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Original Article

Ultrasound evaluation of the rotator cuff after osteosynthesis of proximal humeral fractures with locking intramedullary nail☆

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ABSTRACT

Objective: To evaluate supraspinatus tendon integrity with ultrasound (US) in patients submitted to proximal humeral fracture (PHF) fixation with a locking intramedullary nail.

Methods: Thirty-one patients with PHF treated with curvilinear locking intramedullary nail, aged between 50 and 85 years, were assessed by US at six months postoperatively and clinically at six and 12 months postoperatively. The primary aim was supraspinatus tendon integrity, evaluated by US at six months postoperatively. Secondary aims included the Constant-Murley, DASH score, and visual analog pain scores, as well as complications and reoperation rates.

Results: Full-thickness rotator cuff ruptures were observed in four patients (13%), supraspinatus ruptures in three cases (10%), and subscapularis ruptures in one case (3%). Partial ruptures were diagnosed in 10 cases (32%). The results using the Constant-Murley score at 12 months were 71.3 ± 15.2 points for the entire series, with 73.2 ± 16.1 points for patients without rotator cuff ruptures and 68.7 ± 14.1 points for those with partial or complete ruptures, without a statistically significant difference ($p = 0.336$). Complications, exclusively for rotator cuff ruptures, were observed in nine patients (29%).

Conclusion: A high rate of rotator cuff ruptures was demonstrated, with partial ruptures in 32% of cases and full-thickness ruptures in 13%. However, clinical results are satisfactory, and are not influenced by the presence of rotator cuff ruptures.

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Avaliação ultrassonográfica do manguito rotador após a osteossíntese de fraturas da extremidade proximal do úmero com haste intramedular bloqueada

Palavras-chave:
Fraturas do ombro
Fixação intramedular de fraturas
Manguito rotador
Ultrassonografia

RESUMO

Objetivo: Avaliar a integridade do tendão do supraespinal por meio da ultrassonografia (US) em pacientes submetidos à fixação de fraturas da extremidade proximal do úmero (FEPU) com haste intramedular bloqueada.

Métodos: Foram avaliados por exame de ultrassonografia aos seis meses de pós-operatório e clinicamente aos seis e 12 meses de pós-operatório 31 pacientes com FEPU entre 50 e 85 anos, tratados com haste intramedular bloqueada inclinada. O objetivo primário foi avaliar a integridade do tendão supraespinal e os secundários incluíam descrever os demais achados da ultrassonografia, as escalas de Constant-Murley, EVA e Dash e a taxa de complicações e comparar os resultados clínicos dos pacientes com e sem rotura do manguito rotador.

Resultados: Roturas transfixantes do manguito rotador foram observadas em quatro pacientes (13%), com rotura do supraespinal em três casos (10%) e do subescapular em um caso (3%). Roturas parciais foram diagnosticadas em dez casos (32%). Os resultados pela escala de Constant-Murley aos 12 meses foram de 71,3 ± 15,2 pontos para toda a amostra, de 73,2 ± 16,1 pontos para os pacientes sem rotura do manguito rotador e de 68,7 ± 14,1 pontos para aqueles com rotura parcial ou completa (p = 0,336). Complicações, exclusive a rotura do manguito rotador, foram observadas em nove pacientes (29%).

Conclusão: Observou-se uma alta taxa de alterações nos tendões do manguito rotador, com roturas parciais em 32% dos casos e transfixantes em 13%. No entanto, os resultados clínicos são satisfatórios, não influenciados pela presença de rotura do manguito rotador.

Introduction

Fractures of the proximal humerus (PHF) are the third most common fracture in the elderly.[1] Despite the current controversy over the advantages of surgical treatment,[2,3] deviated fractures are commonly treated with fixation or arthroplasty, with a 25% increase in surgical indications in five years.[4]

Locked intramedullary nails have been used for PHF since before the development of locked plates[5]; however, they have not achieved the same popularity, with the main reasons being related to the potential risks of rupture of the rotator cuff, and because they do not help in the reduction of fractures.[6,7] However, there are biomechanical advantages[8–10] for the use of nails, and they can be used through minimally invasive approaches, with less potential damage to soft tissues.[11]

Clinical results are similar among patients undergoing osteosynthesis with locking plates or nails.[6,7,12–15] However, there is disagreement as to which one generates a higher rate of complications.[6,14,16] The risk of rupture or changes in the rotator cuff after intramedullary nails has been scarcely studied,[7,13,17,18] and no article mentions a standardized and detailed evaluation of the rotator cuff.

The primary aim of the study was to evaluate the integrity of the supraspinatus tendon by means of ultrasonography (US) in patients submitted to the fixation of PHF with a locking intramedullary nail. The secondary aim was to correlate the presence of rupture of the rotator cuff with the Constant-Murley, DASH and VAS scores, and to compare the clinical results of patients with and without rotator cuff rupture.

Methods

Study design

A prospective study involving 31 patients with fractures deviated from the proximal humeral extremity, underwent surgical treatment with locking intramedullary nail through a minimally invasive anterolateral approach. The patients were part of a previous randomized study[19] and were operated between March 2011 and December 2014 at the same Center. The operations were performed by the same surgeon, with the same model of implant. The protocol was approved by the Ethics Committee of our medical facility.

Participants

Inclusion criteria were ages between 50 and 85 years, PHF with deviation ≥1 cm or ≥45 degrees of angulation between the head and the humeral shaft, with or without major tubercle involvement. Fractures of the minor tubercle, regardless of deviation, and fracture-dislocations were not included. Patients with neurological injuries, associated fractures in the affected limb, pathological fractures, and previous surgery of the affected shoulder or previously diagnosed full thickness rupture of one of the rotator cuff tendons were also not

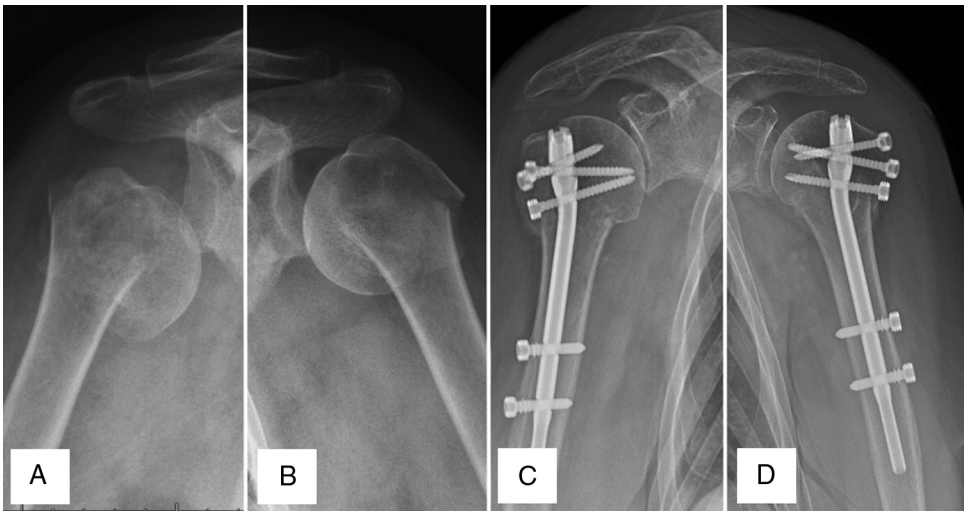

Fig. 1 – (A) Bilateral fracture of the humeral proximal extremity, deviated in varus, right shoulder; (B) left shoulder; (C) radiographs, at three months postoperatively of fixation with intramedullary nail, right shoulder; (D) left shoulder.

included. Patients with irreversible rupture of the rotator cuff, those who did not undergo US, or those with loss of follow-up before the first clinical evaluation at 3 months were excluded.

Surgical treatment

The locking intramedullary nail used was Centronail® (Orthofix®, Verona, Italy), made of titanium, 15 cm long and 7 cm thick, and with a slightly curved proximal end.

A longitudinal anterolateral transdeltoid approach of 5 cm was made, beginning at the anterolateral extremity of the acromion. The deltoid muscle was dissected between the anterior and middle portions up to 5 cm distal to the acromion, with no release from its origin, and up to the identification of the subacromial bursa and the rotator cuff. The supraspinatus and infraspinatus tendons were identified and sutured with polyester non-absorbable surgical thread. The humeral head was reduced and provisionally secured with two Kirschner wires percutaneously from the anterior face of the diaphysis toward the posterosuperior portion of the humeral head. In cases with larger tubercle fractures, transosseous sutures with polyester surgical thread were made, and the fracture was reduced before passing the intramedullary nail.

Following fracture reduction and temporary fixation of the humeral head to the diaphysis, access was made for insertion of the intramedullary nail. After palpation of the small tubercle and tendon of the long head of the biceps, a guidewire was positioned 1 cm posterior to the intertubercular groove and 1 cm medial to the transition between the humerus head and the greater tubercle, that was confirmed by radioscopy with the shoulder at 30 degrees of external rotation. After confirmation of the correct positioning of the wire, the 1.5-cm longitudinal opening of the supraspinatus tendon was performed with a scalpel, near the medial border of the greater tubercle, without damaging its attachment.

The guidewire was then inserted, and its correct positioning checked with radioscopy. A 2-cm deep resurfacing of the humeral head was performed. There was no need to ream the humeral metaphysis and diaphysis. The nail was introduced and we sought to maintain its upper portion 5 mm below the surface of the humeral head. The nail was proximally locked with three screws and distally with two screws. A channel plug was then inserted. Tension band sutures were made around the proximal screws, with the non-absorbable surgical threads passed in the supraspinatus and infraspinatus tendons. The opening of the supraspinatus tendon was sutured with at least three simple sutures with polyester # 2 non-absorbable surgical thread, followed by deltoid muscle, subcutaneous and skin sutures.

The sling was used for four weeks and physical therapy started after 14 days, with passive and active assisted exercises for the gain of range of motion. Active exercises were started after 30 days, and active resistance exercises after two months.

Outcome

The primary outcome adopted was the evaluation of the integrity of the supraspinatus tendon through an ultrasound (US) examination performed at the sixth postoperative month. Secondary outcomes were: the Constant-Murley[20] and EVA scores and the DASH questionnaire,[21] and other US findings, as well as complications and reoperations. The Constant-Murley score was assessed at 6 and 12 months postoperatively and the other scores at 12 months. The clinical scoring was applied by an evaluator who did not participate in the rehabilitation or clinical follow-up of the patient.

An ultrasound examination was performed at six months postoperatively to assess the integrity of the rotator cuff. The examinations were made in the radiology department of the institution by the same team of musculoskeletal radiologists. The Logiq E9 (GE Healthcare, Waukesha, WI) device was used with linear transducer ML6-15 (6- to 15-MHz linear ML-6-15, GE Healthcare). The findings related to the rotator cuff tendons were classified, according to the affected tendon, in normal tendon, tendinopathy, partial (articular, bursal or interstitial)

Table 1 – Clinical characteristics of patients undergoing osteosynthesis with locked intramedullary nail.

	n	Rotator cuff		*p*
		No rupture (*n* = 18)	Partial + complete rupture (*n* = 13)	
Age, years		65.7 ± 9.5	63.5 ± 9.4	0.541
Smoking	4	1 (25%)	3 (75%)	0.284
Female gender	21	13 (62%)	8 (38%)	0.530
Dominant side	20	13 (65%)	7 (35%)	0.291
Osteoporosis	9	6 (67%)	3 (33%)	0.535
Time between trauma and surgery, days		10.2 ± 3.5	10.2 ± 4.4	0.995
Cuff rupture (intraoperative)	2	2 (100%)	0	0.497
Neer classification				
2 parts	15	10 (67%)	5 (33%)	0.347
3 parts	16	8 (50%)	8 (50%)	
Coronal deviation				
Varus	16	11 (69%)	5 (31%)	0.285
Valgus	14	7 (50%)	7 (50%)	
Neutral	1	0	1 (100%)	

and transfixing rupture. In the presence of a lesion, the retraction and extension of the rupture was observed. All tendons of the rotator cuff were evaluated. The long head of the biceps tendon was evaluated for integrity, tendinopathy and stability.

Complications were written down according to their occurrence and the total number recorded separately for each patient. The reoperations and type of surgery were also recorded.

Statistical analysis

We evaluated the normality of the data through the Shapiro–Wilk test and equality through the Levene test. We disclose the continuous variables in mean and standard deviations and the categorical variables in absolute and percentage values.

For the analysis of the outcome, the patients were divided into two groups, according to the absence or presence of cuff rupture. Patients with complete rupture were compared to those without rupture. Those with partial ruptures were grouped with full rupture for comparison with those without rupture. The correlation between the independent variable (integrity of the supraspinatus tendon evaluated by the US) and the dependent variables (Constant-Murley and EVA scores and DASH questionnaire) was done using the Anova test (parametric data) or the Friedman test (non-parametric data).

The software SPSS version 20.0 (SPSS Inc®, Chicago, IL, USA) was used for data analysis, and the level of significance of 5% was adopted.

Results

Thirty-six patients were operated on with a locked intramedullary nails. Of these, five were excluded, four due to loss of follow-up and one because the US was not performed. The general data of the series can be seen in Table 1. Follow-up was 12 months for all patients. Figs. 1 and 2 show the clinical and radiographic results.

The US examination was performed on 31 patients. Fig. 3 shows an evaluation. This examination showed a transfixing rupture of the rotator cuff in four cases (13%), with involvement of the supraspinatus tendon in three patients, and of the subscapularis in one case. The mean extension of transfixing supraspinatus ruptures was 8 mm and the mean retraction was 9 mm. Partial ruptures were diagnosed in 10 cases (32%), with all of them affecting the supraspinatus tendon at the joint surface. Two patients revealed rupture of the rotator cuff intraoperatively and were submitted to repair. No recurrence of tendon rupture was detected in these patients, and had an average of 92 points on the Constant-Murley score. US data can be observed in Table 2.

Table 2 – Results of ultrasound examination for evaluation of rotator cuff tendons and the long head of the biceps tendon.

Tendon	*n* (%)
Supraspinatus	
Complete rupture	3 (10%)
Partial joint rupture	
<50%	6 (20%)
>50%	1 (3%)
Interstitial rupture	3 (10%)
Tendinopathy	16 (52%)
Normal	2 (6%)
Subscapular	
Complete 1/3 proximal	1 (3%)
Tendinopathy	19 (61%)
Normal	11 (35%)
Infraspinatus	
Tendinopathy	13 (42%)
Normal	18 (58%)
Long head of the biceps	
Rupture	3 (10%)
Tendinopathy	14 (45%)
Normal	14 (45%)

The results by the Constant-Murley score at 12 months were 71.3 ± 15.2 points for the entire series, 73.2 ± 16.1 points for patients without rotator cuff rupture and 68.7 ± 14.1 points for those with partial or complete rupture, with no statistically significant difference ($p = 0.336$). At six months, the mean

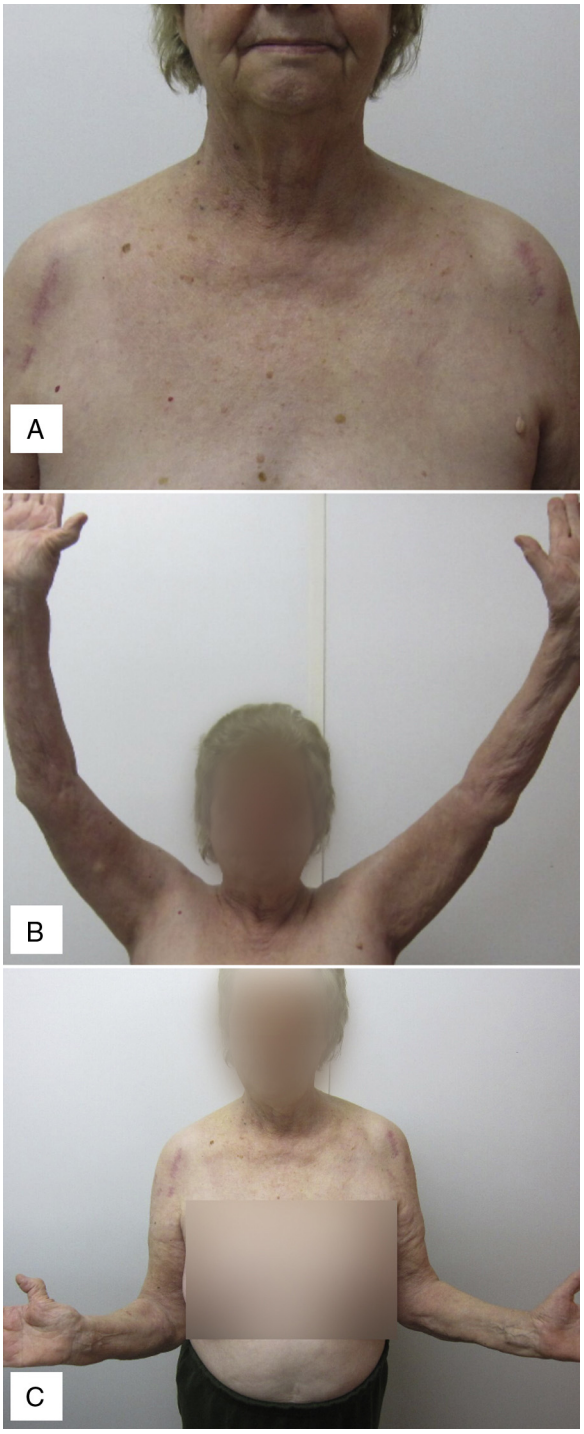

Fig. 2 – Postoperative clinical evaluation at three months demonstrates anterolateral incision (A), elevation (B) and external rotation (C).

average of the whole series was 64.9 ± 17.6 points, in the group without rupture of the rotator cuff it was 67.7 ± 17.3 points and in the group with rupture it was 61, 1 ± 17.9 points, also without statistically significant difference ($p = 0.308$). Patients with rotator cuff transfixation showed a Constant-Murley score of 62.0 ± 21.7 points at 12 months, with no statistically significant difference in relation to the group without ruptures ($p = 0.138$). In the evaluation of the abduction force at 6 and 12 months, we also did not observe differences between the groups.

The results from the 12-month DASH questionnaire were 20.0 ± 18.1 points for the entire series, better in the group without rupture of the rotator cuff (13.7 ± 15.1 versus 20.8 ± 21.0), but without statistically significant difference ($p = 0.270$). By the EVA score at 12 months, the whole series had a mean of 1.5 ± 1 1.9 points and the groups presented mean differences below one point. Clinical outcomes can be seen in Table 3.

Complications, other than rupture of the rotator cuff, were observed in nine patients (29%). The most common complications were shoulder stiffness in four patients (13%), loss of humeral head reduction greater than 10 degrees of the head-shaft angle in three cases (9%), joint protrusion of the proximal screws in three patients (9%), and osteonecrosis in two cases (6%). In no case did the nail remain in an inadequate position, that is, above the greater tubercle. Of the four patients with transfixing rupture of the rotator cuff, two had other complications, with 43.5 ± 6.4 points on the Constant-Murley score at 12 months. The two cases with isolated rupture of the cuff had 80.5 ± 0.7 points. The rotator cuff rupture rate (partial or complete) in patients with some complication was 33%, with no statistically significant difference when compared to cases without other complications ($p = 0.535$). Six patients (19%) underwent reoperations.

Discussion

We demonstrated good clinical outcomes for PHF patients treated with a locked intramedullary nail, with an average of 71 points on the Constant-Murley score throughout the series. Our results were lower than those of Zhu et al.[6] and Konrad et al.,[12] but similar to those of several other authors.[7,13,16,22,23] However, the complication rate was high, as it occurred in 29% of our series, higher than that reported by Zhu et al.[6] (4%) but similar to or lower than in other studies.[7,12,24]

We observed a high rate of rotator cuff changes on ultrasonographic analysis. The most affected tendon was the supraspinatus in 94% of cases, followed by subscapular (64%) and infraspinal (42%). The long head of the biceps tendon showed changes in 55% of the patients. We observed complete ruptures in four cases (13%), higher than those reported by Gradl et al.[7] (3%) and Boudard et al.[13] (3.3%), which describe only transfixing supraspinatus ruptures. Fjalestad et al.[25] describe (partial and complete) ruptures in 28% of non-surgically treated patients evaluated by magnetic resonance imaging.

The presence of rotator cuff changes following PHF occurs irrespective of the treatment method; a rupture is described in 25% of patients treated with non-locked plates, percutaneous fixation or non-surgically.[26] The risk of postoperative supraspinatus tendon changes following fixation with locked intramedullary nail is evident. For the introduction of synthesis material, an incision is necessary, and its microcirculation is diminished, even after it being sutured.[27]

On the other hand, we did not observe clinical repercussion of rotator cuff changes. This is corroborated by studies demonstrating that partial or complete ruptures do not necessarily progress with worse clinical outcomes and may be

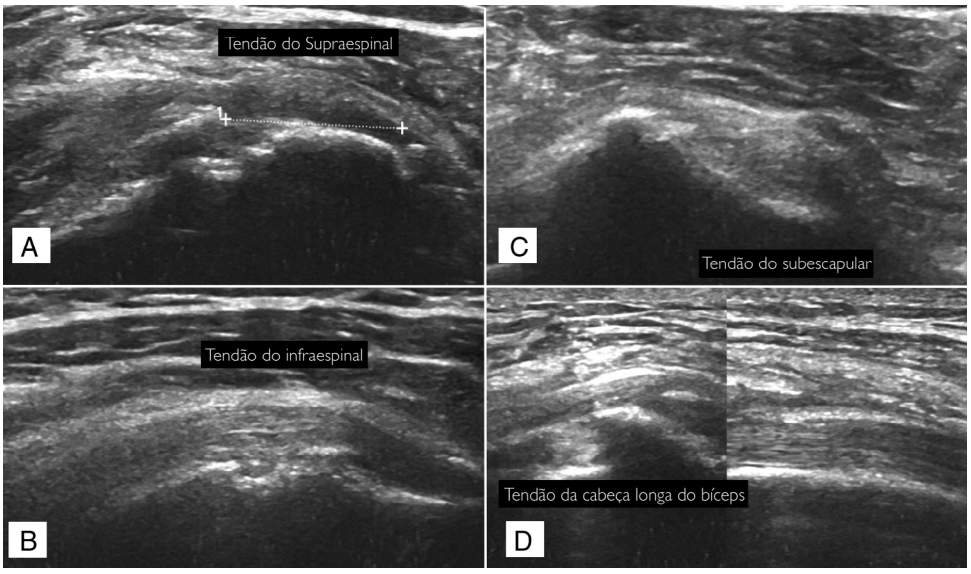

Fig. 3 – Ultrasonographic evaluation of the rotator cuff. (A) Supraspinatus tendon rupture; (B) infraspinatus tendon; (C) subscapular tendon; (D) long head of the biceps tendon.

Table 3 – Results of clinical scoring, compared according to the presence or not of rotator cuff rupture.

Scales	Rotator cuff			
	Total	No rupture ($n = 18$)	Partial + complete ($n = 13$) rupture	p
Constant-Murley points				
6 months	64.9 ± 17.6	67.7 ± 17.3	61.1 ± 17.9	0.308
12 months	71.3 ± 15.2	73.2 ± 16.1	68.7 ± 14.1	0.336
EVA points				
12 months	1.5 ± 1.9	1.2 ± 1.7	1.8 ± 2.1	0.416
DASH points				
12 months	20.0 ± 18.1	13.7 ± 15.1	20.8 ± 21.0	0.270

asymptomatic.[28,29] Of the patients between 60 and 70 years of age, 25.6% may present transfixing rupture of the rotator cuff and up to 16.9% of asymptomatic individuals may present complete ruptures.[30]

As positive points of our study, we can mention that the US was done at the same medical Center, with the same team of musculoskeletal radiologists and with the same device, which increases the internal validity of our measurement. We can also mention that this is the first study to detail rotator cuff analysis after PHF osteosynthesis with locked intramedullary nails, not only describing the presence of transfixing ruptures. In addition, our series was based on a prospective study, with standardized timing.

As limitations, we can mention that the US examination was not previously validated or compared to MRI after fractures of the proximal end of the humerus. Although rotator cuff inspection was performed in all surgeries, it is not possible to rule out the presence of partial ruptures at joint level through intraoperative evaluation. The presence of a previous rupture of the rotator cuff cannot be confirmed by our study, since there is no image analysis before the fracture. Another limitation is related to subgroup analyses. The grouping of partial and complete ruptures was aimed at reducing the comparison bias among small groups, but due to the small number in our series, this comparison may be subject to false negatives. Finally, the model of the nail used, that is slightly curved, presents a greater risk of pain related to the cuff and greater risk of reoperations, as demonstrated by Lopiz et al.[24] Our results show that rotator cuff disorders were present in 64.1% of the series, 41.2% tendinopathy, 11.0% partial rupture and 12.2% complete rupture.

Conclusions

Our study provides an epidemiological basis for rotator cuff ruptures in patients with fractures of the proximal humerus undergoing fixation with a slightly curved locked intramedullary nail. We demonstrated a high rate of alterations in the rotator cuff tendons, with partial ruptures in 32% of cases and transfixing in 13%. However, the clinical results are satisfactory, and are not influenced by the presence of rupture of the rotator cuff, despite the limitations of evaluation due to the small number in our series.

Conflicts of interest

The authors declare no conflicts of interest.

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