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Surgical fixation of periprosthetic humeral shaft fracture about a short-stem anatomic total shoulder arthroplasty with a proximal humeral locking plate: surgical technique and report of 3 cases

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The increasing demand for shoulder arthroplasty has resulted in an obligatory rise in periprosthetic fractures of the humerus. The primary goal of treating these injuries is to maintain glenohumeral motion and implant stability while restoring shoulder function.[6] Fracture displacement, stability, location, and the presence of humeral stem loosening are key factors in determining whether a patient requires surgical intervention or can be managed nonoperatively. The Wright and Cofield classification system was developed to help categorize these injuries and guide treatment options.[19] Type A fractures are defined as those occurring about the stem and propagating proximally. Type B fractures are localized to the stem with less proximal extension. Type C fractures are humeral shaft fractures that occur distal to the stem.

Nonoperative management is reserved for nondisplaced fractures proximal, at, or distal to a well-fixed humeral stem.[16,19] Patients with unstable humeral stems can be treated with revision of the humeral component to a long stem construct with fracture fixation.[4,7,8] Open reduction and internal fixation (ORIF) are utilized for displaced fractures with stable implants. Fixation around the humeral stem is often the greatest challenge, sometimes requiring cerclage wires, strut allograft, or extension plates to obtain adequate proximal fixation.[5,8,15] Cerclage wires provide poor axial compression and torsional resistance compared to unicortical and bicortical screws.[11] Standard plates may present a challenge as the humeral stem sits within the canal, blocking bicortical screw purchase.[9] Additionally, more proximal fracture patterns may make plate placement difficult due to the flare of the greater tuberosity.

Locking plate technology provides the ability to overcome some of these challenges by allowing for placement of unicortical screws as well as multiple polyaxial proximal screws.[9,10,17,18] Proximal humeral locking plates have been described to treat periprosthetic humeral shaft fractures after reverse total shoulder arthroplasty (RTSA).[12,13] To date, no studies have evaluated the use of proximal humeral locking plates in the setting of periprosthetic humeral shaft fractures about a well-fixed short-stem anatomic total shoulder arthroplasty (aTSA). The purpose of this study was to describe a novel technique for ORIF of periprosthetic humeral shaft fractures about a well-fixed short-stem aTSA utilizing a proximal humeral locking plate. The secondary goal of this study was to describe the short-term outcomes of this procedure in a series of three patients.

Methods

This was a retrospective analysis of all patients undergoing ORIF of a periprosthetic humeral shaft fracture about a well-fixed, short-stem aTSA using a proximal humeral locking plate at a single institution from 2005-2020. A shoulder arthroplasty database was queried in order to identify patients for inclusion utilizing Current Procedural Terminology codes 24515 (fracture and/or dislocation procedures on the humerus and elbow) and 23615 (open treatment of proximal humeral fracture) and The International Classification of Diseases, Tenth Revision Codes (ICD10) codes Z96.611/Z96.612/Z96.619 (presence of artificial shoulder joint), M97.31/ M97.31

Institutional review board approval was not required for this case report.

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(periprosthetic fracture around internal prosthetic shoulder joint), or S42.341/S42.342 (spiral fracture of shaft of humerus). Institutional review board approval was not required for the completion of this study.

Inclusion criteria consisted of patients with a displaced humeral shaft periprosthetic fracture about a short-stem aTSA, presence of a well-fixed humeral component, both radiographically and intraoperatively, and treatment consisting of ORIF using a proximal humerus locking plate. Exclusion criteria included any patient with a standard or long humeral prosthesis, stemless shoulder prosthesis, utilization of a straight locking compression plate (LCP), or presence of a loose humeral component requiring extraction.

A data query identified 35 patients, five of whom had a periprosthetic fracture around a well-fixed short-stem aTSA. Two of these patients were excluded as they had been treated with a 4.5-mm straight LCP. The remaining 3 patients were treated via ORIF with a proximal humeral locking plate and included for analysis. Data collected from electronic medical records, radiographic evidence of union, preoperative and postoperative range of motion (ROM), patient-reported level of pain, satisfaction, and postoperative complications.

Technique

Operative setup and exposure

The patient is placed in the beach chair position with appropriate arm positioners. Intraoperative C-arm fluoroscopy is brought in perpendicular to the patient from the contralateral side. An extended anterolateral approach is used, incorporating the prior deltopectoral skin incision. The deltopectoral fascia is incised, and the cephalic vein is identified, mobilized, and retracted. The clavipectoral fascia is then divided, allowing identification and protection of the axillary nerve. The incision is then extended distally, anterolateral to the biceps. The brachialis muscle is split to allow for full visualization of both ends of the humeral shaft fracture. The fracture fragments are exposed and mobilized to visualize cortical edges as well as the distal tip of implant. Deltoid insertion and pectoralis major tendinous insertions are partially taken down as needed to visualize fracture fragments. Implant stability is assessed under direct visualization via manipulation of the distal stem at the fracture site. Once the implant is determined to be stable, we proceed with ORIF.

Reduction and fixation

Prior to placing clamps and hardware, the radial nerve is identified distally between the brachialis and brachioradialis and traced proximally to avoid any iatrogenic damage.

The humeral shaft fracture and any intercalary fragments are reduced with small point-to-point reduction clamps. Intercalary fragments are lagged to larger fracture fragments with 2.7 mm or 3.5 mm cortical screws, bicortically, in a lag by technique fashion. Following provisional reduction and fixation of the humeral shaft fracture, an appropriately sized 3.5 mm proximal humerus locking plate is chosen. This is done by selecting the plate that allows for multiple locking screws to be placed proximally around the humeral prosthesis and at least three bicortical screws in the distal humeral segment. The plate is applied to the lateral aspect of the bicipital groove and at least 5 mm distal to the tip of the greater tuberosity proximally. Typically, the 2.7 mm or 3.5 mm holes distal to the humeral stem are filled first to reduce the plate to the bone. Proximal fixation about the tuberosities is performed with multiple 2.7 mm or 3.5 mm unicortical locking screws. Polyaxial proximal locking screws facilitate screw placement around the humeral prosthesis. The metaphyseal region is fixed with unicortical locking screws or cerclage wires. Prior to the passage of cerclage wires, the humerus is dissected from lateral to medial to protect the radial nerve. Finally, the anatomic layers are closed sequentially, and the skin edges are reapproximated.

Postoperative rehabilitation

Postoperatively, patients are immobilized in a sling. At the 2-week follow-up, radiographs are taken, and the patient is permitted to remove their sling to start gentle passive ROM exercises. At the 6-week follow-up, patients can discontinue using their sling entirely and begin formal physical therapy, allowing ROM as tolerated with rotator cuff and periscapular strengthening. A final follow-up appointment at 3 months is utilized to assess patient pain, objective ROM, and radiographic evidence of healing.

Surgical tips

During the surgical approach, try to elevate only the anterior third of the deltoid and limit detaching the pectoralis major from its humeral insertion. This avoids disrupting the blood supply of the fractured fragments and decreases the risk of nonunion. Provisional reduction of the fracture can be obtained with cerclage wires, as classic reduction forceps may interfere with plate application. Although this is an ideal technique to use when there is a stable implant, it is important to have backup options available at the time of surgery. If the fracture is unstable after provisional fixation, then use of allograft struts or a second locking plate distally may aid in stabilizing the fracture. Any evidence of stem loosening intraoperatively should prompt the surgeon to revise to longer anatomic stem. In addition, if there is any sign of rotator cuff pathology, the surgeon needs to be ready to convert to a reverse total shoulder.

Clinical scenarios and results

Patient 1

A 78-year-old female underwent an uncemented aTSA (Aequalis Ascend Flex Stem, Tornier Inc., Bloomington, MN, USA) for severe glenohumeral arthritis. An uncemented size 5A short-stem, 46 short offset head, and 48 glenoid were implanted. Postoperatively, she reported significant improvement in pain and was objectively able to obtain 150° of forward flexion (FF) and 30° of external rotation (ER) at final follow-up. Six years after her index procedure, the patient suffered a periprosthetic humeral shaft fracture (Fig. 1, *A* and *B*). Due to the displacement, long spiral nature of the fracture extending proximal and distal to the humeral stem (Wright and Cofield Type B, OTA/UCPF 1[IB1]), and lack of radiographic and intraoperative evidence of component loosening, ORIF with an 8-hole, 3.5 mm proximal humerus locking plate (Miami Device Solutions, Miami, FL, USA) was performed with the technique described above.

The patient was seen at her 2-week follow-up, at which time radiographs were taken (Fig. 1, *C*). At her 6-week follow-up, she had passive FF of 120° and ER of 25°. At her 3-month follow-up, ROM improved to 160° of FF and 45° of ER. She was pain-free, had radiographic evidence of union (Fig. 1, *D* and *E*), and allowed to follow-up as needed.

Patient 2

A 78-year-old male underwent an aTSA (Aequalis Ascend Flex Stem, Tornier Inc., Bloomington, MN, USA) for severe glenohumeral arthritis. An uncemented 20A short-stem, 50 mm high offset head,

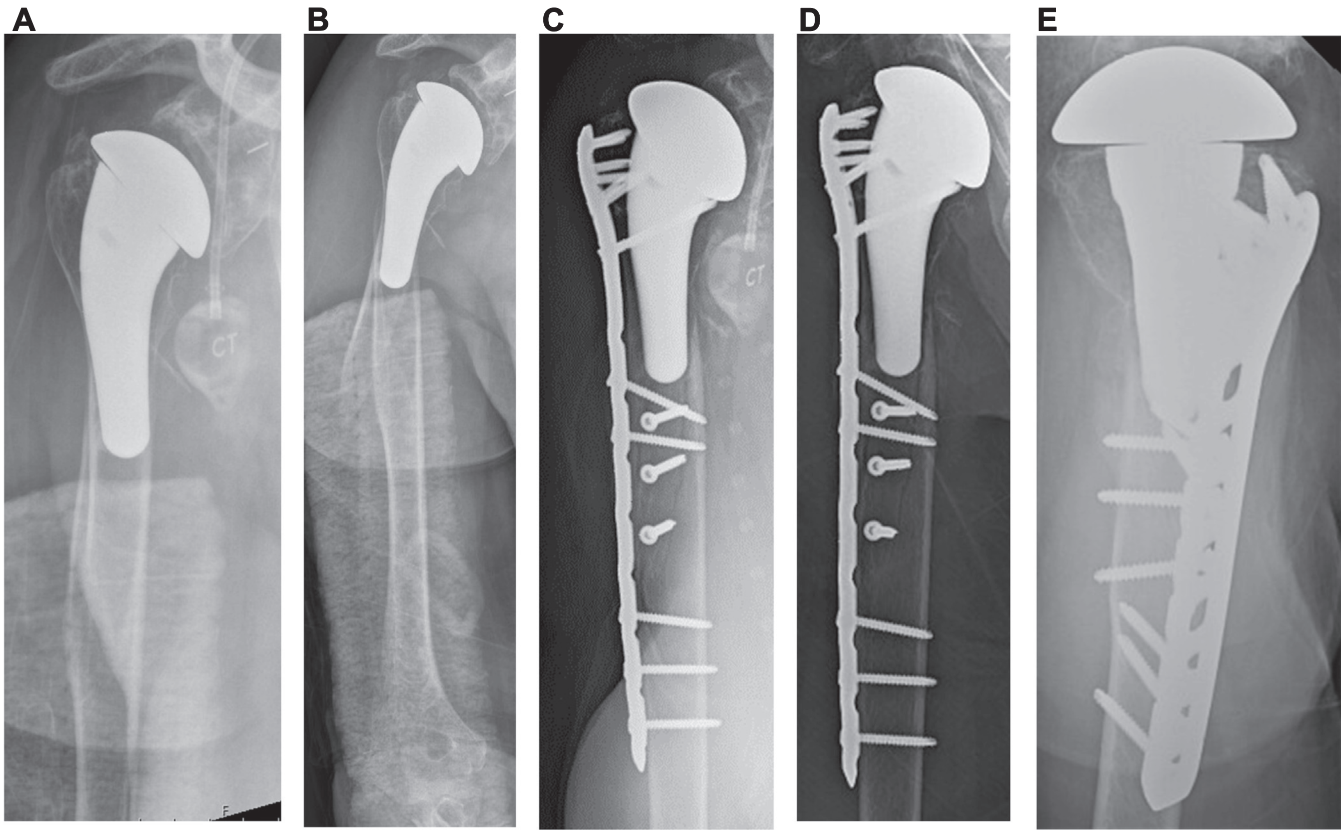

Figure 1 Patient 1. Figure (**A** and **B**) preoperative injury films. (**C**) Two-week postoperative follow-up X-ray. (**D** and **E**) Final follow-up X-rays demonstrating fracture union.

and 52 glenoid were implanted. Postoperatively, he reported improvement in pain. At final follow-up, his ROM was 160° and 45° with FF and ER, respectively. Nine years after his index surgery, he suffered a periprosthetic humeral shaft fracture (Fig. 2, *A* and *B*). Due to the fracture displacement, long spiral nature of the fracture at the tip of the humeral stem, extending distally (Wright and Cofield Type B, OTA/UCPF 1[IB1]), and lack of radiographic and intraoperative evidence of component loosening, ORIF with an 8-hole, 3.5 mm proximal humeral locking plate (Integra Inc., Austin, TX, USA) was performed. In addition to the proximal humeral locking plate, an 8-hole, 3.5-mm Dynamic Compression Plate (Miami Device Solutions, Miami, FL, USA) was used distally to address the extension of the fracture into the distal humeral metaphysis.

The patient was seen at 2-week follow-up, and radiographs were obtained (Fig. 2, *C* and *D*). At his 6-week follow-up, passive ROM of 140° of FF and 40° of ER was noted. At the final 3-month follow-up, radiographs demonstrated evidence of fracture union (Fig. 2, *E* and *F*) and the patient demonstrated active ROM of 155° of FF and 45° of ER. The patient reported complete resolution of pain and was permitted to follow-up as needed.

Patient 3

A 78-year-old female underwent an aTSA (DJO Altivate Anatomic; DJO Global, Lewisville, TX, USA) for symptomatic glenohumeral arthritis. An uncemented size 12 short-stem, 46 x 12 mm head, and size 46 glenoid were implanted. Postoperatively, she reported complete resolution of her pain, 145° of FF and 40° of ER. Two years after her surgery, she sustained a fall, suffering a displaced periprosthetic fracture (Fig. 3, *A* and *B*). Due to the fracture displacement, short spiral nature extending distal to the humeral stem (Wright and Cofield Type B, OTA/UCPF 1[IB1]), and no radiographic or intraoperative evidence of humeral stem loosening, ORIF with a 3.5 mm proximal humeral locking plate (Synthes, West Chester, PA, USA) was performed. Due to the fracture comminution and osteoporotic bone quality cancellous allograft chips were used to fill the boney void, which was then covered with two tibial allograft struts and fixed with cerclage wires.

The patient was seen at her 2-week follow-up and radiographs were obtained (Fig. 3, *C* and *D*). At the 6-week follow-up, she demonstrated passive ROM of 40° of ER and 130° of FF. At her 6-month follow-up appointment, she demonstrated active ROM of 90° of FF, 40° of ER, and internal rotation (IR) to L5. One year following surgery, the patient was able to actively achieve 100° of FF, 40° of ER, and IR to L5. Radiographs at 1-year demonstrated fracture union (Fig. 3, *E* and *F*), and the patient was discharged from care with follow-up as needed.

Discussion

A major challenge associated with shoulder arthroplasty is the maintenance of humeral bone stock. Newer generations of implants have transitioned to shorter stem designs in an effort to preserve native humeral bone. Periprosthetic fractures are not an uncommon complication of shoulder arthroplasty, with intraoperative and postoperative incidences ranging between 1.2% and 19.4%.[6] Unfortunately, this injury is likely to become more ubiquitous with the use of shorter humeral implants due to the addition of stress risers within the humeral metaphysis.[2] Multiple studies have shown that revision arthroplasty for periprosthetic humeral fractures are associated with high complication rates and yields poorer clinical outcomes compared to ORIF with stem maintenance.[1,3,14,19] The present case

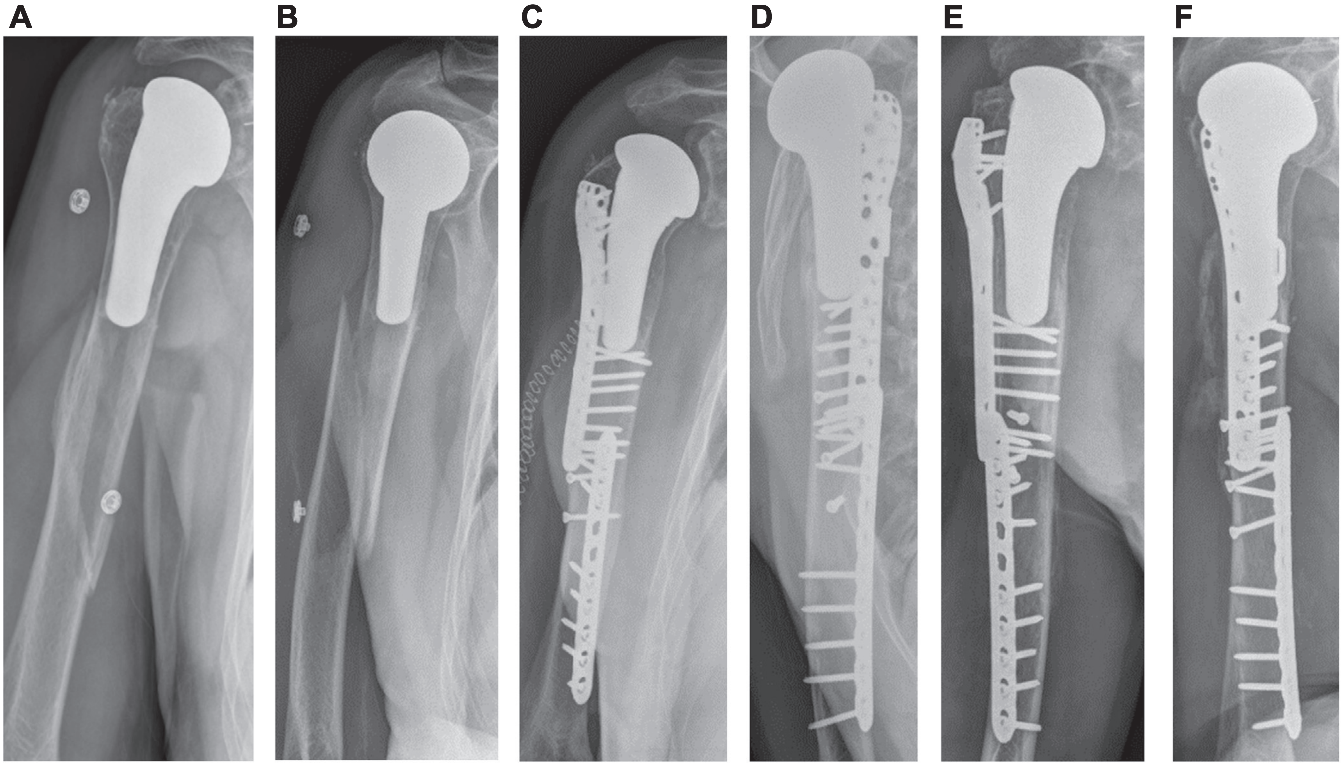

Figure 2 Patient 2. Figure (**A** and **B**) preoperative injury films. (**C** and **D**) Two-week postoperative follow-up X-ray. (**E** and **F**) Final follow-up X-ray demonstrating fracture union.

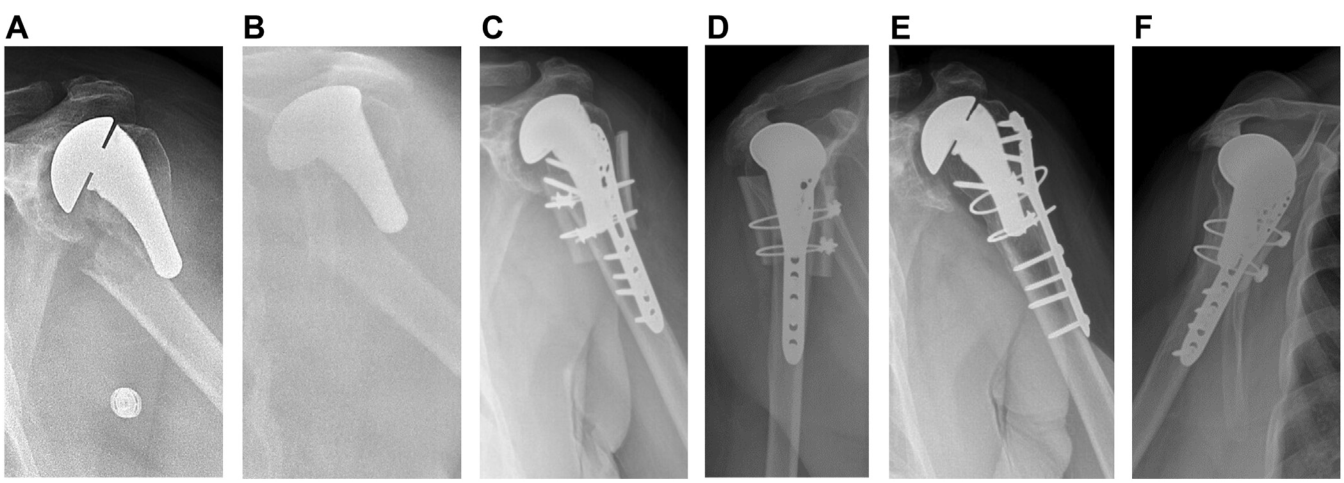

Figure 3 Patient 3. Figure (**A** and **B**) preoperative injury films. (**C** and **D**) Two-week follow-up X-rays. (**E** and **F**) Final follow-up X-ray at 1-year demonstrating fracture union.

series describes a novel technique for fixation of periprosthetic fractures in the setting of a stable, well-fixed short-stem aTSA.

To the author's knowledge, this is the first report demonstrating the use of a proximal humeral locking plate for this specific injury pattern. Saltzman et al described a case report of a periprosthetic fracture about a short-stem RTSA treated with a proximal humeral locking plate.[13] Their single patient was found to have preinjury FF of 120°, ER of 15°, and IR to the level of the greater trochanter. Postoperatively, the patient was found to have improved FF and IR to 125° and L5, respectively, with full active ER. Similarly, Saito et al presented a case report of a periprosthetic humeral shaft fracture after onlay-type short-stem RTSA treated with a proximal humeral locking plate.[12] The patient reported complete resolution of pain and full return of motion postoperatively by 6 months. Our patient cohort demonstrated similar outcomes regarding ROM and pain relief following ORIF of a periprosthetic fracture around a short-stem aTSA using a proximal humeral locking plate. Patients were discharged at an average of 33 weeks postoperative (range, 24-52), with mean visual analog scale pain of 0.3 (range, 0-1) and mean SANE of 97.8% (range, 93.3%-100%). At final follow-up, mean active forward elevation was 140 (range, 110-160) and active ER was 43 (range, 40-45). These short-term results are consistent with current literature. However, additional follow-up is required to evaluate the long-term outcomes of this treatment option.

Periprosthetic fractures of the humerus can be challenging to treat. Proximal humeral locking plates provide several advantages in the setting of a well-fixed, short-stem aTSA. Eccentric screw placement permitted with locking plates allows for multiple points of fixation around a humeral stem, whereas standard plates are often limited to screw trajectories obstructed by the humeral implant.[9] Locking plates have been proven to withstand greater loads before failure compared to standard plates.[18] In addition, unicortical and bicortical locking screws have demonstrated greater biomechanical strength than cerclage wires in resistance of axial and torsional loads.[11] Collectively, these characteristics provide increased construct stability for the duration of fracture healing and should be considered for fracture fixation in the setting of a well-fixed short-stem aTSA.

This study is not without limitations. For starters, it is a case series with only three patients and short-term follow-up. Patients were treated by two different surgeons, who although use the same technique, used different implants. The patients are all the same age, so there is a lack of generalizability in this case series. Future studies with a larger number of patients, use of a single implant, and longer follow-up will be important to better highlight the benefits of proximal humerus locking plates when treating periprosthetic fractures about a well-fixed short-stem aTSA.

Conclusion

Periprosthetic fractures about a short-stem aTSA can be successfully treated with a proximal humeral locking plate if the humeral stem is well-fixed. Locking plates provide multiple eccentric screw holes that facilitate unicortical or bicortical screw fixation around the humeral implant that act to increase stability in comparison to standard LCP options.

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