Original article

Could direct transdeltoid approach to severely displaced proximal humerus fracture be advantageous for a better reduction?

Tommaso Maluta, Andrea Amarossi, Manuel De Masi, Andrea Dorigotti, Matteo Ricci, Eugenio Vecchini, Stefano Negri, Elena Manuela Samaila, Bruno Magnan,
Orthopaedics and Surgery Department. University of Verona, Verona, Italy

Abstract. *Background and aim*: Surgical treatment of proximal humeral fractures (PHF) is a challenge for orthopaedic surgeons. Despite the wide application of open reduction and internal fixation with locking plates, the optimal surgical approach of PHF is still debated. This study aims to evaluate the radiological outcomes, defined as anatomical restoration of the greater tuberosity and humeral head-shaft angle, of the deltopectoral (DPA) and the lateral transdeltoid (LTA) approaches in three- and four-part PHF, treated with locking plate. *Materials and methods*: This retrospective series review identifies 74 PHF surgically treated between January 2012 and December 2019. Patients were divided into two groups according to the surgical approach (DPA vs LTA). Demographic data, duration of surgery, radiological pre- and post-surgery parameters (greater tuberosity displacement and humeral head-shaft angle) were collected. The association between the surgical approach and the quality of fractures reduction was assessed. *Results*: The use of LTA approach correlates with a better reduction of greater tuberosity displacements compare to DPA (63% in DPA vs 100% LTA). No significant association was found with the humeral head-shaft angle (restored in 89% of the patients in DPA and 86% in LTA group), and surgical times (range 40 – 210 minutes ± DS 33,56 for the DPA; range 45 – 170 minutes ± 29,60 for LTA). *Conclusions*: The results of this radiological study suggest that PHF with significant displacement of the grater tuberosity could benefit from the adoption of a lateral transdeltoid approach for the ORIF procedure. Further studies are needed to confirm these findings. (www.actabiomedica.it)

Key words: Humeral Fractures, Locking plate, Deltopectoral approach, Transdeltoid approach, Greater tuberosity fractures

Introduction

Proximal humeral fracture (PHF) accounts for 5% of all fractures and, after distal radius and hip fractures represents the most common fracture of the extremities (1).

They are usually related to low-energy trauma occurring in elderly patients, particularly women affected by post-menopausal osteoporosis (2–5). The incidence of this kind of fracture is expected to rise since the geriatric population is growing continuously (6).

Despite various kinds of treatment strategies available, the management of complex PHF remains demanding.

Conservative treatment with short-term immobilization in bandage has been a well experienced treatment option in stable and simple fractures, but it has been recently demonstrated to be a good option for complex fractures in low-demanding elder patients (7).

The main surgical choices are open reduction with internal fixation (ORIF), closed reduction and internal fixation, minimally invasive percutaneous plating osteosynthesis (MIPPO), closed reduction and external fixation and arthroplasty (8). Each approach may be

appropriate based on the specific fracture's and patient's "personality" (9,10).

ORIF technique with locking plate has been developed and refined in the last decade, and according to the literature, it leads to a good clinical and functional outcome for even the most complex fractures such as 3- 4 parts pattern according to Neer classification (9,11).

Another controversial topic for surgery is the choice of surgical approach.

The deltopectoral approach (DPA) remains widely used because of its excellent exposition of the anterior structure with limited concern about injuring the axillary nerve. Furthermore is more convenient for a potential intraoperative conversion to arthroplasty (12). However, this approach could not extensively expose the lateral-posterior aspect of the proximal humerus, provides a disadvantageous lever arm for the screws (due to the anterior-lateral plate location), and involves extensive soft tissue dissection and muscle retraction which may increase the risk of avascular necrosis (13).

The direct lateral transdeltoid approach (LTA), instead, is less invasive, provides a more advantageous lever arm for the screws, and permits a direct lateral view of the humeral greater tuberosity. On the other hand, this approach could lead to axillary nerve injury.

The goal of a good reduction of any PHF is to restore the humeral head-shaft angle and the correct position of the greater tuberosity in order to achieve a better clinical outcome (14–18).

The aim of this study was to retrospectively evaluate the radiological outcomes comparing direct lateral transdeltoid and deltopectoral approaches in three- and four-part PHF according to Neer classification, treated by ORIF technique with locking plate (11).

Ethical Approval: Patient data was retrospectively analysed and did not change patient care. Ethical Committee approval was therefore deemed unnecessary.

Materials and Methods

All participants provided written informed consent to participate in this study. This study was con-ducted under the principles of the Declaration of Helsinki. We retrospectively selected from hospital's records 257 PHF surgically treated between January 2012 and December 2019. Inclusion criteria were three-part fracture with surgical neck and greater tuberosity involvement or four-part fracture with involvement of surgical neck, greater and lesser tuberosity according to the Neer classification, treated by open reduction and internal fixation using a locking compression plate (Philos, Synthes, Oberdorf, Switzerland), the availability of preoperative X-ray and CT scan, and postoperative radiographs, age of 18 years or older. Exclusion criteria were inability to acquire the planned imaging, minimal displacement PHF or two-part fracture, type 5 and fracture-dislocation of the humeral head according to the Neer classification, pediatric fractures (physeal injuries), osteosynthesis with intramedullary nail, percutaneous pinning, external fixation, MIPPO and shoulder arthroplasty replacement (Table 1).

According to inclusion criteria we recruited 74 patients (Fig. 1).

For each patient were recorded: demographic data, duration of surgery, side of the fracture and surgical approach.

These patients were divided into 2 groups based on the surgical approach: deltopectoral (group A-DPA) or direct lateral transdeltoid approach (group B-LTA).

Table 1: Study inclusion and exclusion criteria

INCLUSION CRITERIA	EXCLUSION CRITERIA
- Three-part fracture with surgical neck and greater tuberosity involvement according to the Neer classification - Four-part fracture with involvement of surgical neck, greater and lesser tuberosity according to the Neer classification	- Minimal displacement PHF Two-part fracture according to the Neer classification - Type 5 and fracture-dislocation of the humeral head according to the Neer classification
- ORIF using locking compression plate	- Osteosynthesis with intramedullary nail, Percutaneous pinning, Ex-fix, MIPPO - Shoulder arthroplasty replacement
- Pre- and postoperative radiographs - Preoperative CT scan	Inability to acquire: - Pre- and postoperative X-ray - Preoperative CT scan
	- Pediatric fractures

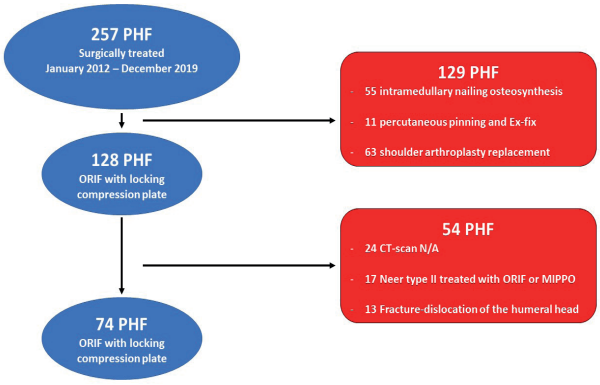

Figure 1: Patient selection algorithm. The blue circles show the progressive patients selection flow. The red boxes show the number and the criteria of the excluded patients.

Two Authors independently classified the fractures' pattern by preoperative CT scans from hospital's records and evaluated plane radiographs preoperatively and at the last follow-up, measuring the greater tuberosity fracture displacement (> or < 5mm), the humeral head-shaft angle (anatomical range 120°-145°) (14–19).

Statistical analysis was performed using R v3.6.3 (https://www.r-project.org).

The association between surgical approach and duration of surgery was detected using the Wilcoxon-Mann-Whitney test.

The association between surgical approach and surgeon's chance to reduce the fracture into normal ranges was detected using the Fisher test for dichotomous nominal variables.

Surgical approaches and Technique

Four senior surgeons, who were trained in both surgical approaches, operated both groups using the beach-chair position on an OPT 100 table with modular helmet headrest (Opt surgicalsystems ® Calliano

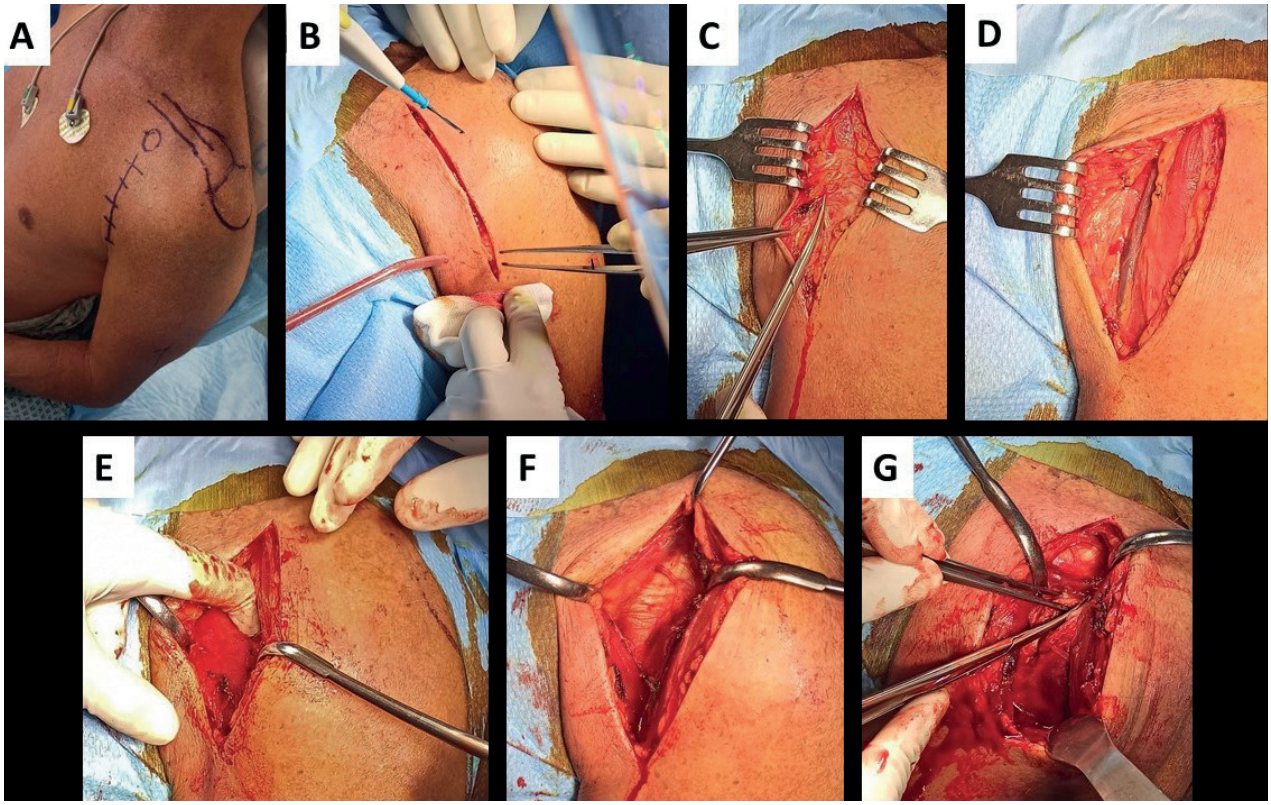

Figure 2: Representative intra-operative images from DPA group. (A) Surface marking of bony landmarks; (B) skin incision following the delto-pectoral sulcus and careful hemostasis; (C-D) incision of the fascia and isolation of the cephalic vein; (E) identification the internervous plane between deltoid muscle (axillary nerve) laterally and pectoralis major muscle (medial and lateral pectoral nerves) medially; (F) exposure the tendon of the subscapularis muscle; (G) capsule incision and intra-articular access.

(TN), Italy). The mobile C-arm with image intensifier was positioned at the head of the patient, on the homolateral side. Fluoroscopy was carried out in anteroposterior and, when possible, axillary view to define fragment configuration, position, and size.

DPA (Fig. 2 A-G) consists of a straight skin incision starting from the coracoid process, following the delto-pectoral sulcus. An incision of the subcutaneous tissue is made until the fascial plane is reached. Identified and protected the cephalic vein, an incision of the fascia is made following the superficial internervous plane consisting of the deltoid muscle laterally (axillary nerve) and the pectoralis major muscle medially (medial and lateral pectoral nerve).

The deltoid muscle is separated from the pectoralis muscle and the cephalic vein is mobilized either medially or laterally as needed. The clavipectoral fascia is opened, allowing the identification of the lateral margin of the conjoined tendon. Below this structure runs the subscapularis muscle that covers the joint capsule. It is necessary to extrarotate the limb to bring the circumflex nerve posteriorly, which normally crosses postero-anteriorly. If the fracture does not involve the small tuberosity resulting in its separation from the humeral head, the tendon of the subscapularis muscle should be incised at about 2 cm from its insertion to preserve vascularization, exposing the joint capsule and the fracture site.

LTA (Fig. 3 A-E) consists of a straight skin incision about 5 cm anterolateral to the deltoid, starting from the lateral margin of the acromion along the humeral diaphyseal axis. The fascia covering the del-

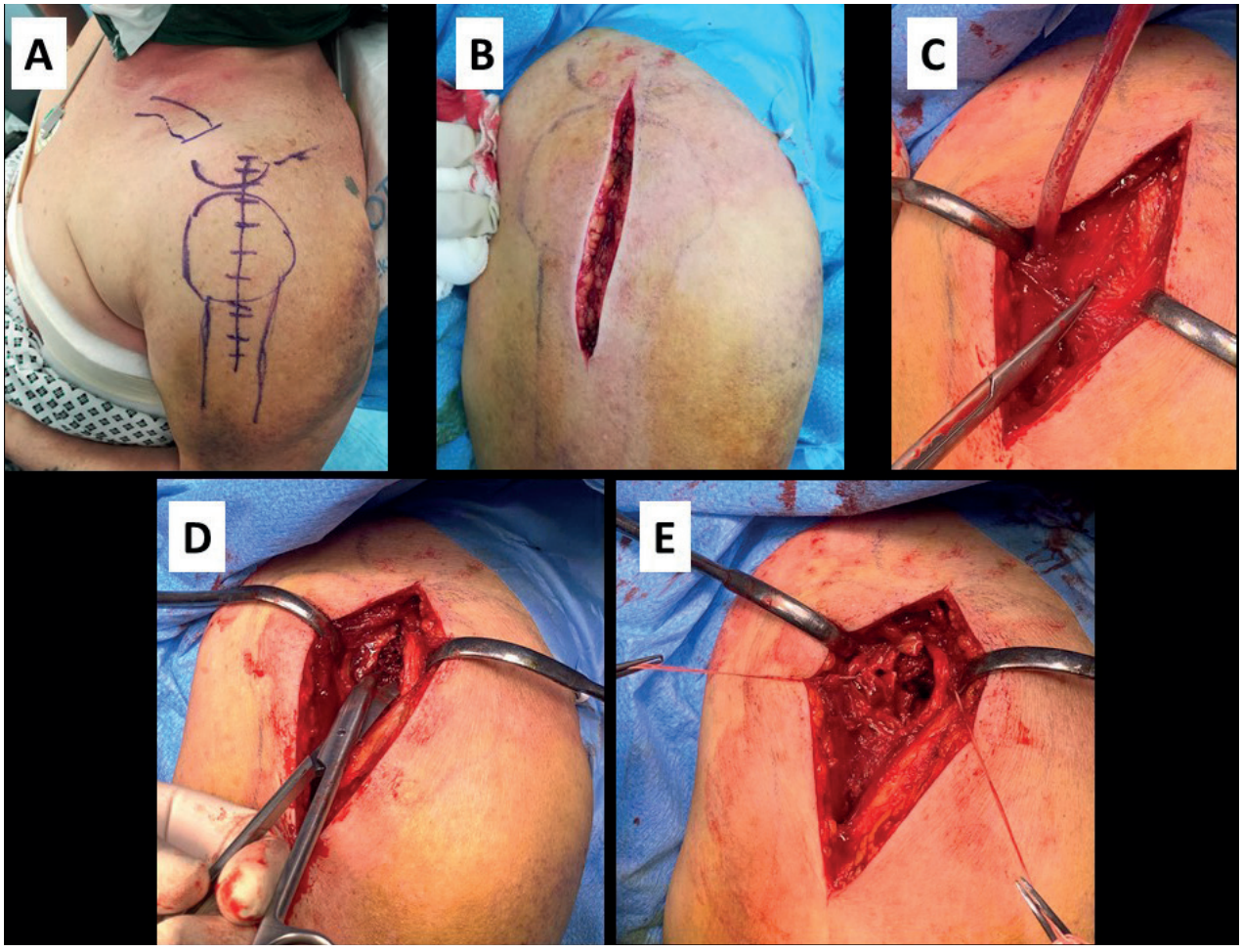

Figure 3: Representative intra-operative images from LTA group. (A) Surface marking of bony landmarks; (B) straight skin incision; (C-D) incision of the fascia to access to the osteotendinous plane; (E) exposure of the proximal humerus through the deltoid muscle fibers.

toid muscle is incised and the osteotendinous plane is reached through the deltoid muscle. It is important not to extend the incision below 5 cm from the lateral margin of the acromion because of the risk of damaging the circumflex nerve, which leaves the posterior wall of the axilla by crossing the quadrangular space of Velpeau. This nerve surrounds the humerus and penetrates deeply into the deltoid.

Results

In our series, DPA approach was predominant 52/74 (72%) vs 22/74 (28%). Group A was composed of 31 females and 21 males, the mean age was 57 ± SD 9,77 (range 39-77), while group B was composed of 16 females and 6 males, and the mean age was 60 ± SD 15,33 (range 20-80) (Table 2).

The average radiological follow-up period was 12 months (range 10 – 15, ± SD 1.15).

The radiological outcomes are summarized in table 3.

In group A-DPA there were 38 PHF with preoperative displacement of the greater tuberosity > 5mm. The reduction was obtained in 24 patients (63 %) while in 14 (37 %) this was not achieved (Fig. 4 A-F).

In group B-LTA there were 16 patients with preoperative greater tuberosity displacement > 5mm. The greater tuberosity anatomy was restored in all of cases (100 %). The humeral head-shaft angle malalignment (< 120° or >145°) was restored in 12 patients out of 14 (86 %). (Fig. 5 A-F).

The Fisher test was used to investigate the possible relationship between the surgical approach and the quality of the reduction in displaced fractures. The LTA significantly correlated with a better reduction of the greater tuberosity displacement ($p < 0.05$). No correlation was found between the surgical approach and restoration of the humeral head-shaft angle ($p > 0.05$). The mean time of surgery was 84,85 ± 33,56 minutes for the DPA (range 40 - 210) and 80,59 ± 29,60 minutes for LTA (range 45 - 170) ($p > 0.05$).

Table 2: Demographic data related to patients included in the study

Surgical approach	Gender	Side of fracture	Neer 3	Neer 4
Deltopectoral approach	M 21 / F 31	L 31 / R 21	39 (75%)	13 (25%)
Lateral trandeltoid approach	M 6 / F 16	L 9 / R 13	19 (86,4%)	3 (13,6%)

Discussion

PHF treatment remains a challenge in orthopaedic surgery (20) and there is no consensus upon the best treatment option (21–24). The decision-making process, in addition to the fracture's pattern, is also influenced by factors related to the surgeon and the patient. Most patients with PHF are elderly with many comorbidities and limited expectations. Operative treatment is then rarely indicate in patients older than 80 years (25). Conservative management continues to be the best option for the majority of patients but approximately in 20% of them surgery is required (25). When the fracture is severely displaced, surgery is recommended but the final outcome is correlated to multiple factors (24,26). Among patients younger than 65 years old, anatomic reduction with ORIF is crucial (26).

In case of surgery, the choice of the best surgical approach is crucial (27). DPA is mostly performed by

Table 3. Radiological outcomes and duration of surgery for both surgical approaches.

Surgical approach	Preoperative greater tuberosity fracture displacement > 5mm	Postoperative greater tuberosity fracture displacement > 5mm	Preoperative humeral head-shaft angle malalignment (<120° or >145°)	Postoperative humeral head-shaft angle malalignment (<120° or >145°)	Duration of surgery (Mean, ± SD)
Deltopectoral approach	38	14 (37 %)	44	5 (11%)	84,8, ± 33,5
Lateral trandeltoid approach	16	0 (0%)	14	2 (14%)	80,6, ± 29,6
	p < 0,05		p > 0,05		p > 0,05

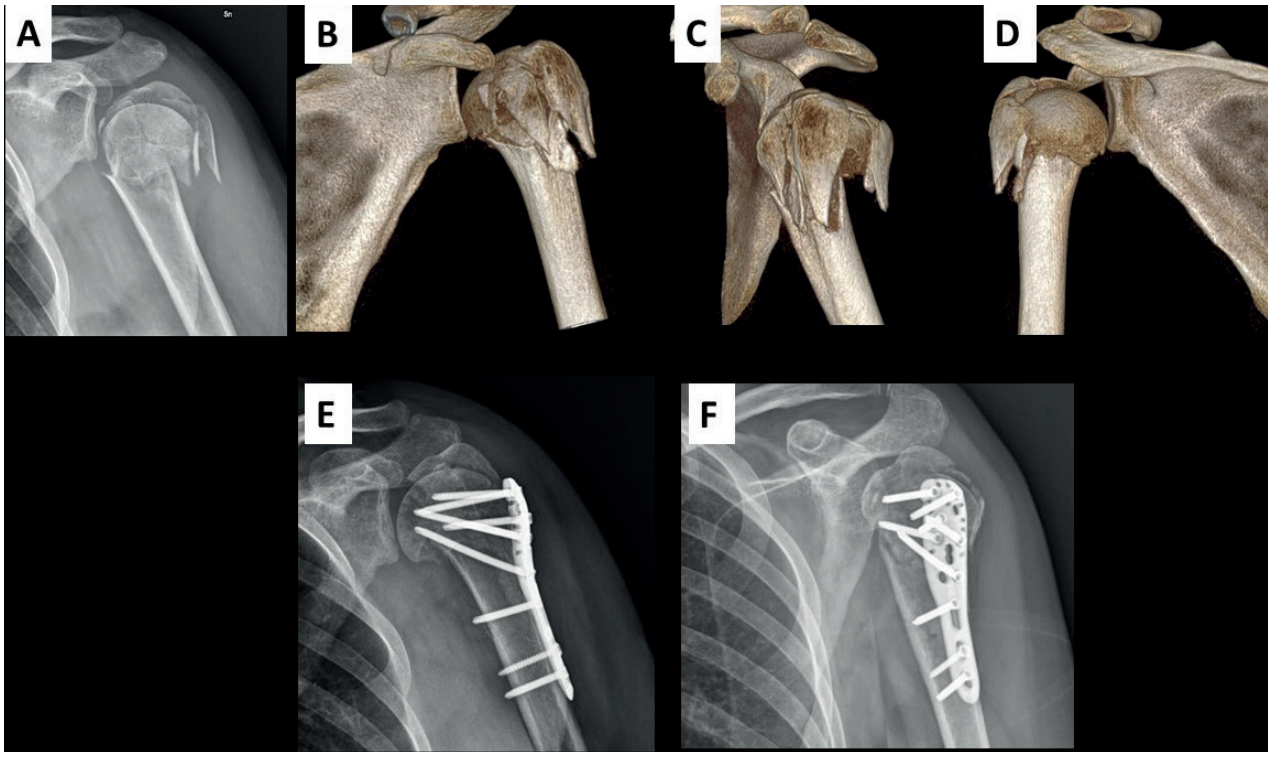

Figure 4: Clinical case 1: Male, 61 years old. Proximal humeral fractures Neer 4 treated by ORIF using deltopectoral approach (DPA). (A) Preoperative anteroposterior X-Rays (XR); (B-D) 3D CT-scan Anterior/Lateral/Posterior views; (E-F) Postoperative XR AP and LL views. The use of this surgical approach succeeded in the humeral head-shaft angle restoration, but not the in greater tuberosity reduction (> 5 mm of residual displacement).

surgeons and described in literature. However, this approach requires an extensive soft-tissue dissection including a partial release of the deltoid insertion and its over retraction. These actions on the muscle can lead to functional deficits of the muscle. Furthermore, soft tissue release increases the risk of avascular necrosis of the humeral head (13).

LTA allows a direct plating zone of the lateral proximal humerus, requiring less deltoid retraction and soft tissue dissection. It does not affect the blood supply of the humeral head, namely the anterolateral branch of the anterior humeral circumflex artery. This approach, however, has a higher risk of axillary nerve damages and paralysis of the anterior portion of the deltoid muscle (28). The axillary nerve lies anterior to the subscapularis, wraps around the surgical neck of the humerus, and passes through the quadrangular space to innervate the teres minor and deltoid muscles. The location of the axillary nerve is around 6.32 cm (range, 5.20-7.6 cm) distal from the anterolateral aspect of the acromion and the course of this nerve must be kept in mind during the surgical approach to avoid neural injuries (29).

Defining which is the better surgical approach is still an open debate (24). In 2013 Buecking et al. published a prospective randomized trial of 120 patients that compared these two approaches using three main parameters (pain, clinical Constant score, complications) and did not detect any significant differences (30). A recent systematic review and meta-analysis by Xie and Zhang suggested that LTA had less humeral head necrosis and shorter surgical time (27). The authors also concluded that both approaches have similar results in functional outcomes, number of complications, and time of hospitalization.

Although in literature many studies about PHF can be found, just few of them take into account defined radiological parameters and none of them unequivocally answers which is the most appropriate surgical approach for each specific type of fracture and each specific patient (27). In our study, X-rays

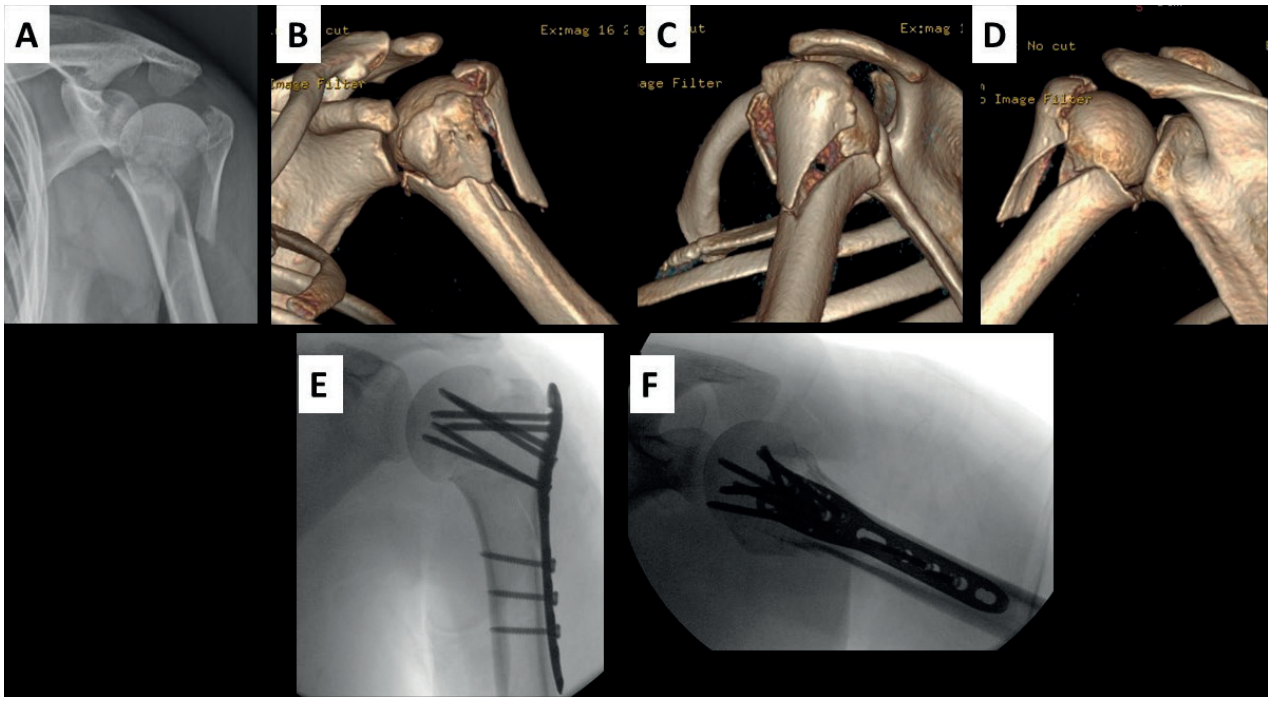

Figure 5: Clinical case 2: Female, 67 years old. Proximal humeral fractures Neer 4 treated by ORIF using direct lateral transdeltoid approach (LTA). (A) Preoperative AP view X-Rays (XR); (B-D) 3D CT-scan Anterior/Lateral/Posterior view; (E-F) postoperative AP and LL X-Ray. The restoration of the humeral head-shaft angle was obtained in combination with a good reduction of the humeral greater tuberosity.

and CT-scans of patient before PHF and immediate X-ray post-surgery were detected, thus comparing the two approaches by two radiological parameters strictly related to the clinical outcome: the humeral greater tuberosity displacement and the head-shaft angle. In fact, the greater tuberosity acts as a fulcrum over which 3 of the 4 muscles of the rotator cuff act on; therefore its good reduction is crucial for a good functional recovery of the shoulder (18,31–33). Posterosuperior displacement of the greater tuberosity of more than 5 mm can result in malunion and impingement of the shoulder due to an altered rotator cuff insertion site influencing the motion in the glenohumeral joint (34).

The physiological humeral head-shaft angle is normally 135° with an interindividual variability of 10-15°; this angle measures the proximal humeral displacement on the coronal plane being measured on true anterior-posterior (AP) radiographs. The goal of a good reduction of any proximal humeral fracture is to restore this anatomic-functional axis (35–37).

No statistically significant differences regarding the restoration of the humeral head-shaft angle were found between the two surgical approaches. This is because the reduction of the fracture at the anatomical or surgical neck level may be obtained through both surgical windows. Concerning the displacement of the humeral greater tuberosity instead, the result could be better through LTA, since this approach allows a direct exposure of this structure, permits to isolate it and to pull it parallelly to its axis obtaining an anatomical reduction and conferring a better tightness of the screws as their force vector is perpendicular to the fracture line.

Furtherly this surgical approach does not significantly affect the length of surgery.

Regarding early postoperative neurological complication, no damages of the circumflex nerve were reported by hospital's records in the LTA group, being the nerve isolated and protected during the surgical procedure.

The main limitations of this study are the small sample size, the uneven distribution of patients through the two groups, a higher percentage of PHF type Neer 4 in the DPA group compared with LTA group, and the lack of clinical evaluation at follow up.

In the future it would be interesting to perform a clinical assessment of these patients to evaluate if the two surgical approaches have an impact on the shoulder function and range of motion.

Conclusion

Direct lateral deltoid splitting approach (LTA) compared to deltopectoral approach (DPA) has significant advantages in the reduction of the grater tuberosity displacement.

No difference between the two approaches in the restoration of the physiological humeral head-shaft angle was found.

Lastly, the length of the surgery was similar in both groups, being not significantly affected by the surgical approach.

Conflicts of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Ethical Approval: Patient data was retrospectively analyzed and did not change patient care. Ethical Committee approval was therefore deemed unnecessary.

References

1. Bartonícek J, Dzupa V, Fric V, Pacovský V, Skála-Rosenbaum J, Svatos F. Epidemiology and economic implications of fractures of proximal femur, proximal humerus, distal radius and fracture-dislocation of ankle). Rozhl Chir 2008; 87: 213–9.
2. Nikose S, Khan S, Mundhada G, et al. Complex Proximal Humeral Fractures (Three or Four Part) with Dislocation: Outcome Analysis of Percutaneous Reduction and External Fixation. MOJ Orthop Rheumatol 2016; 6: 17–23.
3. Knowelden J, Buhr AJ, Dunbar O. Incidence of fractures in persons over 35 years of age. A report to the MRC working party on fractures in the elderly. Br J Prev Soc Med 1964; 18: 130–41.
4. Donaldson LJ, Cook A, Thomson RG. Incidence of fractures in a geographically defined population. J Epidemiol Community Health 1990; 44: 241–5.
5. Maluta T, Amarossi A, Dorigotti A, et al. External fixation can be an option for proximal humerus fractures Neer 3-4. Acta Bi-omed 2020; 91: 14-S.
6. Palvanen M, Kannus P, Niemi S, Parkkari J. Update in the epidemiology of proximal humeral fractures. Clin Orthop Relat Res 2006; 442: 87–92.
7. Fjalestad T, Hole MØ. Displaced proximal humeral fractures: operative versus non-operative treatment--a 2-year extension of a randomized controlled trial. Eur J Orthop Surg Traumatol 2014; 24: 1067–73.
8. Baudi P, Campochiaro G, Serafini F, et al. Hemiarthroplasty versus reverse shoulder arthroplasty: Comparative study of func-tional and radiological outcomes in the treatment of acute proximal humerus fracture. Musculoskelet Surg 2014 Apr; 98 Suppl 1: 19-25.
9. Verdano MA, Lunini E, Pellegrini A, Corsini T, Marenghi P, Ceccarelli F. Can the osteosynthesis with locking plates be a better treatment for unstable fractures of the proximal humerus? Musculoskelet Surg 2014; 98: 27–33.
10. Vicenti G, Antonella A, Filipponi M, et al. A comparative retrospective study of locking plate fixation versus a dedicated ex-ternal fixator of 3- and 4-part proximal humerus fractures: Results after 5 years. Injury 2019; 50: S80–8.
11. Neer CS 2nd. Displaced proximal humeral fractures. II. Treatment of three-part and four-part displacement. J Bone Joint Surg Am 1970; 52: 1090–103.
12. Robinson CM, Murray IR. The extended deltoid-splitting approach to the proximal humerus: variations and extensions. J Bone Joint Surg Br 2011; 93: 387–92.
13. Zlotolow DA, Catalano LW 3rd, Barron OA, Glickel SZ. Surgical exposures of the humerus. J Am Acad Orthop Surg 2006; 14: 754–65.
14. Robertson DD, Yuan J, Bigliani LU, Flatow EL, Yamaguchi K. Three-dimensional analysis of the proximal part of the humerus: relevance to arthroplasty. J Bone Joint Surg Am 2000; 82: 1594–602.
15. 15. DeLude JA, Bicknell RT, MacKenzie GA, et al. An anthropometric study of the bilateral anatomy of the humerus. J Shoulder Elb Surg 2007; 16: 477–83.
16. 16. Hertel R, Knothe U, Ballmer FT. Geometry of the proximal humerus and implications for prosthetic design. J Shoulder Elb Surg 2002; 11: 331–8.
17. Pearl ML. Proximal humeral anatomy in shoulder arthroplasty: Implications for prosthetic design and surgical technique. J Shoulder Elb Surg 2005; 14: 99S-104S.
18. Rouleau DM, Mutch J, Laflamme G-Y. Surgical Treatment of Displaced Greater Tuberosity Fractures of the Humerus. J Am Acad Orthop Surg 2016; 24: 46–56.
19. Klug A, Wincheringer D, Harth J, Schmidt-Horlohé K, Hoffmann R, Gramlich Y. Complications after surgical treatment of prox-imal humerus fractures in the elderly—an analysis of complication patterns and risk factors for reverse shoulder arthroplasty and angular-stable plating. J Shoulder Elb Surg 2019; 28: 1674–84.
20. Hertel R. Fractures of the proximal humerus in osteoporotic bone. Osteoporos Int 2005; 16: 65–72.
21. Blonna D, Castoldi F, Scelsi M, Rossi R, Falcone G, Assom M. The hybrid technique: potential reduction in complications re-lated to pins mobilization in the treatment

of proximal humeral fractures. J Shoulder Elb Surg 2010; 19: 1218–29.
22. Williams GRJ, Wong KL. Two-part and three-part fractures: open reduction and internal fixation versus closed reduction and percutaneous pinning. Orthop Clin North Am 2000; 31: 1–21.
23. Fattoretto D, Borgo A, Iacobellis C. The treatment of complex proximal humeral fractures: analysis of the results of 55 cases treated with PHILOS plate. Musculoskelet Surg 2016; 100: 109–14.
24. Beks RB, Ochen Y, Frima H, et al. Operative versus non-operative treatment of proximal humeral fractures: a systematic review, meta-analysis, and comparison of observational studies and randomized controlled trials. J Shoulder Elb Surg 2018; 27: 1526–34.
25. Murray IR, Amin AK, White TO, Robinson CM. Proximal humeral fractures: Current concepts in classification, treatment and outcomes. J Bone Jt Surg - Ser B 2011; 9 B: 1–11.
26. Burkhart KJ, Dietz SO, Bastian L, Thelen U, Hoffmann R, Müller LP. Behandlung der proximalen Humerusfraktur des Erwach-senen. Dtsch Arztebl Int 2013; 110: 591–7.
27. Xie L, Zhang Y, Chen C, Zheng W, Chen H, Cai L. Deltoid-split approach versus deltopectoral approach for proximal humerus fractures: A systematic review and meta-analysis. Orthop Traumatol Surg Res 2019; 105: 307–16.
28. Knežević J, Mihalj M, Čukelj F, Ivanišević A. MIPO of proximal humerus fractures through an anterolateral acromial approach. Is the axillary nerve at risk? Injury 2017; 48 Suppl 5: S15–20.
29. Traver JL, Guzman MA, Cannada LK, Kaar SG. Is the Axillary Nerve at Risk During a Deltoid-Splitting Approach for Proximal Humerus Fractures? J Orthop Trauma 2016; 30: 240–4.
30. Bockmann B, Buecking B, Franz D, Zettl R, Ruchholtz S, Mohr J. Mid-term results of a less-invasive locking plate fixation method for proximal humeral fractures: A prospective observational study. BMC Musculoskelet Disord 2015; 16: 1–7.
31. George MS. Fractures of the greater tuberosity of the humerus. J Am Acad Orthop Surg 2007; 15: 607–13.
32. Unnithan A, Matti Z, Hong TF. Outcome following Fractures of the Greater Tuberosity of the Humerus: A Retrospective Study. Shoulder Elb 2013; 5: 221–5.
33. White EA, Skalski MR, Patel DB, et al. Isolated greater tuberosity fractures of the proximal humerus: anatomy, injury patterns, multimodality imaging, and approach to management. Emerg Radiol 2018; 25: 235–46.
34. Mattyasovszky SG, Burkhart KJ, Ahlers C, et al. Isolated fractures of the greater tuberosity of the proximal humerus: A long-term retrospective study of 30 patients. Acta Orthop 2011; 82: 714–20.
35. Assunção JH, Malavolta EA, Beraldo RA, Gracitelli MEC, Bordalo-Rodrigues M, Ferreira Neto AA. Impact of shoulder rotation on neck-shaft angle: A clinical study. Orthop Traumatol Surg Res 2017; 103: 865–8.
36. Jia X-Y, Chen Y-X, Qiang M-F, et al. Postoperative Evaluation of Reduction Loss in Proximal Humeral Fractures: A Comparison of Plain Radiographs and Computed Tomography. Orthop Surg 2017; 9: 167–73.
37. Petros RSB, Ribeiro FR, Teno AC, et al. Proximal humerus fracture with locking plate: Functional and radiographic results. Ac-ta Ortop Bras 2019; 27: 164–8.
38. Large TM, Adams MR, Loeffler BJ, Gardner MJ. Posttraumatic Avascular Necrosis After Proximal Femur, Proximal Humerus, Talar Neck, and Scaphoid Fractures. J Am Acad Orthop Surg 2019; 27: 794–805.

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Correspondence:
Andrea Amarossi, MD
ORCiD: 0000-0001-9987-5541
Orthopaedic and Traumatology Department
AOUI Verona
Piazzale A. Stefani, 1 - 37136 Verona
Phone number: 00390458123542
Fax number: 00390458123578
Email: andrea.amarossi@gmail.com