Technical Note

Fracture Avulsion of the Greater Tuberosity: Arthroscopic Transosseous Augmented Technique

Claudio Chillemi, M.D., Riccardo Proietti, M.D., Marco Rengo, M.D., Marco Damo, M.D., Domenico Paolicelli, M.D., and Alessandro Castagna, M.D.

Abstract: The fracture avulsion of the greater tuberosity (GT) represents 2% of all humerus fractures, but the true incidence is likely to be higher, being challenging the initial diagnosis on radiograph. The fracture avulsion of the GT could have different treatments: nondisplaced or minimally displaced fractures are treated conservatively, whereas for displaced or comminuted fractures surgical treatment is preferred. The most important finding of this study is the employment of an all-arthroscopic transosseous augmented technique for the treatment of a displaced humeral GT fracture avulsion. This technique shows all the advantages of the transosseous fixation and arthroscopic approach.

Fractures of the proximal humerus represent approximately 5% of all fractures and almost half of all humeral fractures.[1] The 20% of the latter are represented by isolated fractures of the greater tuberosity (GT).[1] These fractures may be more challenging to identify on initial plain radiographs because of osseous overlap when the glenohumeral joint is internally rotated. Additionally, small comminuted fragments may simply be overlooked or misinterpreted as calcific deposition within the rotator cuff or intra-articular loose bodies,[1] so that its true incidence may therefore be higher.[1]

From the Department of Orthopaedic Surgery, Istituto Chirurgico Ortopedico Traumatologico (ICOT), Latina, Italy (C.C.); Department of Anatomical, Histological, Forensic Medicine and Orthopaedics Sciences, Sapienza University of Rome, Istituto Chirurgico Ortopedico Traumatologico (ICOT), Latina, Italy (R.P., M.D., D.P.); Department of Medico-Surgical Sciences and Biotechnologies, Sapienza University of Rome, Diagnostic Imaging Unit, Istituto Chirurgico Ortopedico Traumatologico (ICOT), Latina, Italy (M.R.); and Shoulder Unit IRCCS Humanitas Institute, Milan, Italy (A.C.).

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Address correspondence to Claudio Chillemi, M.D., Department of Orthopaedic Surgery, Istituto Chirurgico Ortopedico Traumatologico, Franco Faggiana 1668, 04100 Latina, Italy. E-mail: c_chillemi@libero.it

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The demographics of patients who sustain isolated GT fractures have been more extensively reviewed, and their occurrence is predominantly in young male patients.[1] The treatment of this kind of fracture is controversial. Generally nondisplaced or minimally displaced fractures are treated conservatively. If the displacement is more than 5 mm or if the fractures are comminuted a surgical treatment is preferred.[2] Although open procedures are preferred for comminuted, widely displaced fractures, arthroscopic procedures can be used for multifragment bony avulsion of the supraspinatus tendon and isolated one-part GT fractures with minimal displacement.[1] The displacement of the fracture is determined by the rotator cuff attachments on the superior margin of the GT that is marked by 3 distinct flat impressions: the superior, middle, and inferior facets.[3] The arthroscopic technique, even if it could appear more demanding, allows a more complete evaluation of the shoulder (i.e., associated lesions) and reduces the soft tissue damage.[4] To treat the GT fracture avulsion different techniques are proposed,[5,6] such as the tension band wire suture, transosseous braided-tape, and double-row suture bridge with anchor.[7,8] The last 2 options may be considered superior in terms of mechanical proprieties, strength, and stability. Especially in comminuted or eggshell fractures when rigid fixation is not feasible with only anchors, the aim to prevent GT fracture displacement has been recently proposed with the use of the subacromial spacer (InSpace balloon, Stryker, USA) to better compress and stabilize the fracture.[9]

The purpose of this article was to describe a reproducible, all-arthroscopic transosseous augmented (ATA) technique as a fixation method for the treatment of the avulsion-type GT fractures with a strong and stable construct.

Surgical Technique

Indication

The presented technique is indicated for patients suffering from a displaced fracture avulsion of the GT deemed at risk of fragment comminution if using standard and larger fixation hardware (e.g., screws with or without plate). In the presence of a consistent bony fragment, open reduction internal fixation would be more appropriate. Preoperative imaging is essential for treatment choice. Radiographs are needed for the first diagnosis of the fracture, showing the presence of the fragment, its eventual dislocation, and its size. Imaging study includes computed tomography scans along with 3-dimensional reconstructions, and magnetic resonance imaging to confirm the appropriateness of the indication. Illustrative cases are reported in Figs 1 and 2.

Preparation (With Video Illustration)

The surgery (Video 1) is performed under an interscalene block procedure with ultrasound guidance in the presurgical room. The patient is positioned in lateral decubitus, stabilized in a bean bag, with a dorsal tilt of 30° with the glenoid surface parallel to the floor as a reference. A sterile surgical field is prepared after standard skin disinfection, and sterile skin traction is applied and connected to the traction system.

Portal Placement, Diagnostics, and Debridement

The first arthroscopic portal is standard posterior through the soft spot for the arthroscope is introduced into the intra-articular space. An anterior portal is then created under direct visualization (outside-in technique), without any cannula positioning. After diagnostic arthroscopy, a motorized shaver is introduced into the anterior portal to remove blood clots and to exactly locate the fracture avulsion of the GT.

The arthroscope is then moved from the same posterior portal into the subacromial space, usually occupied by blood clots. With the use of a spinal needle, centered to the lesion and tangent to the fractured area, the superolateral portal is then created. The edge of the

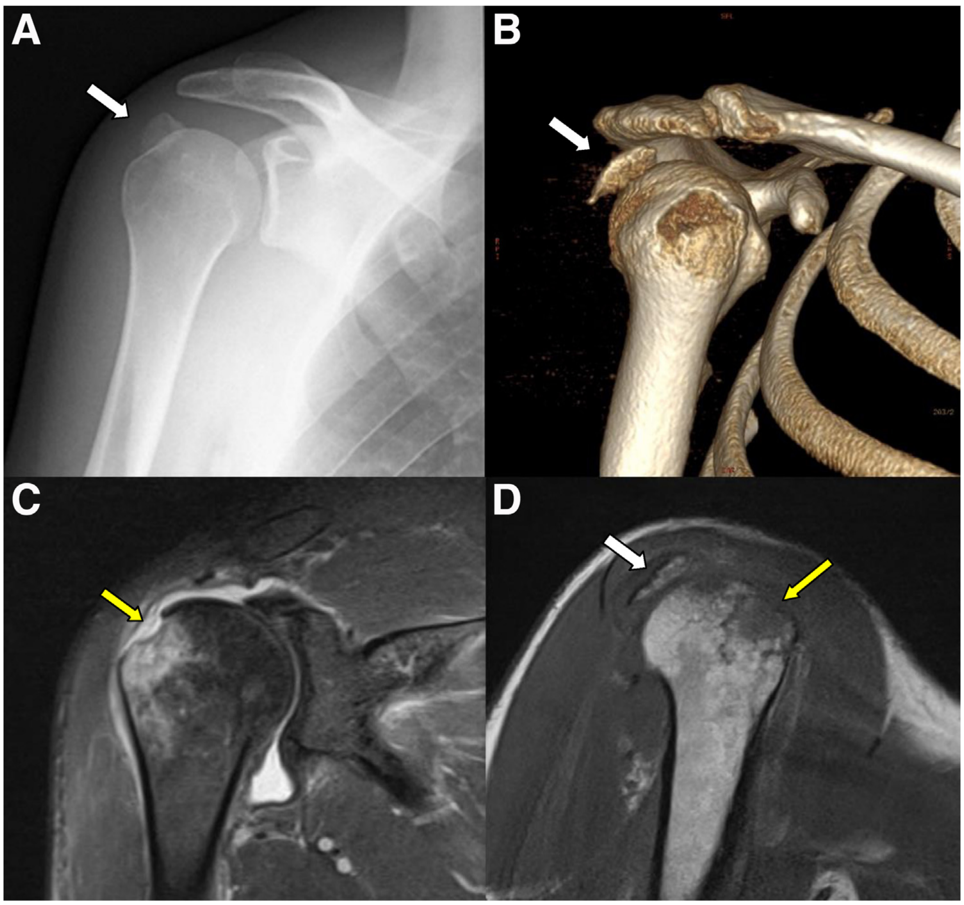

Fig 1. Case #1: A 45-year-old man reported direct trauma on his right shoulder after a fall on skis. His diagnostic procedure consisted of (A) radiograph, anteroposterior view performed at the emergency room. The fracture avulsion of the greater tuberosity (→) may simply be misinterpreted as calcific deposition within the rotator cuff. (B) Computed tomography scan with 3-dimensional reconstruction. A superior displaced fracture avulsion of the greater tuberosity (→) is easily detected. (C, D) Magnetic resonance imaging (1.5 Tesla). Oblique coronal STIR (C) and sagittal T1 (D) views. The crater of the fracture (yellow arrow) is located in the proximal humerus and presents widespread edema and bone bruise, whereas the fragment (white arrow) appears superiorly displaced.

Fig 2. Case #2: A 56-year-old woman reported an accident at work involving her right shoulder. Her diagnostic procedure consisted of (A) radiograph, anteroposterior view. Fracture avulsion of the greater tuberosity. (B) Magnetic resonance imaging (1.5 Tesla), oblique coronal STIR views. The crater of the fracture is located in the proximal humerus and presents widespread edema and bone bruise. Ten days after the trauma the patient underwent surgery (open reduction and fixation with a screw with a washer, reinforced with a knotless anchor) and was immobilized in a sling for 30 days. At this time radiograph showed the failure of reduction of the fracture (C). The patient was reoperated almost 3 months after the initial trauma: the fracture avulsion of the greater tuberosity was reduced with the arthroscopic transosseous augmented technique after removal of the screw (D).

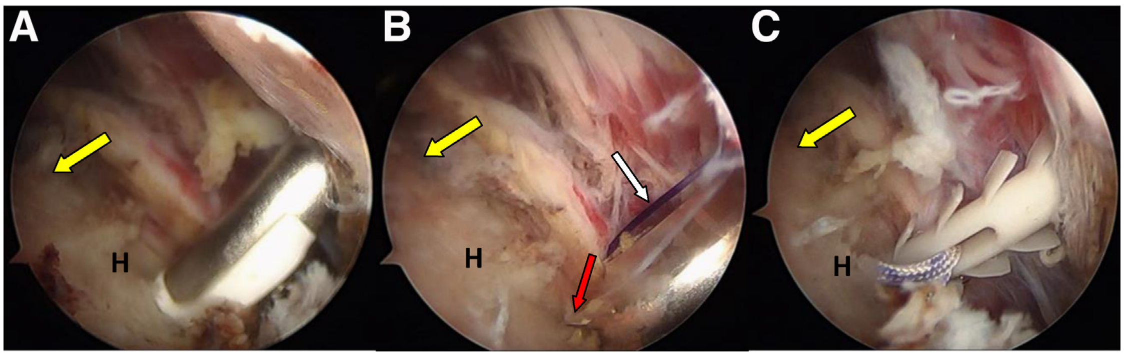

Fig 3. Humeral lateral aspect preparation: arthroscopic view, right shoulder, lateral decubitus, the arthroscope is posterior to the subacromial space. (A) From inferior lateral portal with the radio frequency probe the accurate preparation around the lateral margin of the fracture and the adjacent healthy metaphyseal humeral cortex make the visualization and the insertion of the cortical lateral augmentation easier, all the fibrotic tissue is removed and the lateral aspect of the humerus is debrided. This preparation around the lateral margin of the fracture (yellow arrow) and the adjacent healthy metaphyseal humeral cortex (H) must be accurate to improve visualization and ease the insertion of the cortical lateral augmentation. (B) The lateral entry point for the Taylor Stitcher is located almost 2 cm below the lateral fracture margin (yellow arrow). Note the PDS #1 suture (white arrow) as a shuttle inserted into the eyelet of the superelastic transosseous needle (red arrow). (C) Entry point of the Elite-SPK with the loaded sutures below the lateral fracture margin (yellow arrow). Several stabilizing flaps are attached to the main body of this PEEK device, which in combination with the wide supporting under the head have the function to provide an optimal primary stability of the implant.

Fig 4. Taylor Stitcher Evo connected with a superelastic transosseous needle.

bony fragment and the crater of the fracture are debrided. At this moment, associated anterosuperior rotator cuff tear may be easily identified. An additional inferolateral portal, performed 2 cm below the superolateral portal, is then created. Through the latter portal the lateral aspect of the humerus is prepared (Fig 3A) to perform the transosseous tunnel with a dedicated instrument: the Taylor Stitcher Evo (NCS Lab Srl, Medical Devices Factory, Italy) connected with a superelastic transosseous needle (STN) (Fig 4).[10] The lateral entry point is established 2 cm below the lateral fracture margin to prevent cracking the cortex (Fig 3B). This dedicated instrument allows the creation of the transosseous tunnel by manually tapping the advancement mechanism on the handle to deploy the STN. Tunnels are 1.9 mm in diameter and present a smooth, curved morphology. Once the tunnel is created, a polydioxanone monofilament (PDS #1, Ethicon, Somerville, NJ) is passed as a shuttle wire. To avoid any peak stress on the healthy bone below the margin of the fracture, a cortical lateral augmentation named Elite-SPK (NCS Lab Srl, Medical Devices Factory, Italy) is employed (Fig 3C). Three different sutures (1 of #1.2 mm and 1 of #2.2 mm of XBraid TT [Stryker] nonabsorbable, smooth, low-profile ultra-high molecular weight polyethylene suture tape; and 1 HS-Fiber (Riverpoint Medical) nonabsorbable braided ultra-high molecular weight polyethylene suture), initially loaded into the front eyelet of this PEEK implant, are passed. In the external eyelet of the implant, a violet Vicryl (Ethicon) is positioned. This will be used later to laterally shuttle the medial sutures to achieve a repair in a closed loop.

Fracture Reduction and Fixation

Both ends of the HS-Fiber suture and of the XBraid TT tape #2.2 mm are medially passed (from posterior to anterior) into the inserted tendon on the bony fragment. Later, the XBraid TT tape #1.2 mm is employed to repair the supraspinatus tendon tear. The sutures are closed in a mattress type, then one limb of each suture is shuttled with the help of the violet Vicryl from anterior to posterior in the external eyelet of the Elite-SPK, and are laterally tied respectively with their remaining free ends (Fig 5).

Rehabilitation

Immediately after surgery and for the first 4 postoperative weeks a shoulder sling with 15° to 20° of arm

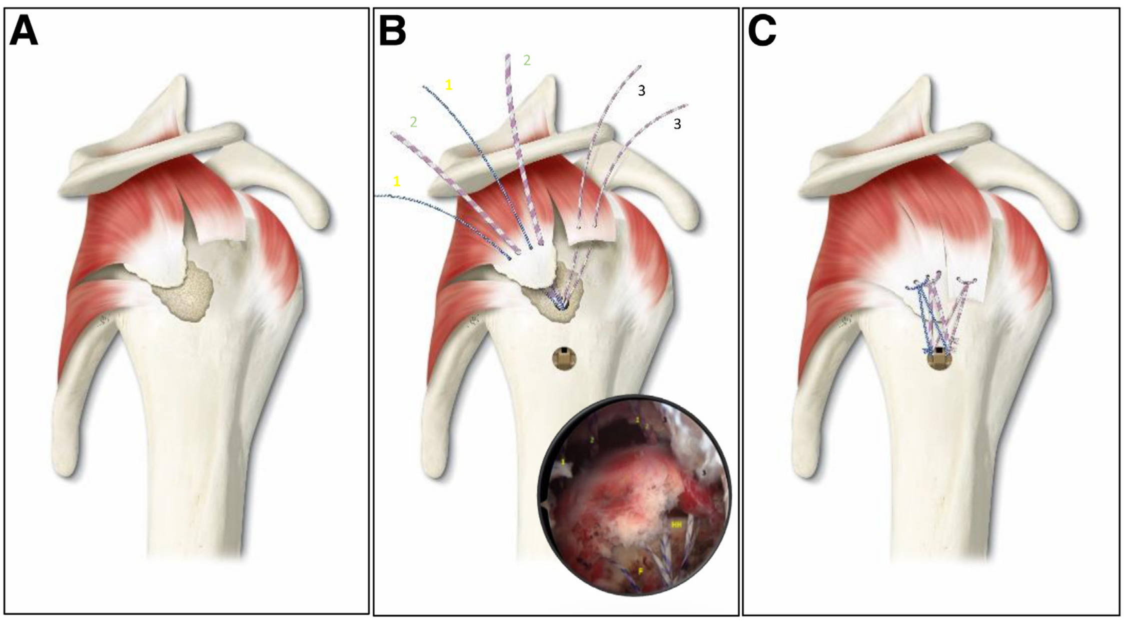

Fig 5. Illustrations of the arthroscopic transosseous augmented technique for the treatment of the fracture avulsion of the greater tuberosity. (A) Superior displaced fracture avulsion of the greater tuberosity. (B) Once the augmentation is implanted on the lateral cortex of the humerus the sutures, coming out from the transosseous exit point into the crater fracture, are passed posteriorly into the tendon of the avulsed fragment ([1] and [2]) and anteriorly into the torn tendon [3]. In the circle: the arthroscopic view showing the suture distribution as depicted in the figure. (C) Final configuration: all the sutures are tied in a double-row configuration so that the fracture is reduced and stable, and the rotator cuff tear is repaired.

Table 1. Advantages and Risk/Limitations of the Arthroscopic Transosseous Augmented Technique

Transosseous Technique		Arthroscopic Approach	
Advantage	Risks/Limitations	Advantage	Risks/Limitations
Mechanical properties	High demand technique	Minor soft-tissue trauma → lower scar tissue adhesions	Need advanced arthroscopy skills
No risk of anchor pullout	Humeral fracture	Lower peri- and postoperative morbidity (blood loss)	Large greater tuberosity fracture (difficult reduction)
No risk of suture damage	Large greater tuberosity fracture (axillar nerve damage)	Visualization and treatment of any associated lesions	
Cost reduction		Optimal visualization and mobilization of the fragment	

abduction and neutral rotation is used. Elbow-wrist and hand active exercises are permitted. Passive shoulder mobilization can start after 3 weeks. Assisted active rehabilitation programs for full range of motion recovering, strengthening, and proprioception can be initiated by week 6, progressively, allowing light activities and noncontact sports by 3 months, and more demanding activities and sports by 4 months.

Discussion

The ATA technique illustrated here for the treatment of a displaced humeral GT fracture avulsion shows all its advantages because of the combined transosseous fixation and arthroscopic approach (Table 1). The latter, with the daily advancements, still seems the treatment of choice with the double-row suture anchor fixation technique, improving the initial repair strength and restoring the normal anatomy.[11] However, the double-row technique presents some concerns regarding the surgical time (longer), the feasibility (high-demanding), and the safety (iatrogenic damage to the intact rotator cuff). As elucidated, the use of the ATA technique seems to almost completely overcome all the concerns reported earlier. Moreover, the ATA technique presented additional valuable aspects related to (1) the use of the tape instead of conventional high-strength sutures, and (2) the use of a lateral cortical augmentation. Regarding the former, from a biomechanical point of view, the tape increases the pressure at the footprint and the construct strength compared with the conventional sutures.[12] The lateral cortical augmentation with its peculiar shape and features may be considered as a suture platform that overcomes all the questions related to the bad bone quality of the GT[13] that a shoulder surgeon can encounter during an avulsion-type GT fracture, providing a reliable fixation. In addition, the use of the Elite-SPK shows other beneficial surgical details, reducing the risk of suture cut and bone damage (because there is no sliding of the sutures into the transosseous tunnel) and generating a compression vector perpendicular to the fracture area. The latter effect results in a maximization of the contact area, with an optimal pressure distribution, while reducing sutures-bone tunnel impingement. Moreover, the transosseous braided-tape additionally presents an economic advantage being less expensive.[7]

This technique has some risks and limitations (Table 1) related to the creation of the transosseous tunnel, such as the iatrogenic fracture of the humerus that may result in the need to convert to open surgery. For this reason, to prevent cracking the cortex, it is mandatory that the lateral entry point is established 2 cm below the lateral fracture margin. Because the distance from the nerve to the top of the humeral head is approximately 5 to 6 cm, the entry point is located in the safe zones to avoid nerve injury.[14]

Keeping this aspect in mind, a large GT fracture is to be considered too risky for the nerve.

In conclusion, the ATA technique was shown as a valid, reproducible surgical option in the treatment of displaced fracture avulsion of the GT of the humerus and seems to be ideal in such cases with smaller fragments, avoiding the risk of its splitting when using the screw.

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