RESEARCH ARTICLE

Anterior Bridge Plate Osteosynthesis in Comminuted Fracture Shaft of Humerus in Manual Workers- is it Optimum Choice?

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Abstract

Background: Bridge plate osteosynthesis of fractures by minimal invasion and near acceptable reduction is becoming popular and acceptable entity. Management of humeral shaft fracture has evolved a lot with their pros and cons. Anterior bridge plate osteosynthesis (ABPO) for humeral shaft fracture is pertinent to a minimal invasive procedure, and it has evolved as a new entrant in the surgical techniques. This study was designed to carry out the results and efficacy of ABPO in the comminuted fracture shaft of the humerus in the manual workers.

Methods: Study included the closed comminuted fracture of shaft of humerus in skeletally mature patients engaged predominantly in manual works, like overhead sports activity, laborers, and industrial workers. All fractures were managed by either 4.5-mm narrow locking compression plate (LCP) or dynamic compression plate (DCP).The functional outcome for elbow was measured by Mayo's elbow performance score (MEPS) and functional outcome of shoulder was measured by UCLA (University of California at Los Angeles) shoulder score system.

Results: In this study 37 patients were enrolled. Mean duration for satisfactory radiographic union was 12.3 weeks. The mean duration of follow-up period was 14.5 months. In respect to elbow function, the average Mayo elbow score was 92.42 ±2.17 and average UCLA score of shoulder function was 34 ±0.34.

Conclusion: The ABPO is an optimum choice for managing the comminuted fracture shaft of humerus in manual labors. The outcomes are favorable and reproducible with very few risks.

Level of evidence: IV

Keywords: Humerus, Fractures, Comminuted

Introduction

Not merely the solid union, but the immediate and sustained function of the limb is also of prime importance in the new era of orthopaedics. Resultantly, the indications of surgical intervention for humeral fractures are increased with time to obtain union with adequate function in the shortest feasible duration. Strikingly the humerus bone is endowed with adaptability, that the fracture can be treated successfully by conservative method (due to the virtue of the wide range of acceptance criteria) by functional cast as well as by surgical intervention. Interestingly, it is the versatility of humerus that the plate osteosynthesis can be the executed by lateral, anterior, and posterior approach and even the antegrade and retrograde intramedullary nailing can be done (1 and 2). So, it is prudential to individualize the suitable treatment option for a particular patient profile in the availability of various treatment options for humeral shaft fracture.

Overhead motion of shoulder is a coordinated function

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of muscle units and distinctly require well aligned humerus with shoulder and elbow joint. Overhead movement is composed of six different phase named as windup, stride, arm cocking, arm acceleration, arm deceleration, and follow-through (3). Strenuous manual workers like a daily wager, athlete, and industry worker needs the flawless function of elbow, humerus, and shoulder joint to perform overhead activities for their profession. In other words, any breach in the either of three may precipitate the difficulty in overhead motion. Rotator cuff injury by interlocking nail and potential soft tissue disruption with larger scar are well-known complications of traditional plating. So, the ABPO seems a rational "middle path regime" for fixation of humeral shaft fracture in the milieu of the manual worker.

Anterior bridge plate osteosynthesis (ABPO) for humeral shaft fracture is pertinent to a minimal invasive procedure, and it has evolved as a new entrant in the surgical techniques and becoming popular day by day. In the last decade, ABPO for humeral shaft fracture has been advocated by various literatures in the general population cohort (4). But even after diligent search, we do not find adequate literature showing the results of ABPO for the management of comminuted fracture shaft humerus in patients predominantly engaged in manual labor. Such patients routinely use to place a heavy workload on his upper limbs as well the overhead activity involvement is also more than the normal population. So, this study was designed to carry out the results and efficacy of ABPO in the comminuted fracture shaft of the humerus in the manual workers.

Materials and Methods

This prospective study was carried out from March 2017 to August 2018. Institutional Ethics committee reviewed the study design and ethical committee code was obtained with letter no. ortho/416/10/03/2017. The inclusion criteria of our study were all traumatic closed comminuted fracture of shaft of humerus in skeletally mature patients engaged predominantly in manual work like overhead sports activity, laborers, and industrial workers. Patients having sedentary lifestyle, open fracture, neurovascular deficit pathological fracture, open physis, coexisting medical disorder, poly-trauma (injury severity score>16) and those who did not consent for the surgery and follow-up were excluded from the study. Informed consent was taken from all patients. All fractures were classified as AO-ASIF trauma classification system and either 4.5-mm narrow locking compression plate (LCP) or dynamic compression plate (DCP) was used to fix all fractures (5).

The functional outcome for elbow was measured by Mayo's elbow performance score (MEPS) which is graded as excellent - ≥90 points, good -75–89 points, fair- 60–74 points and poor <60 points, and functional outcome of shoulder was measured by UCLA (University of California at Los Angeles) shoulder score system which is graded as excellent 34–35 points, good 29–33 points, fair 21–28 points, and poor 0–20 points (6 and 7). At the end of the follow-up, all patients were asked for questionnaire to get their satisfaction quotient. Questionnaire was (1) absence of pain and discomfort (2) is he okay with function of limb (3) is he happy with life and resuming of pre-trauma activity (4) likelihood of recommendation of same procedure to others. Answers were collected in yes/no format only. Patient was called fully satisfied if he answered all questions as yes, satisfied if he answered first three questions as yes and deemed as not satisfied if he answered only first two questions as yes.

The data of continuous variables were designated as mean ± standard deviation (SD), and on the other hand, data on categorical variables were designated as number of patients (%). The statistical analysis was done by Microsoft XL 2007 (data add in functions were installed for data analysis). Student T-test was chosen to compare the values, and all the p value ≤ 0.05 was considered significant.

surgical technique

After informed consent and suitable anesthesia, patient was positioned in supine position over radiolucent table. Procedure involved the two separate incisions. Arm was abducted to 60° and traction was given with flexed elbow. Closed reduction maneuvers were used for optimal acceptable fracture reduction under control of image intensifier. Throughout the procedure, the forearm was kept in a supine position to keep the radial nerve away from fracture. The first proximal incision (about 3-cm long) given as a part of the deltopectoral approach, between the deltoid and medial border of biceps in this intermuscular plane and further dissection was done to the humerus, by retracting the deltoid laterally and biceps muscle medially. Under fluoroscopic control, the distal second incision (about 5-cm long) was given as far as away from the fracture site along the lateral border of biceps tendon [Figure 1]. Biceps belly was medially retracted and brachialis muscle was split longitudinally. Half of the brachialis belly along with musculocutaneous nerve (overlies to brachialis) was retracted medially and lateral half of brachialis was retracted laterally to protect the radial nerve.

With the help of artery forceps and osteotome, a submuscular and extraperosteal plane was developed from distal to proximal incision. Plane is smoothly developed, only the slight resistance is offered by deltoid insertion. Traction is applied to attain length and valgus/varus maneuvering done to achieve the rotation and angulation. Now the LCP/DCP of maximum possible length is passed from proximal to distal direction and temporarily fixed with K- wires in anteroposterior directions. The distal most screw was inserted first but not tightened fully, so that it allows better reduction. Then the plate was fixed proximally and now the screws are tightened. Further, the additional screws inserted at each end. Accepted criteria of angulations (150) in any plane) and shortening (1cm) for humeral shaft was used, as described by Wang et al (8). And mal-rotation was checked by cortical step sign and diameter difference sign given by Krettek et al (9).

Figure1. Showing plate placement in submuscular (extraperosteal) tunnel, using two mini incisions used for ABPO in comminuted fracture shaft of humerus.

Post-operatively the limb was kept in slings, and active/passive mobilization started as soon as the pain subsided and permitted. Patients were called at regular follow-up and meanwhile allowed to gradually resume the preoperative strength and function under senior physiotherapist. At each follow-up, clinico-radiological assessment was done. Radiographic assessment was done by standard anteroposterior and lateral radiographs, and at each follow-up fracture union and fracture reduction was checked [Figure 2]. Fracture was called united, when it was painless and showed the bridging callus in three fourth of circumference on the any view of radiographs.

Results

In this study 37 patients, who fulfilled our inclusion criteria were enrolled. Four patients did not return in follow-up, because they returned to their remotely located state after surgery, so our result is based on 33 (n=33) patients. The demography of our study is enumerated in [Table 1]. The average age was 34.1 years (range- min=18, max=50 years). Twenty five (76%) were males and 8 (24%) females. Dominant arm was involved in twenty three (70%) cases. Most common mode of injury was road traffic accident in nineteen patients (58%), followed by fall from height as occupational hazard in 6 patients (18%), sports injury in 5 patients (15%) and direct hit trauma in 3 (9%) patients. Twelve cases had B1, nine cases had B2, five cases had B3, five cases had C1 and two cases had C2 type of fracture.

In twenty three (70%) patients narrow DCP was used and rest 11 patients (30%) were managed by narrow LCP. All the 33 assessed patients, united successfully. None of the cases had coronal/sagittal mal-alignment (>15°) or shortening of > 1 cm. Mean duration for satisfactory radiographic union was 12.3 weeks (range-min=9, max= 18). All patients resumed their original activities at average duration of 16 weeks (range-min=14, max= 20).The mean duration of follow-up period was 14.5 months ((range-min=12, max= 18). In our study, in respect to elbow function the average Mayo elbow score was 92.42 ± 6.3 (range- min=80, max=100), in which 27 cases (82%) had excellent outcome, 6 cases (18%) had good outcome. The average UCLA score of shoulder function was 34 ± 1 (range- min=32, max=35), in which 29 cases (88%) had excellent outcome and 4 cases (12%) had good outcome.

The average of active abduction/flexion at involved shoulder was 108/157 degree and active flexion/extension at involved elbow was 130/5 degree. Though the comparison with normal side was not done for range of movement, but we did not find any clinical significance.

According to questionnaire based satisfaction quotient, 25 patients (76%) were fully satisfied, 4 patients (12%) were satisfied and rest 4 patients (12%) were not satisfied. Till the end of final follow-up, 25 patients (76%) resumed their previous occupation, 6 patients (18%) had to job modification due to exertional pain, stiffness and reduced strength and rest 2 patients (6%) left their job due to fear of refracture.

One patient (3%) suffered from superficial infection at the 5th post-op day. Wound was thoroughly irrigated after pus sample collection and antibiotics given according to culture and sensitivity test. Infection subsided later on. One patient (3%) permanently developed the anesthetic patches along lateral border of forearm due to musculocutaneous nerve injury. Average time of radiation exposure was 149 seconds (range-min=90, max=192) and average duration of surgery was 85 minutes (range-min=65, max=120) and our study. The average blood loss was 70 ml and average dose of radiation was 136 Rads (range-min=110, max=220). Although the statistical analysis was not performed but it was realized that with increasing learning experience of ABPO the surgical time and radiation exposure was decreased.

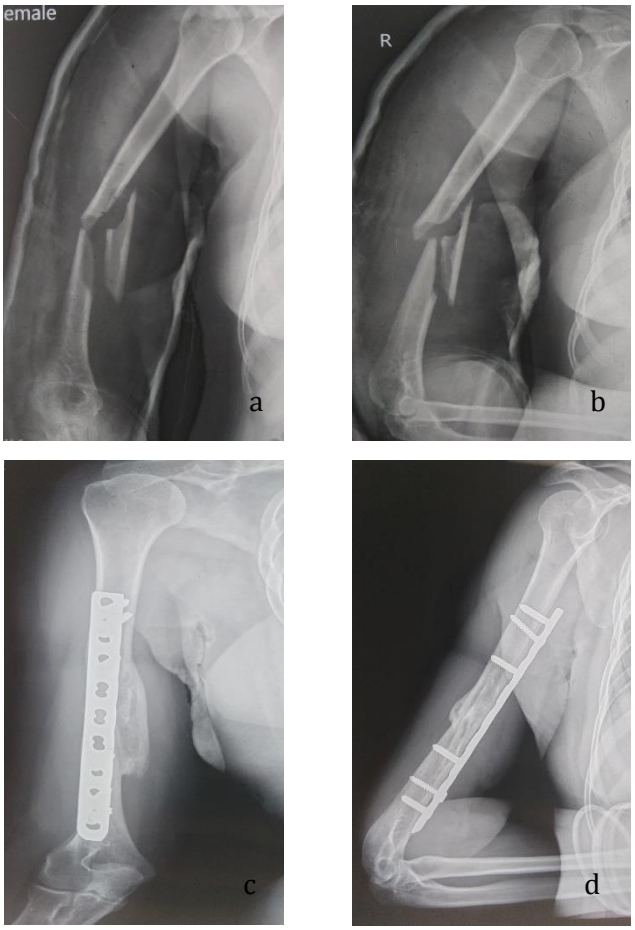

Figure2- X –ray (a) anteroposterior and (b) lateral view of 30 years old female (laborer) showing comminuted fracture shaft of humerus (type- B 2). She was managed with ABPO and fracture was united (c) anteroposterior and (d) lateral view, by the14 weeks of follow-up.

Discussion

Hunter promulgated the proposed theory of Albrecht Haller, that due to injury the vessels surrounding the reparative zone lay down the bone (10). This accomplishment, regarding vital role of vascular network in fracture repair is the mainstay of minimally invasive fracture management. Later on, the entail of minimal invasion technique evolved through the time and named as minimally invasive plate osteosynthesis (MIPO) or bridge/biological plating and the technique is escalating in popularity. In bridge plating, the possible longer plate is applied over the substantial area of comminuted bone, and only short fixation is done over the both ends. Now this assembly becomes elastic and enough to cope up with bending forces reasonably. Due to long plate fixation over bone, the deforming forces are distributed over the long plate and resultantly the net stress shared by per unit area is reduced now which decreases the likelihood of plate failure.

The soft tissue preservation, as well as the absolute anatomical reduction at a same time is a matter of debate and there is always a dissent between these two schools of thoughts. Absolute anatomical reduction with compromising soft tissue and vascularity is a costly biological affair in comparison to the near normal acceptable reduction and stable fixation, which has its own biological advantage (11). Although the conventional open reduction and plate osteosynthesis of humerus spares the rotator cuff injury, but loss of fracture hematoma, long incision (aesthetic issue), soft tissue disruption and direct radial nerve handling is a matter of concern. Though the intra-medullary nailing is a minimally invasive procedure, but the rotator cuff damage and the impingements are potential disadvantages of this technique (12-13). It is the ABPO which has the dual benefit in context of conventional plating and intra-medullary nailing. Minimal invasive, less scarring, joint sparing and least mobilization of neurovascular structures are favorable points of ABPO, which illustrates its superiority over well established traditional plating and nailing techniques. Despite of numerous surgical techniques used for managing the humeral shaft fracture, still there is no consensus regarding the best one. However, the plate osteosynthesis has been accepted as standard method to management of humeral shaft fractures (14).

In comparison to periosteal healing where the callus formation occurs, the endosteal bone healing is without the callus formation. So, the bony union by primary healing (conventional plating) is not strong enough as secondary healing (bridge plate osteosynthesis) and tends to possess the risk of re-fracture after hardware removal (15). The merits of minimally invasive technique are relative stability and minimal soft tissue disruption. Which results to periosteal healing by callus formation and lesser chances of infection and non-union as well (16). The anterior surface of humerus is comparatively safe and sound surface for the bridge plating. Moreover the proximal and distal limited incision allows the percutaneous plate fixation adequately. So the ABPO is obtaining popularity as an innovative alternative for the management of humeral shaft fracture. Moreover, the management of comminuted humeral shaft fracture is associated with greater challenge. Conventional plating (antero-lateral or posterior) is associated with high morbidities and nailing does not suffice to control the rotation, particularly for distal fracture (17).

There is no clear cut guideline regarding the use of DCP or LCP for the diaphyseal fracture of humerus. O'Toole et al. studied over cadaveric bone testing synthetic (modeled comminuted mid-shaft humeral fracture) and found that locking screws don't provide any obvious biomechanical advantage (18). On the contrary, Davis et al. biomechanically tested the plated cadaveric humeri (either by locking or cortical screws) and found that LCP has the improved mechanical performance (19). In our study, the selection of LCP or DCP implant was based on affordability by the patients. Although in this study we did not compare the results between the both types of plates,

but the comparative study between LCP and DCP, used for ABPO could be a new arena of research.

Ziran et al. compared the results between traditional plating and MIPO for mid and distal humeral shaft fractures and found that radial nerve injury occurred in 31.3% in conventional plating and none in MIPO (20). In concern of percutaneous screw placement, the danger zone for the radial nerve entrapment exists between 36% – 59% (largely middle third of humerus) and the danger zone of musculocutaneous nerve is 18% – 42% of the humerus length proximally from the lateral epicondyle (21). Since the screw placement in ABPO is anterior to posterior direction and in lower one third of humeral shaft, so the radial nerve injury in unlikely to occur. Conversely, if the fracture extends up to the distal third part of humerus then the only distal most (1/5th) part of the humerus can be used for the screws placement and it poses the risk for the musculocutaneous nerve injury. In our study, musculocutaneous nerve was injured in one case (segmental fracture of shaft of humerus). Probably excessive traction caused the nerve injury, which could be used due to the smaller incision which was given to avoid the loss of fracture hematoma [Figure 3].

Livani et al. measured the distance (ultrasonographic cadaveric study) between plate (fixed by ABPO technique) and the radial nerve and found that farthest distance between radial nerve and the implant in a humeral mid shaft fracture was between 1.6 and 19.6 mm (average- 9.3 mm) and in lower-third fractures it ranged between 1.0 and 8.1 mm (mean- 4.0 mm). Moreover, the brachialis muscle encloses the anterior aspect of humerus and further reduces the risk of iatrogenic radial nerve injury when the plate in inserted in the created sub-muscular plane (22).

When the forearm is pronated, there is medial displacement of radial nerve and it comes more close to the distal part of plate and prone for iatrogenic injury. So the supinated forearm is a preferred position, and we kept the forearm supinated during the surgery and so it could be reason that no radial nerve injury occurred in our series.

The goal of our study was to know the efficacy of ABPO for the management of comminuted fracture shaft of the humerus in the patients, particularly engaged in manual works involving overhead activity. We achieved our aim with excellent clinico-radiological outcomes and it was comparable to the other similar studies. The ABPO for the management of humeral shaft fractures has been described with fair results in previous reports, but none is exclusively for the comminuted humeral shaft fractures (23). The range of motion (ROM) and strength of opposite side was set as reference value and mostly patients achieved to the previous values. Though the statistical analysis was not done for the ROM and strength, but based on satisfaction quotient the fully satisfied (76%) patients are indirect measure of credibility of ABPO. In our series, the average time of bony union was 12.3 weeks and comparable to the reported time duration of 9–12 weeks for union by conventional plating procedures (24).

In our series, mean duration of bony union is less than the series of Zhiquan et al. for their series of ABPO of humeral shaft fractures (25). Although average duration for union in our series is relatively more than that reported by Mahajan et al. for their ABPO of humeral shaft fractures (26). Since our series only included the comminuted fractures of shaft humerus, so probably it could be the cause.

The functional assessment of involved shoulder and elbow in our series was done by UCLA shoulder and MPES method respectively and the outcomes were accordant to the other similar studies (27-28). In this study 29 cases (88%) had the excellent UCLA scores and 27 cases (82%) had the excellent outcome by MEPS, so the higher UCLA score could be due to involvement of mid shaft and distal third fracture of humerus. In comparison to UCLA, the more post-operative time (7 months) was taken to obtain the final values of MEPS, which may be also due to distal third fracture of humerus.

Our study has certain drawbacks, like relatively small number of cases and lack of control group to compare the results with some other technique. Selected patient population and use of two different (LCP and DCP) implant could also be a potential limitations in our study. Moreover, in this study we also did not compare the exact difference of the performance in their corresponding field of work before the trauma and after the return to the work. Since, the measurement of range of movement is a subjective finding, so it could have also introduced an error.

Figure3 - X –ray (a) anteroposterior and (b) lateral view showing type- C2 fracture in 45 years old volley-ball player. Patient developed the permanent anesthetic patches along lateral border of forearm. The musculocutaneous nerve was injured, probably due to excessive traction used to reduce the segmental fracture. Fracture was united (c) anteroposterior and (d) lateral view, by the 18 weeks of follow-up.

Conclusion

The ABPO is an optimum choice for managing the comminuted fracture shaft of humerus in manual laborers. The outcomes are favorable and reproducible with very few risks of complications. Although initially the plate placement and fixation by indirect reduction and rotational checking of humerus required longer surgical

time and experience, but in later cases surgical time reduced relatively. The outcomes, respected to the described technique and it is aesthetically acceptable and safe. Although randomized controlled trials comparing this ABPO with other conventional method of plating and nailing are necessary, but it is commendable to use this treatment modality in patients engaged in manual and overhead works.

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