



TREATMENT OF HUMERAL SHAFT FRACTURES: ANTEGRADE INTERLOCKING INTRAMEDULLARY NAILING WITH ADDITIONAL INTERLOCKING NEUTRALIZATION SCREWS THROUGH FRACTURE SITE

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SUMMARY – The aim of this study was to compare union time between two different nail designs for the treatment of humeral shaft fracture, i.e. antegrade interlocking intramedullary nail with and without additional interlocking neutralization screws. The retrospective study included 51 patients treated with antegrade humeral intramedullary nailing between January 2015 and December 2017. The inclusion criteria of the study were proximal and middle third humeral shaft fractures. Fifty-one patients met the inclusion criteria; 23 patients were treated with antegrade intramedullary nail with additional interlocking neutralization screws through fracture site (group A) and 28 patients were treated with antegrade intramedullary nail without additional interlocking neutralization screws (group B). Medical documentation and radiographic images taken preoperatively and postoperatively were reviewed. Radiological union was defined as cortical bridging of at least three of four cortices in two-plane radiographs, with disappearance of the fracture gap. There were no significant differences in union time between the groups ($p > 0.05$). To our knowledge, this is the first report of antegrade interlocking humeral nailing with additional interlocking neutralization screws through fracture site. Hypothetical advantages of fracture gap reduction by additional interlocking neutralization screws to promote union were not confirmed by this first clinical trial.

Key words: *Humerus; Humeral fractures; Fracture fixation, intramedullary; Bone and bones*

Introduction

Humeral shaft fractures account for up to 3% of all fractures and 20% of all fractures of the humerus^{1,2}. Humeral shaft fracture incidence is bimodal, with the first peak in young males as the result of high-energy trauma, and the second most prominent peak in wom-

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en between sixty and eighty years of age, as the result of low-energy trauma^{3,4}. Humeral shaft fractures can be treated conservatively and operatively. Conservative treatment has been proven as an excellent method with very low complication rate⁵. However, some fracture patterns are not suitable for conservative treatment such as periarticular and long spiral fractures. It has to be emphasized that the outcome of conservative treatment is strongly influenced by patient compliance as well^{6,7}. Internal fixation can be performed *via* intramedullary nailing or plating. Intramedullary nailing has shown some advantages in terms of biological fixation with preservation of blood supply⁸. Intramedullary nail is a load-sharing device and should be considered as the treatment of choice for pathological fractures as well⁹. There are two insertion possibilities of humeral intramedullary nails: antegrade insertion with entry point at the shoulder and retrograde insertion with entry point at the elbow, each associated with entry site morbidity¹⁰. Many authors still consider osteosynthesis with plate as the gold standard because they refer to complications associated with the old design of noninterlocking nails in previous studies¹¹⁻¹⁴. However, contemporary interlocking nails showed similar results in fracture healing in comparison with plating^{15,16}. It can be difficult to perform closed reduction or obtain the required stability from fixation with an intramedullary nail in highly unstable fractures of the humeral shaft in which there are complex or severely displaced fragments, and such difficulties could result in delayed union or non-union¹⁷. In our study, it was hypothesized that using interlocking neutralization screws through fracture site would improve stability and reduce fracture gap, thus promoting union. The aim of this study was to compare union time between two different nail designs, i.e. antegrade interlocking intramedullary nail with and without additional interlocking neutralization screws.

Patients and Methods

The present retrospective study included 51 patients treated with antegrade humeral intramedullary nailing between January 2015 and December 2017 at Department of Traumatology, Sestre milosrdnice University Hospital Centre in Zagreb, Croatia. The inclusion criteria of the present study were proximal and middle third humeral shaft fractures, whereas the ex-

clusion criteria were non-unions, pathological and periprosthetic fractures. Patients were divided into group A treated with intramedullary nail with additional interlocking neutralization screws through fracture site and group B treated with intramedullary nail without neutralization screws. Proximal and distal interlocking screws were used in both groups. In group A, proximal interlocking screws and additional interlocking neutralization screws were inserted by targeting device according to the nail technical guidelines, and distal interlocking screws were inserted by free-hand technique. Medical documentation and radiographic images taken preoperatively and postoperatively were reviewed. We analyzed union rate and time to union and delayed union. All fractures were classified using the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification system by reviewing the radiographs¹⁸. Radiological union was defined as cortical bridging of at least three of four cortices in two-plane radiographs, with disappearance of the fracture gap¹⁹. Delayed union was defined as failure of radiological union at 4 months post fracture with no progress towards healing seen on the most recent radiographic images. Patients were followed-up for 6 months. The decision on intramedullary osteosynthesis with additional interlocking neutralization screws through fracture site or without neutralization screws was made by the attending surgeon, based upon his knowledge and expertise. Statistical analysis was performed by using the IBM SPSS Statistics version 23. Outcomes of union were compared between group A and group B, and were defined as categorical variables as follows: time to union <4 months and >4 months. Results of categorical variables were analyzed using the χ^2 test or Fisher exact test if cell counts were less than five. The level of $p < 0.05$ was considered statistically significant.

Results

In total, 96 humeral shaft fractures were treated operatively. We excluded 45 patients mostly with insufficient follow up. This study included 51 patients: 23 patients were treated with antegrade intramedullary nail with additional neutralization screws through fracture site (group A) and 28 patients were treated with antegrade intramedullary nail without additional neutralization screws (group B). Representative radio-



Fig. 1. Group A at admission.



Fig. 2. Group A: one month postoperatively.



Fig. 3. Group A: final follow-up.



Fig. 4. Group B at admission.



Fig. 5. Group B: one month postoperatively.



Fig. 6. Group B: final follow-up.

graphs of group A patients and group B patients at admission, one month postoperatively, and at final follow up are shown in Figures 1-6.

The majority of patients were female (60.8%) and the mean age at the time of injury for all patients was 61.3 years.

Table 1 shows distribution of fractures according to AO types and subtypes. Type A humeral shaft fractures were most common (54.9%) and type C least common (17.7%). The A1 spiral humeral shaft fracture was the most common subtype (41.2%).

The overall delayed union rate was 11.76%. One patient with delayed union was in group A and five patients with delayed union were in group B. In group A, patients with delayed union (A1 subtype) had transitory radial nerve palsy. In group B, four patients with delayed union (A1, A2, B1 and C3 subtypes of fracture) had proximal nail migration and one patient with delayed union (A3 subtype of fracture) had too short nail. Time to union did not differ significantly between the groups (Tables 2 and 3). There was a trend towards

faster union time in group A; however, this trend was not statistically significant ($p=0.204$, two-sided Fisher exact test). Overall, we noted two cases of postoperative transitory radial nerve palsy that fully recovered within 6 months.

Discussion

The main operative goal of humeral shaft fractures is to restore alignment, length and rotation with stability that allows early motion²⁰. Interlocked intramedullary nailing of humeral shaft fractures is one of the few possible treatment options for humeral shaft fractures. In early years, studies showed controversial results of humeral shaft fracture treatment comparing plating with nailing due to disadvantages of old intramedullary nail design²¹. For example, the Seidel nail had complications such as rotational instability and intraoperative fracture caused by insecure distal locking mechanism and too large nail head²². The later Russell-Taylor nail had rotational instability due to discrepancy between the size of screw and the hole²³. However, with improved nail designs and operative technique, more recent studies have reported satisfactory results with nailing^{15,16,24}. Contemporary nails have demonstrated improved clinical results with proximal and distal multiple locking screws²⁵⁻²⁷. Proximal and distal interlocking screws tend to provide rotational stability and prevent shortening or lengthening of the humerus. Biomechanical studies have also shown that

Table 1. *Arbeitsgemeinschaft für Osteosynthesefragen (AO) types and subtypes*

AO type	Frequency	Percent	AO subtype	Frequency	Percent
A	28	54.9	A1	21	41.2
			A2	2	3.9
			A3	5	9.8
B	14	27.4	B1	10	19.6
			B2	4	7.8
C	9	17.7	C1	7	13.7
			C2	1	2.0
			C3	1	2.0
Total	51	100.0	Total	51	100.0

Table 2. *Type of intramedullary nail/time to union cross tabulation*

		Time to union		Total
		<4 months	>4 months	
Type of intramedullary nail	Nail with additional interlocking neutralization screws through fracture site	22	1	23
	Nail without additional interlocking neutralization screws	23	5	28
Total		45	6	51

Table 3. χ^2 and Fisher exact tests

	Value	df	Asymptotic significance (2-sided)	Exact sig. (2-sided)	Exact sig. (1-sided)
χ^2 test	2.220 ^a	1	0.136		
Fisher exact test				0.204	0.146
Valid cases (n)	51				

interlocking nails ensure increased stability in comparison with non interlocking nails in rotationally unstable humeral fractures²⁸. Distal interlocking of an antegrade humeral nail is more difficult than distal interlocking in the femur or tibia because of triangular distal humerus shape and lateral x-ray view of the humerus cannot be easily obtained. Freehand distal interlocking of intramedullary nails requires a long learning curve and orthopedic surgeons have difficulty with it at the beginning of their professional career²⁹. Humeral shaft fractures can be treated with antegrade or retrograde nails³⁰. In our study, we performed antegrade nailing for proximal and middle third humeral shaft fractures because of insertion from the shorter to the longer fragment. Biomechanical studies showed increased stability if the nail was inserted from the shorter to the longer fragment¹⁰. The main complications of antegrade humeral nailing are nail migration, distraction, long proximal locking screws, additional diaphyseal fracture, rotator cuff pain and shoulder impingement³¹⁻³³. In our study, the main complication was proximal nail migration with overall four cases in group B. Several studies demonstrated delayed union rates of 9%-19% after operative treatment³⁴⁻³⁶. Data from our study (11.76%) are comparable with those found in current literature. Gender distribution (female 60.8%) and AO fracture type distribution (A type 54.9%) in our study is consistent with the current epidemiological literature¹.

To our knowledge, this is the first report of antegrade interlocking humeral nailing with additional interlocking neutralization screws through fracture site. The application of additional interlocking neutralization screws is suitable for the fracture in the proximal third of the humeral shaft and for the long oblique and long spiral fracture in the middle third of the humeral shaft with extension in proximal third. By applying these screws, the fracture distraction can be prevented during humerus manipulation owing to inserting distal interlocking screws by freehand technique because the additional neutralization screws are placed near the fracture site by targeting device before the distal interlocking screws. Additional interlocking neutralization screws can prevent the postoperative complication of proximal nail migration, as suggested by the fact that there was no proximal nail migration in group A. The benefit of additional interlocking neutralization screws is fracture gap reduction without opening

the fracture site, thus preserving blood supply and allowing biological fixation for some unstable humeral shaft fractures. Additional interlocking neutralization screws can promote union by reducing fracture gap as well. However, hypothetical advantages of fracture gap reduction by additional interlocking neutralization screws to promote union were not confirmed in this first clinical trial. The additional interlocking screw across fracture site acts as a positioning screw that neutralizes fragments, thus it does not apply any interfragmentary compression. However, this can be considered as a possible disadvantage that can interfere with fracture healing. Nevertheless, we did not observe such a complication, which might be explained by completely preserved blood supply that promotes fracture healing regardless of the screw applied through the fracture site. The limitation of our study was retrospective, non-randomized study design. The decision on operative treatment between group A and group B was made by attending surgeon according to his preferences and previous experience. Data on the functional outcome and time to full resumption of daily activities were unavailable in this retrospective study. In conclusion, further randomized prospective study should be performed in a larger sample to evaluate time to union, functional outcome and time to early motion in correlation with reducing fracture gap by additional neutralization interlocking screws. A biomechanical study should be performed to examine the stability of interlocking intramedullary nail with additional interlocking neutralization screws in comparison with interlocking intramedullary nail without these screws.

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Sažetak

PRIJELOMI DIJAFIZE HUMERUSA: LIJEČENJE ANTEGRADNIM USIDRENIM ENDOMEDULARNIM ČAVLOM S PRIMJENOM NEUTRALIZACIJSKIH VIJAKA KROZ FRAKTURNU PUKOTINU

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Cilj ovoga istraživanja bio je usporediti vrijeme cijeljenja prijeloma dijafize humerusa pri liječenju s dva različita dizajna intramedularnog čavla: antegradni ukotvljeni intramedularni čavao s dodatnim ukotvljenim neutralizacijskim vijcima i bez njih. Retrospektivna studija obuhvatila je 51 bolesnika liječenog antegradnim humeralnim intramedularnim čavlima između siječnja 2015. i prosinca 2017. godine. Kriteriji uključanja u studiju bili su prijelomi proksimalne i srednje trećine dijafize humerusa. Pedeset i jedan bolesnik je ispunio kriterije uključanja: 23 bolesnika su liječena antegradnim intramedularnim čavlom s dodatnim ukotvljenim neutralizacijskim vijcima kroz mjesto prijeloma (skupina A), a 28 bolesnika je liječeno antegradnim intramedularnim čavlom bez dodatnih ukotvljenih neutralizacijskih vijaka (skupina B). Analizirana je medicinska dokumentacija i radiološke slike učinjene prije i poslije operacije. Radiološko cijeljenje prijeloma definirano je kao kortikalno premošćivanje najmanje tri od četiri korteksa u dvoprofilnim radiografima, s nestankom frakturne pukotine. Nije bilo značajne razlike u vremenu cijeljenja prijeloma između skupina ($p > 0,05$). Prema našim spoznajama, ovo je prva studija o liječenju prijeloma humerusa antegradnim intramedularnim čavlom s dodatnim ukotvljenim neutralizacijskim vijcima kroz mjesto prijeloma. Hipotetsku prednost redukcije prijelomne pukotine s dodatnim ukotvljenim neutralizacijskim vijcima u svrhu poticanja cijeljenja nije potvrdila ova prva klinička studija.

Ključne riječi: *Humerus; Humerus, prijelomi; Prijelom, fiksacija, intramedularna; Kosti*