plating, and IMN. In the present study, it was observed that all methods presented high rates of consolidation, with few reported complications, proving to be suitable options for the surgical treatment. EFs were the definitive method of treatment in some cases of high-energy trauma, presenting a high rate of pseudoarthrosis. This incidence may be related to the type of fracture and adjacent soft tissues lesions, but the present sample did not include enough cases to allow a definitive conclusion.

Conflicts of interest

The authors declare no conflicts of interest.

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