

Ultrasound Evaluation of the Rotator Cuff after Osteosynthesis of Humeral Shaft Fractures with Interlocking Intramedullary Nail- A Prospective Interventional Study

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ABSTRACT

Introduction: Antegrade intramedullary nailing in humeral shaft fracture allows a stable fixation with satisfactory outcomes. However, shoulder impairment remains an important complication of intramedullary nailing. The procedure involving the splitting of supraspinatus tendon to expose humeral head for nail insertion has been attributed for it, even though it is followed by the repair of the tendon.

Aim: To evaluate rotator cuff integrity with Ultrasonography (USG) in patients who underwent humeral fracture fixation with an intramedullary interlocking nail and to evaluate the clinical outcome of the shoulder joint in patients with and without rupture of the rotator cuff using Constant-Murley and QuickDASH scores.

Materials and Methods: This prospective interventional study was conducted in the Department of Orthopaedics of AJ Institute of Medical Sciences, Mangaluru, India, from August 2018 to September 2020 in which 20 adult patients with acute humeral shaft fractures were treated with closed intramedullary nailing in antegrade manner. Patients were followed-up for six months clinically and radiologically. The USG evaluation of rotator cuff was done at six months follow-up, along with clinical evaluation

using Constant-Murley and QuickDASH scores. Association between variables was analysed by using Chi-square test for categorical variables. Unpaired t-test was used to compare the mean of quantitative variables. The level of significance was set at 0.05. Data were entered into Microsoft Excel (Windows 7; Version 2007) and analyses were done using the Statistical Package for the Social Sciences (SPSS) for Windows software (version 22.0; SPSS Inc, Chicago).

Results: At six months follow-up, patients were evaluated by USG showing ruptured supraspinatus tendon in 3 (15%) of the study patients. The results by Constant-Murley score were 76.50±12.61 for the entire series, 77.82±12.75 for patients without rotator cuff rupture, and 69±10.53 for patients with partial rupture of the rotator cuff, with no statistical difference (p=0.275). QuickDASH scores were 9.90±7.69 for the entire series, better in the group without rupture of the rotator cuff (9.41±7.92 versus 12.70±6.84) but without statistically significant difference (p=0.510).

Conclusion: The functional outcome of the shoulder joint was satisfactory and was not influenced by the presence or absence of a rotator cuff tear following the procedure.

Keywords: Constant-murley score, Deltoid muscle, QuickDASH score, Supraspinatus rupture

INTRODUCTION

Humerus fracture is the third most common non vertebral osteoporotic fracture in individuals older than 65 years of age after hip and distal radius fracture [1,2]. Humeral diaphyseal fractures represent about 20% of all humerus fractures [3,4]. Bimodal occurrence of fractures is seen in the elderly above 60 years and in younger individuals from high energy trauma [5].

Most diaphysis fractures are undisplaced or minimally displaced and can be managed non operatively with satisfactory outcomes [6]. However, patients in modern times have been demanding faster union and earlier return to preinjury activities while preserving the functionality of nearby joints. Therefore, over the last few decades, there have been significant advances in the field of surgical management of diaphysis humeral fractures. With major advances in approaches and implants, internal fixation has gained higher importance and is being tried for all types of humeral diaphysis and metaphyseal fractures with increasing frequency [7,8].

Two modalities of internal fixation are popularly practiced-plate osteosynthesis and intramedullary (IM) interlocking nails. However, the implant of choice remains controversial. Fracture healing rates are similar in patients undergoing fixation with plates and nails, but there is disagreement over which one generates a higher rate of complications [9,10]. Plate osteosynthesis requires extensive

dissection and is complicated by the proximity of radial nerve and mechanical failure in osteopenic bones [11]. Biomechanically IM nail being load sharing device, prevents stress shielding and is a better implant. They are subjected to a smaller bending loads and are less likely to fail due to fatigue [12].

However, in some recent studies, plate osteosynthesis is being preferred over intramedullary nailing in humeral diaphyseal fractures for multiple reasons. Anatomical reduction and stable fixation, decreasing rates of radial nerve palsy with modified approaches, and minimal shoulder impairment are some of them responsible for the above preference of plate osteosynthesis [13-15]. One main reason is the shoulder impairment seen in post IM nailing patients for humeral diaphysis fractures [16]. The procedure involving the splitting of supraspinatus tendon to expose the humeral head and for subsequent nail insertion has been attributed to shoulder impairment even though it is followed by the repair of supraspinatus tendon [17].

The primary aim of the study was to evaluate the integrity of the supraspinatus tendon and other rotator cuff muscles by means of Ultrasonography (USG) in patients submitted to the fixation of humerus fracture with a locking intramedullary nail. The secondary aim was to assess the clinical results of patients with and without rotator cuff rupture using the constant murley and QuickDASH scores.

MATERIALS AND METHODS

This prospective interventional study was conducted in the Department of Orthopaedics of AJ Institute of Medical Sciences, Mangaluru, India, from August 2018 to September 2020 after obtaining approval from the Human Ethics Committee (approval number-AJEC/REV/186/2018).

Inclusion criteria: Patients from 18-90 years of age presenting with closed humeral shaft fractures who gave informed consent were included in the study.

Exclusion criteria: Patients with pathological fractures, open fractures, and with diagnosed preoperative rotator cuff lesions or with preoperative shoulder impairment were excluded.

Consecutive sampling technique was followed where all patients presenting with humerus shaft fracture meeting the inclusion criteria in the study duration were included. Fractures were classified as per AO classification of humerus fracture [18]. A total of 20 cases were included and all were treated by closed intramedullary interlocking nail except two cases which required open reduction at the fracture site for unacceptable reduction.

Study Procedure

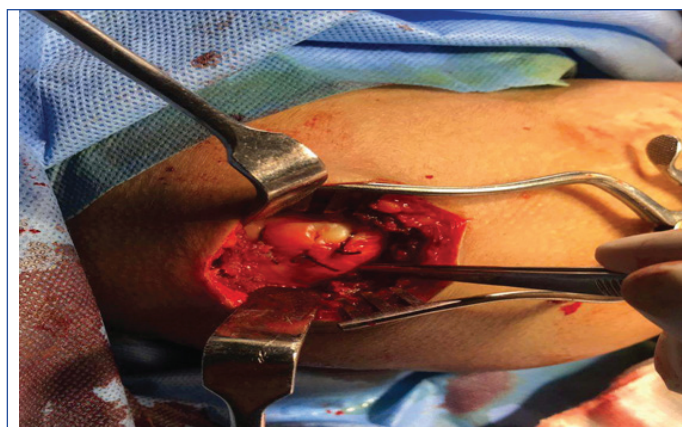
Surgical technique: The approach to humerus head for portal insertion was started with a 2-3 cm skin incision which was made from the anterolateral edge of the acromion obliquely forward. Deltoid muscle underneath was incised longitudinally to reveal the subacromial bursa and rotator cuff as shown in [Table/Fig-1]. The location of the entry portal of the nail was verified with an image intensifier to minimise the possibility of a poorly placed incision that might cause unnecessary damage to the rotator cuff. To enable adequate retraction and anatomical closure of supraspinatus following the preprocedure, stay sutures were put for supraspinatus on exposure before its dissection.



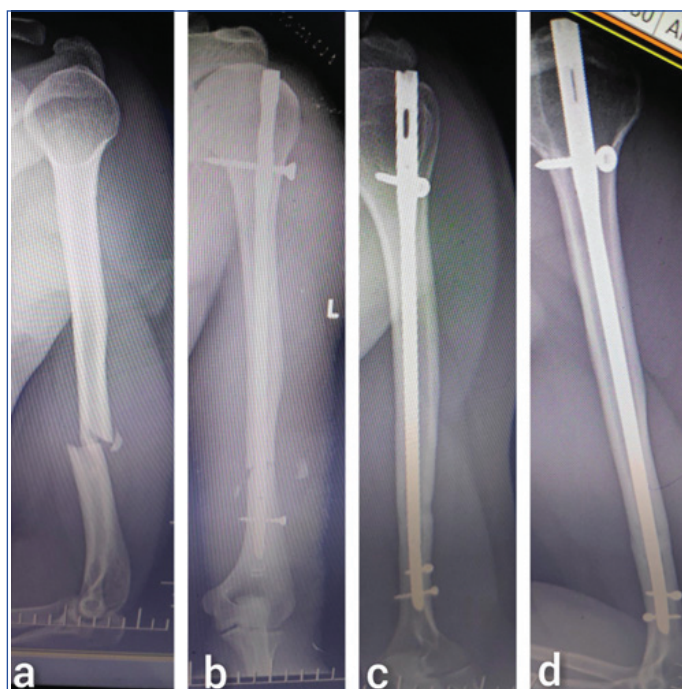
[Table/Fig-1]: Oblique directed incision with underneath cut deltoid (left) and exposed rotator cuff (right).

The rotator cuff was then incised in the direction of the supraspinatus tendon about 1.5 cm, preferably more near the musculotendinous portion to avoid injury to the supraspinatus footprint. Later, with the arm adducted, an entry portal was made, the nail was inserted through the reduced fracture site and was fixed proximally and distally with self-tapping cortical screws. Importance was given to avoid protrusion of the nail from the humeral head to prevent impingement and shoulder impairment postoperatively. At the end of the procedure, the split rotator cuff was repaired with absorbable sutures [Table/Fig-2] followed by the repair of deltoid musculature. Postoperatively, arm pouch was used for four weeks and elbow Range Of Motion (ROM) was initiated from postoperative day 1. Shoulder passive and active assisted ROM was started from postoperative day 12 after suture removal. Active shoulder exercises were started at four weeks and active resistance exercises were started at six weeks.

Patients were followed-up regularly thereafter at six weeks, three months and six months following the surgery. Radiographs involving Anteroposterior (AP) and lateral views were taken for six weeks and three months follow-up to assess for radiological union [Table/Fig-3]. In the final follow-up at six months, patients were evaluated both



[Table/Fig-2]: Repair of rotator cuff following fracture fixation.



[Table/Fig-3]: (a) Humerus shaft fracture which was fixed with intramedullary nail as in (b) and final radiological union seen at six months as shown in (c) and (d).

clinically and ultrasonographically for the rotator cuff. Patients were assessed with two main functional scoring systems for shoulder, namely, Constant-Murley scores and QuickDASH scores involving questionnaire and clinical examination [19,20]. The Constant-Murley score is a multi-item functional scale assessing pain, activities of daily living, ROM, and strength of the affected shoulder. Its score ranges from 0 to 100 points, representing worst and best shoulder function, respectively. The QuickDASH is a shortened version of the DASH outcome measure where instead of 30 items, the QuickDASH uses 11 items to measure physical function and symptoms in people with musculoskeletal disorders of the upper limb. In the QuickDASH score questionnaire, each item has 5 response options from which scale scores are calculated, ranging from 0 (no disability) to 100 (most severe disability). Ultrasonography evaluation involved an ultrasonogram of the operated shoulder which was carried out by a single experienced radiologist in the Department of Radiology. All the scans were performed on Philips EQIP 5 USG machine using a broadband linear array transducer L12-5 50 mm following a standard shoulder USG protocol [21]. In each case, the presence or absence of a rotator cuff tear and the extent of the tear into the cuff substance were recorded. The tendon injuries were classified as normal, tendinopathy, partial thickness <50%, partial thickness >50%, and complete tear [22].

STATISTICAL ANALYSIS

Data were entered into Microsoft Excel (Windows 7; Version 2007) and analyses were done using the Statistical Package for the Social

Sciences (SPSS) for Windows software (version 22.0; SPSS Inc, Chicago). Descriptive statistics such as mean and Standard Deviation (SD) for continuous variables, frequencies, and percentages for categorical variables were calculated. Association between variables was analysed by using the Chi-square test for categorical variables. Unpaired t-test was used to compare the mean of quantitative variables. The level of significance was set at 0.05.

RESULTS

In the present study, the age distribution with >60 years (30%), with a range of 19-72 years and a mean age of 45.75 ± 18.07 years. Males were more commonly affected ($n=16$) than females [Table/Fig-4].

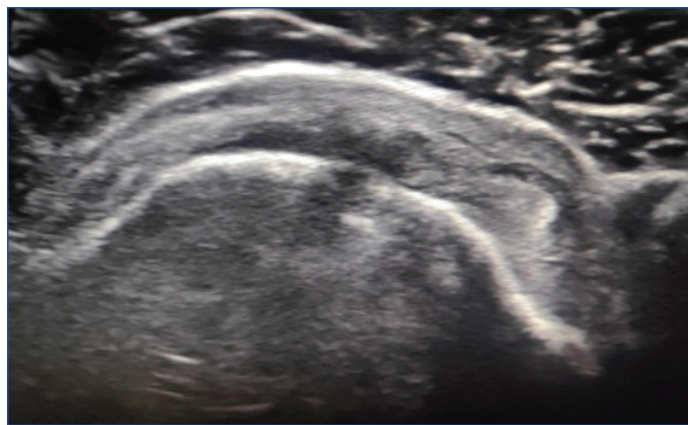
Variables	Rotator cuff		p-value (Chi-square test used)
	No rupture n (%)	Partial rupture n (%)	
Age (years)			
18-30	5 (29.4)	1 (33.3)	0.222
31-60	8 (47)	-	
61-90	4 (23.5)	2 (66.6)	
Gender			
Male	14 (82.3)	2 (66.6)	0.531
Female	3 (17.6)	1 (33.3)	
AO classification of fractures			
12-A2 (n=5)	4 (23.5)	1 (33.3)	0.928
12-A3 (n=9)	8 (47)	1 (33.3)	
12-B1 (n=4)	3 (17.6)	1 (33.3)	
12-B2 (n=1)	1 (5.8)	-	
12-C2 (n=1)	1 (5.8)	-	
Dominant side			
Left	3 (17.6)	1 (33.3)	0.531
Right	14 (82.3)	2 (66.6)	
Time between trauma and surgery			
0-2 days	5 (29.4)	-	0.398
3-5 days	10 (58.8)	2 (66.6)	
6-10 days	2 (11.7)	1 (33.3)	
Abduction (degrees)			
61-90	1 (5.8)	-	0.420
91-120	4 (23.5)	2 (66.6)	
121-150	10 (58.8)	1 (33.3)	
>150	2 (11.7)	-	

[Table/Fig-4]: Baseline characteristics of the participants (N=20).

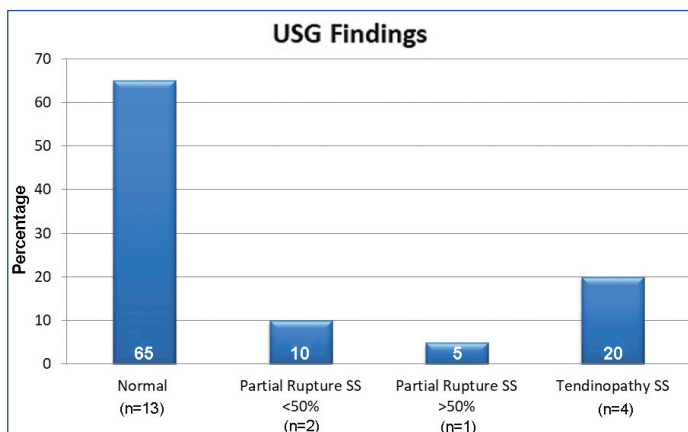
At six months follow-up, USG was performed which showed partial rupture of supraspinatus tendon involving >50% in one patient and partial rupture of supraspinatus with <50% involvement in two patients [Table/Fig-5]. No patient was found to have complete rupture of any of the rotator cuff tendons. Tendinopathy of supraspinatus was reported in 4 (20%) patients and normal study in 13 patients (65%) [Table/Fig-6].

The results by Constant-Murley score were 76.50 ± 12.61 for the entire series, 77.82 ± 12.75 for patients without rotator cuff rupture, and 69.00 ± 10.53 for patients with partial rupture of the rotator cuff, with no statistical difference ($p=0.275$) between them. The results from the QuickDASH questionnaire were 9.90 ± 7.69 for the entire series, better in the group without rupture of the rotator cuff (9.41 ± 7.92 versus 12.70 ± 6.84) but without statistically significant difference ($p=0.510$) [Table/Fig-7,8].

Since supraspinatus was the only rotator cuff tendon involved, abduction of the shoulder joint was noted in all patients. No patients had difficulty in the initial 30° of abduction with the majority in the range of 121-150° 11 (55%), six patients had an abduction range of



[Table/Fig-5]: Partial thickness tear of supraspinatus at six months follow-up.



[Table/Fig-6]: The USG findings (N=20).

Scores	Mean±SD	Range
CM score	76.50 ± 12.61	48-95
QuickDASH score	9.90 ± 7.69	2.2-27.2

[Table/Fig-7]: The CM and QuickDASH Scores of study subjects (N=20).

CM: Constant-Murley; QuickDASH: Disabilities of the arm, shoulder and hand

Scores	No rupture (Mean±SD)	Rupture (Mean±SD)	p-value
CM score	77.82 ± 12.75	69 ± 10.53	0.275
QuickDASH score	9.41 ± 7.92	12.70 ± 6.84	0.510

[Table/Fig-8]: Association between rupture and CM and QuickDASH score (N=20).

Unpaired t-test; p-value not significant; CM: Constant-Murley; QuickDASH: Disabilities of the arm, shoulder and hand

91-120°, and two of them had full range of >150° and one was in the minimum range of 61-90°. The association between abduction limitation and rupture of supraspinatus was evaluated by Chi-square test showing no statistical significance ($p=0.491$).

DISCUSSION

Conservative treatment has been the accepted treatment for acute, closed, humeral diaphysis fractures in ambulatory, co-operative patients [6,23]. Operative fixation is indicated in certain fractures including those patients with unsatisfied closed reduction, multiple injuries, and requiring faster mobilisation. Many comparison studies have been done between plate osteosynthesis and intramedullary nail over implant of choice and various conclusions are drawn [9,10,12,24]. Even though both are reported to have similar union rates in fracture healing, some studies have reported higher complications with intramedullary nailing, especially shoulder impairment [25].

Hence, many studies concentrating on shoulder impairment following intramedullary nailing can be observed. Flankkila T et al., concluded in their comparison study between intramedullary nailing and humerus plating on 73 patients that antegrade nailing

if performed properly should not be considered responsible for shoulder joint impairment [26]. The mean Constant-Murley score in intramedullary nailing patients was 71 (41-97), which was better in the present study. However, this was disputed by Li Y et al., in their comparison study between humerus plating and intramedullary nailing who showed that patients who underwent antegrade nailing have lower shoulder functional scores and a decreased shoulder range of motion [27].

The procedure involving the splitting of the rotator cuff (supraspinatus tendon precisely) for nail introduction has been implicated in impaired shoulder function and decreased range of motion, especially abduction [28]. The above statement was supported by Geiger P et al., in their study on microcirculatory sequelae of the rotator cuff by Orthogonal Polarisation Spectral (OPS) imaging after antegrade nailing in proximal humerus fractures [29]. They concluded that the implantation of an antegrade humerus nail, which necessarily includes a splitting of the rotator cuff, nearly halves the functional capillary density of the supraspinatus tendon. However, this effect seems to be reversible. The drawback of the above study was the absence of follow-up data and evaluation of clinical outcomes after the phase of healing. Yoo HJ et al., in their study on monographic assessment of postoperative changes after repair of the rotator cuff stated that the morphologic appearance of the repaired tendon and peritendinous soft tissue changes improved over time and nearly normalised within six months of surgery [30].

Verdano MA et al., evaluated the consequences for rotator cuff in patients who underwent antegrade intramedullary nailing for humeral diaphysis fractures [31]. They did a retrospective cohort on 48 patients, in which three patients were found to have partial rupture and one patient had complete rupture (total of 8.3% rupture) of the supraspinatus. In the current study of 20 patients, we had 3 partial ruptures of supraspinatus with no case of complete rupture (total of 15% rupture). The USG scan was done after an average of three years in their study which could be the reason for the decrease in the percentage of observed rotator cuff tears and marginally better Constant-Murley score. With the above result, Verdano MA et al., concluded that antegrade humeral nailing provides an acceptable functional result with no significant clinical monographic impact [31].

A similar study was carried out by Gracitelli ME et al., on 31 patients in the age group of 50-85 years after intramedullary nailing in proximal humeral fractures [22]. The outcome was assessed by USG at six months for rotator cuff, similar to the present study and clinically using CM, DASH and Visual Analog Scale (VAS) scores. A high rate of rotator cuff tear was demonstrated in them compared to the present study, with partial ruptures in 32% (15% in the current study) and full thickness tears in 13% (no complete rupture in the current study) of the patients. The clinical outcome was better in the present study compared to theirs in terms of Constant-Murley score. They concluded that a high rate of alterations in rotator cuff tendons was demonstrated. However, their clinical results were satisfactory and not influenced by the presence of rotator cuff rupture [22].

In the present study, the incidence of supraspinatus rupture was 15% which is lesser than the prevalence of rotator cuff tears in asymptomatic general population (16.9%) [32].

Supraspinatus is commonly implicated in shoulder impairment following surgery [28]. This study helps in evaluating the supraspinatus and shoulder outcome in intramedullary nailing patients and may be a key tool in deciding over implant of choice among various factors for humerus diaphysis fractures. Since the USG has been carried out by the same radiologist, it will increase the internal validity of the present study. Future studies may be benefitted from a larger sample size and longer clinical and radiological follow-up. Preoperative imaging for the rotator cuff may be helpful in minimising false positives and may improve the significance of the study.

Limitation(s)

The presence of a previous rupture of the rotator cuff cannot be confirmed, since there is no image analysis before surgery. Rotator cuff tears may exist in 16.9% of the general population with increasing prevalence by age [32], which may result in false positive rotator cuff tears. Ultrasonogram is less effective in diagnosing partial thickness tear of rotator cuff compared to a Magnetic Resonance Imaging (MRI) scan [33]. Radiological and clinical follow-up of six months may be short.

CONCLUSION(S)

Although there are chances of rotator cuff injury during the procedure of intramedullary nailing of the humerus, a prevalence of 15% is less which is no higher than the presence of asymptomatic rotator cuff tear (16.9%) in the general population. Intramedullary interlocking nailing provides the acceptable functional outcome of the operated shoulder joint with no significant clinical sonographic impact irrespective of the rotator cuff injury. Hence, in conclusion intramedullary interlocking nail remains a safe and potent option in the osteosynthesis of humeral shaft fractures.

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