ORIGINAL PAPER

Clinical and Sonographic Assessment of Rotator Cuff Damage During Antegrade Humeral Nailing

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Purpose. One of the most controversial points about antegrade humeral nailing is that of potential iatrogenic injuries to the rotator cuff. The purpose of this paper is to determine the clinical and sonographic impact associated to the use of the anterolateral approach.
Materials and methods. Transversal study of a retrospective cohort of 23 patients operated on for humeral diaphyseal fractures at the 12 de Octubre Hospital between 1998 and 2004.
Inclusion criteria. Acute humeral shaft fractures treated by means of antegrade nailing. No age threshold was imposed; minimum follow-up was one year.
Exclusion criteria. Patients with an associated rheumatic pathology were excluded as well as those that had suffered a prior glenohumeral traumatic event or a proximal humeral fracture.
Clinical assessment was conducted with Constant's scale and the sonographic study used the contralateral shoulder as control.
Results. Mean score on Contant's scale was 82 points (range: 49-99), with most patients achieving a good result, i.e. 80% obtained more than 65 points. The only sonographic findings described were a few hyperechogenic lines in 4 patients, which were interpreted as partial ruptures of less than 30 mm. These patients had an acceptable functional outcome, with a score of more than 70 points on Constant's scale.
Conclusions. The results of this study suggest that the use of the anterolateral approach for antegrade humeral nailing, provided that there is careful dissection and posterior suturing of the rotator cuff, as well as a sufficiently medialized entry point on the humeral head, ensures a good functional result with no significant clinical-sonographic impact.

Key words: *antegrade humeral nailing, rotator cuff, humeral shaft, fracture.*

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Valoración clínico-ecográfica de la agresión al manguito rotador en el abordaje anterógrado del enclavado humeral

Objetivo. Uno de los puntos más controvertidos relacionados con la vía de abordaje en el enclavado anterógrado del húmero es la iatrogenia en el manguito de los rotadores. El objetivo de este trabajo ha sido determinar el impacto clínico-ecográfico asociado a este abordaje.
Material y método. Estudio transversal sobre una cohorte retrospectiva de 23 pacientes intervenidos con fracturas diafisarias de húmero en el Hospital 12 de Octubre entre los años 1998 y 2004.
Criterios de inclusión. Fracturas agudas diafisarias de húmero tratadas mediante osteosíntesis con enclavado por vía anterógrada sin límite de edad y seguimiento mínimo de un año.
Criterios de exclusión. Pacientes con patología reumática asociada, antecedente traumático previo glenohumeral o fracturas del húmero proximal antiguas.
La valoración clínica se realizó con el test de Constant y el estudio ecográfico utilizó como control el hombro contralateral.
Resultados. La puntuación media del test de Constant fue de 82 (49-99), con una agrupación general de resultado de la serie bueno: 80% más de 65. Los únicos hallazgos ecográficos observados fueron líneas hiperecogénicas en 4 pacientes, interpretadas como roturas parciales inferiores a 30 mm. Estos pacientes obtuvieron un resultado funcional aceptablemente bueno, sumando más de 70 puntos en el test de Constant.
Conclusiones. Los resultados de este estudio sugieren que la utilización del abordaje anterolateral para el enclavado humeral anterógrado, con una cuidadosa disección y posterior sutura del manguito rotador, así como un punto de entrada en la cabeza humeral suficientemente medial garantizan un buen resultado funcional sin un impacto clínico-ecográfico relevante.

Palabras clave: *enclavado humeral anterógrado, manguito rotador, diáfisis humeral, fractura.*

Treatment of diaphyseal humeral fractures by means of closed intramedullary nailing rather than other techniques contributes a series of undeniable advantages such as minimal incisions, shorter OR times and low infection rates.

Several complications have been described in connection with the antegrade humeral approach, with pain and shoulder dysfunction the most frequent; the rates reported range between 16 and 37% according to several authors[1-4]. Surgical insult to the rotator cuff has been cited as the main source of residual pain.

The purpose of our study is to find out what clinical and sonographic repercussions can be attributed to insults incurred on the rotator cuff during antegrade humeral nailing.

MATERIAL AND METHOD

This is a transversal study of a retrospective cohort of patients operated by means of antegrade humeral nailing between February 1998 and May 2004; the unoperated shoulder was used as control.

Inclusion criteria

Patients with no age limit, acute diaphyseal humeral fractures, antegrade humeral nailing further to successful closed reduction, uneventful fracture healing and minimum one-year follow-up.

Exclusion criteria

Patients with a previously-known traumatic and/or degenerative pathology in both shoulders, the need for open reduction and postoperative complications unrelated to the surgical wound.

Series

Of the 33 patients about whom sufficient documentary information was available, 5 did not comply with the above mentioned criteria; 2 cases developed into pseudoarthrosis because of the implant's lack of stability, one patient with a complex diaphyseal fracture needed open reduction prior to nailing and 2 patients had a previous pathology in the shoulder on the operated side (these were a 65-year-old female subjected two years earlier to an arthroscopic subacromial decompression and a 53-year old male who 3 years earlier had sustained a fracture-avulsion of the greater tuberosity that had been treated conservatively).

Contact with 5 of the 28 remaining patients was not possible. The final series was made up of 23 patients (13 males and 10 females), with a mean age of 50.3 ± 20.33 years (17-81) and a mean follow-up of 17.5 ± 10.96 months (12-32) (table 1).

Table 1. Epidemiological data of the series presented in this study

Patient	Gender	Age	Shoulder injured	Handedness	Mechanism of injury	Delay to surgery (days)	Nail type
1	Female	73	Left	RH	Vehicle	14	AIM
2	Female	50	Left	RH	Pedestrian	0	UHN
3	Female	74	Left	RH	FF	9	AIM
4	Female	22	Left	RH	Vehicle	15	AIM
5	Male	76	Right	RH	FF	0	UHN
6	Male	26	LeftD	RH	Vehicle	2	AIM
7	Male	39	Left	RH	FF	20	AIM
8	Female	64	Left	RH	FF	2	UHN
9	Male	17	Right	RH	FH	4	AIM
10	Female	81	Left	RH	FF	0	UHN
11	Male	30	Left	RH	Vehicle	15	AIM
12	Male	27	Right	RH	Fall/assault	13	POLARUS
13	Male	30	Right	RH	Fall fom	4	MDN
14	Male	42	Left	RH	FF	9	POLARUS
15	Male	39	Right	RH	FF	10	AIM
16	Female	72	Izquirda	RH	FF	6	POLARUS
17	Male	52	Right	RH	FF	3	POLARUS
18	Female	75	Left	RH	FF	4	AIM
19	Female	61	Right	RH	Vehicle	0	AIM
20	Male	27	Right	RH	Vehicle	3	POLARUS
21	Female	62	Left	RH	FF	7	POLARUS
22	Male	57	Left	RH	FF	4	POLARUS
23	Male	61	Right	RH	FF	1	MDN

RH: Right-handed; FF: Fortuitous fall; FH; Fall from height.

Clinical assessment

Active and passive ROM were recorded both for the shoulder and the elbow. Function of the operated and the contralateral shoulder was determined through Constant-Murley's test[5,6]. Elbow mobility was normal in all cases.

Scores obtained in this test were distributed into excellent, ? 80; good, 65-79; fair, 50-64; and poor, < 50.

Sonographic assessment

The sonographic examination was performed in all cases by the same radiologist in our center, who is an expert in musculoskeletal sonography. The sonographic examination comprised the anatomical structures involved by the antegrade approach, as well as a dynamic study of the rotator cuff, which consisted of a dynamic ultrasound assessing subacromial sliding.

The examination was a comparative bilateral one, with the operated shoulders making up the active group and the unoperated ones the control group. Findings were documented and grouped into hyperechogenic areas (interpreted as scars and/or partial tears), calcifications and complete tears. Signal alterations at the point of entry of the nail at humeral level were also recorded.

Statistical study

A referential database collected epidemiological data, bilateral Constant test scores and sonographic reports. This data was processed by the Department of Epidemiology and Clinical Research of our hospital using the most appropriate statistical tests for analyzing each variable, and assigning different levels of statistical significance.

Level of evidence

The study's evidence level was IIIb.

RESULTS

Results of the series

The most frequent mechanism of injury was the fortuitous fall (13 cases), followed by motor vehicle accidents (8 cases); there were also 2 cases of falls from height.

In accordance with the AO classification, we obtained 13 type A simple fractures (5 A1, 5 A2 and 2 A3), 4 type B fractures with a spiral wedge third fragment (B1) and 6 complex type C or multi-fragment fractures (2-C1 and 4-C2). As regards fracture location, 13 were sustained in the middle third, 9 in the proximal third and one in the distal portion of the bone. The fractures occurred predominantly on the left side (14 humeri); 10 occurred in the right humerus. Three patients presented with primary radial nerve palsy.

The mean waiting time between trauma and surgery was 6.4 ± 5.9 days (0-20).

Four different types of nails were used at surgery (UHN, MDN, AIM and POLARUS), which were inserted by means of the same anterior acromial approach, with a longitudinal section of the rotator cuff. Nail diameter ranged between 7 and 9 mm and both proximal and distal blocks were used in all cases.

Clinical results

Mean fracture healing time was 2.97 ± 0.9 months (2-5). In 18 patients, rehabilitation started before clinical-radiological healing was achieved, in order to minimize loss of ROM.

The mean Constant score for the operated shoulders was 82 ± 12.94 points (49-99) as compared with 92.6 ± 6.18 (79-100) points for the healthy shoulders. It should be stressed that 17 of the 23 patients obtained a Constant score higher than 80; all of these were ranked as excellent results. Four patients obtained a mean score lower than 65, all of them women over 60. In two of these (patients 8 and 18), the x-rays performed revealed that the nail had protruded proximally. The third (patient 10), afflicted with primary radial palsy, developed a subacromial syndrome as a result of positive exploratory maneuvers (Neer-Yochun-Hawkins). The fourth patient (number 19) presented with stiffness of the operated shoulder due to the late start of her rehabilitation (four months into her post-op period) because of social problems; this was not attributable to any other cause. Of these four patients, two obtained less than 80 points in the contralateral Constant test (patients 10 and 19) (table 2).

Sonographic results

Of the 23 ultrasounds performed of the operated shoulders, 17 were normal, except for a few cicatrizing changes and/or discontinuities smaller than 10 mm in the supraspinatus (at the point of entry of the nail), with no repercussions whatsoever on the dynamics of the rotator cuff. Evidently, the sonographic images of the two women for whom x-rays revealed a high-riding implant also showed the nail protruding into the subacromial space, which led damaged the cuff and hindered its sliding movement.

In 4 patients (patients 1, 3, 13 and 16) partial tears were found of sizes ranging between 26 and 30 mm, which limited the sliding of the cuff, two of them with calcifications adjacent to the tendinous complex.

Control x-rays of the unoperated shoulders showed partial tears in 6 cases and a pattern of calcific tendinitis in 2 (figs. 1 and 2).

Table 2. Clinical data and results

Patient	Fracture type	Location 1/3	Constant score	Contralateral Constant score	Result
1	A1	Middle third	80	90	E
2	B1	Distal third	78	95	B
3	A3	Middle third	80	85	E
4	A2	Middle third	98	98	E
5	A1	Proximal third	81	97	E
6	A3	Middle third	97	100	E
7	C2	Middle third	85	93	E
8	A2	Middle third	49	81	M
9	A3	Middle third	99	100	E
10	A2	Middle third	64	79	B
11	B1	Middle third	90	98	E
12	C2	Proximal third	86	97	E
13	A2	Middle third	91	97	E
14	C2	Proximal third	95	95	E
15	C1	Proximal third	85	93	E
16	B1	Proximal third	83	92	E
17	A1	Proximal third	95	94	E
18	A2	Middle third	61	90	R
19	A1	Proximal third	67	79	B
20	C2	Middle third	85	96	E
21	A1	Proximal third	86	91	E
22	C1	Proximal third	66	95	B
23	B1	Middle third	85	95	E

G: good; E: excellent; P: poor; F: fair.

Results of the statistical analysis

As expected, an indirect significant relationship was found between the patients' age and the Constant score obtained according to Pearson's correlation, which confirmed that the older the patient the poorer the Constant score ($p = 0.0013 < 0.05$).

The female group obtained poorer functional results than the male group. Likewise, in women the left side got fractured more easily. These findings were also statistically significant according to Student's «t» test ($p = 0.026 < 0.05$) and Fisher's Exact Test ($p = 0.028, < 0.05$). No relationship was found between the severity of the fracture and a presumably worse functional result (ANOVA, $p = 0.9034$).

On comparing the unoperated to the operated shoulders, it was seen that the poorest functional results in operated shoulders also corresponded to poor Constant scores for the supposedly healthy shoulders. Also, a comparison of the ultrasounds of both shoulders showed that the incidental findings of partial tears and/or calcific tendinitis in the healthy shoulders without known prior pathology were present in patients with more pathological postoperative sonograms. This two data is statistically significant both on Pearson's correlation ($p = 0.0005, < 0.05$) and Fisher's Exact Test ($p < 0.0001$), respectively.

A comparison of Constant scores with sonographic findings in the operated shoulders reveals that the cuffs that sonographically appeared more severely damaged, in theory as a result of the nailing procedure, did not correspond to the shoulders with the greatest functional deficit.

This observation proved statistically significant with Student's «t» test ($p < 0.05$).

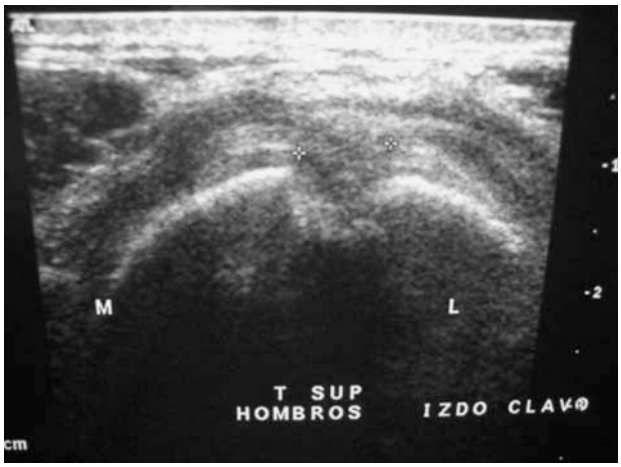

Figure 1. *Postoperative changes (bony notch). Sonographic cross-section of the supraspinatus tendon of the left shoulder showing a discontinuation of the humeral cortex as well as a heterogeneous focal area of the supraspinatus tendon in relations with the entry of the nail.*

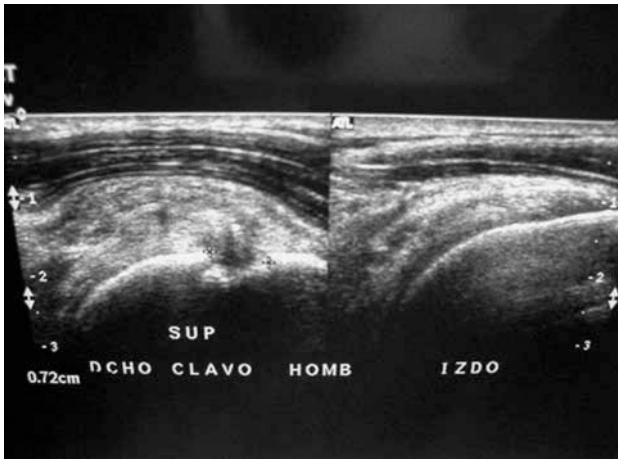

Figure 2. *Postoperative changes (bone notch). Sonographic longitudinal section of both supraspinatus tendons showing a bony notch and a small heterogeneous area on the right supraspinatus tendon at the point of entry of the intramedullary nail.*

DISCUSSION

When selecting the best treatment option for a diaphyseal humeral fracture consideration should be given to the patient's characteristics, the fracture type and the bone quality present. In our recent experience, the best results have been obtained through antegrade nailing. Although this is

not the only approach we use, it is the one we perform most frequently. Alleged iatrogeny to the rotator cuff is still a moot point and remains the chief argument against our preferred approach[2,7,8]. Residual pain and shoulder dysfunction have been the most frequently studied variables by different authors[3,4,9,10]. The purpose of our work has been to consider whether such complications resulted from the damage caused to the joint during the antegrade procedure, or perhaps they could be attributed to other causes, such as the existence of a previous pathology or the commission of technical errors in the performance of the nailing procedure.

We chose rather strict inclusion/exclusion criteria with the sole purpose of focusing the study on our cause/effect model, avoiding any bias that could be brought about by patients with residual complications: infection, delayed healing, pseudoarthrosis. We believe that choosing diaphyseal fractures that healed uneventfully makes it possible to conclude that the functional deficit that might be found can be attributed exclusively to surgical insult caused during the nailing procedure. This strict anatomical criterion, which eliminates the nailing surgeries carried out in our Department to address proximal and metaphyseal fractures, significantly reduces the number of cases in the series, but we think that at the end of the day it permits a greater accuracy of the variable under study, i.e. insults to the rotator cuff, than would be possible otherwise.

Excluding from the study those patients with a known previous pathology in both shoulders, traumatic or degenerative, to a certain degree limits any bias or confounding factor that may exist. Nonetheless, six patients without any deficit in their unoperated cuff showed a certain degree of tendinopathy on their sonographic study. One might wonder whether these findings would have been obtained had the control ultrasound been performed at the time of surgery (prospective cohorts). This type of limitation is inherent in any retrospective study, but we think it lacks enough clinical significance to overrule the conclusions obtained.

The mean Constant score for the operated humerus in our series (82 points) is higher than that of other published series. For example, Flinkkilä[3], in a series of 126 cases, reports an average of 66 points, whereas Gaullier[10] reports a mean value of 78.7 points. On the whole, we believe that the results of this series are satisfactory. Strict patient selection could probably explain this finding, which should not be interpreted as an attempt by the authors to defend this type of treatment. Such a defense would have to be the subject of a separate study with a different scientific design.

Older patients had poorer Constant scores for their operated shoulder. As expected, scores were also lower for the unoperated shoulder. This finding suggests that there is a stronger association between the previous status of the cuff to be operated (partial tears, micro-tears, microvascular alterations, muscle artrophy, etc.) and the final functional outcome than between the insult to the tendinous complex and the patient's final functional result. This suggestion seems to be backed by the fact that there is a close correspondence in sonographic examinations: sonographic findings of the operated shoulder correspond to greater sonographic lesions in the unoperated shoulder. Even if we admit that age tends to lead to poorer Constant scores, we do not believe it should be considered an absolute contraindication when choosing the ideal approach.

The statistical analysis provided two results that came as quite a surprise. Women obtained worse results than men and are more prone to fracture their left humerus. It is tempting to relate this poorer clinical result of women with hypothetical hormonal factors that might alter their tendinous microstructure, but we think that, in real fact, there must be some underlying confounding factor that accounts for the finding above. Perhaps the low number of patients could justify these findings.

If we analyze the worst four scores, we will see that two of them correspond to patients whose radiographic and sonographic studies showed a slight though disabling proximal protrusion of the nail. In these patients, their residual pain and poor functional store are due to a technical error. Of the two remaining patients, only one presented with a clinical subacromial syndrome, while in the other the poor score is due to residual stiffness. We would like to stress the fact that neither of these two patients presented an ultrasound considered pathological, which reveals a clear clinical-sonographic dissociation. In addition, these patients also obtained low scores for their unoperated shoulder. This seems to suggest that, unless there is some technical error in the placement of th4e nail that generates some space conflict, poor functional scores are determined by a previous degenerative situation rather than by the surgical insult itself.

Clinical-sonographic dissociation is even more apparent if we consider the fact that in the four patients in whom partial cuff tears were observed on the ultrasound of the operated side (the tears were between 26-30 mm, two of them with calcifications adjacent to the tendinous complex) the functional result turned out to be acceptable, with a Constant score over 70 points.

Some papers in the literature relate residual pain with the point of entry used to approach the humeral head[10-13]. A small humeral head forces the surgeon to encroach on part of the articular surface in order to align the nail with the greater diaphyseal axis. In our study, it was not possible to look into this issue since no information had been included in the OR report about the entry point used. We might wonder at what point the incision into the rotator cuff should be made[14]. Russell[13] advocates a direct lateral approach that dissects the deltoid fibers in order to reach the area that lies most proximal to the cuff's attachment, i.e. its avascular portion. Seidel[15] and Robinson[16] recommend the anterolateral approach, using the interval between the anterior and the lateral belly of the deltoid in order to access the middle por-

tion of the rotator cuff, without sectioning the coracoacromial ligament, thus gaining better alignment with the humeral canal.

All the operated patients included in this study were subjected to the anterolateral acromial approach, with the arm placed in adduction in order to achieve a point of entry that was medial enough; a few millimeters of the articular surface of the humeral head were even encroached on (fig. 3). Dimakopoulos P[17] and Standard JP[1] have used a point of entry that is more lateral to the attachment of the rotator cuff so as not to injure the latter. This maneuver makes it difficult to align a straight nail in the humeral shaft and, on the basis of the clinical-sonographic results of our study, it is not justified[18].

An analysis of the clinical and sonographic results obtained in our study leads us to affirm that even if the antegrade approach undoubtedly causes iatrogeny of the rotator cuff, the former has no clinical significance, unless there are local contributing circumstances (age, impaired function, etc.). It could be clinically useful to perform a contralateral Constant's test before selecting this therapeutic option. If the contralateral score is poor, a different technical technique may be chosen.

We do not believe that routine performance of preoperative sonographic studies of the shoulder due to be operated and of the contralateral one is indicated since there is a clear clinical-sonographic dissociation and such studies would have little predictive value.

Therefore, to answer the initial question that prompted this study, we believe that pain and dysfunction in the shoulders of some patients operated using antegrade humeral nailing are due to two non-mutually-exclusive factors. In the first place, and more importantly, a technical error made by the surgeon in choosing an implant of the wrong length, which gives rise to space problems. Carefully and accurate measuring the length of the humeral canal, by an experienced surgeon, would lead to improved results. Furthermore, adequately impacting the fracture site, obtaining sufficient subsidence of the nail's proximal end and creating a rigid system with proximal and distal static blocks will prevent proximal nail protrusion, making it possible to rotationally control the fracture. In the second place, it seems obvious that patients with a prior traumatic or degenerative pathology, either in the fractured or the contralateral shoulder, stand a greater chance of developing residual pain and articular dysfunction. For this reason, we suggest that a clinical assessment of the contralateral shoulder by means of the Constant test should be performed before making the decision to use this approach.

Even if we agree that our study includes too few patients and that a IIIb level of evidence is not high enough, we believe that the use of an anterior acromial approach without sectioning the coracoacromial ligament, in patients without no known rotator cuff pathologies, is the best surgical option since it leads to a thick and vascular area of the rotator cuff. A longitudinal incision into the rotator cuff, carefully sparing the soft tissues, will afford a point of entry for the nail that is medial enough so as to provide direct access to the medullary canal without radiological repercussion if the nailing procedure is carried out in a stable and technically correct manner.

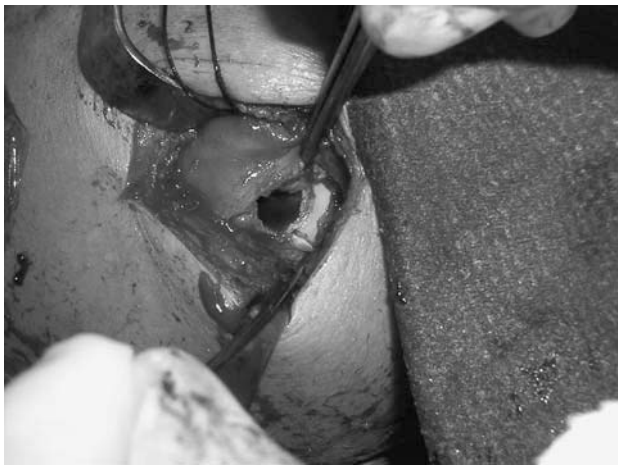

Figure 3. *Cranial view of an anterolateral acromial approach. Note how access through the medial section invades several millimeters of the articular cartilage.*

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Conflict of interests

The authors have declared to have no conflict of interests.