

Management of the Essex-Lopresti Injury

Andrew P. Matson, MD¹ David S. Ruch, MD¹

¹Department of Orthopaedic Surgery, Duke University Medical Center, Durham, North Carolina

Address for correspondence David S. Ruch, MD, Department of Orthopaedic Surgery, Duke University Medical Center, DUMC Box 3000, Durham, NC 27710 (e-mail: D.ruch@duke.edu).

J Wrist Surg 2016;5:172–178.

Abstract

Keywords

- Essex-Lopresti injury
- interosseous membrane
- forearm instability
- pronator rerouting
- central band

Essex-Lopresti injuries (ELIs) are characterized by fracture of the radial head, disruption of the forearm interosseous membrane, and dislocation of the distal radioulnar joint. This injury pattern results in axial and longitudinal instability of the forearm. Initial radiographs may fail to reveal the full extent of the injury, and therefore diagnosis in the acute setting requires a high index of suspicion. Early recognition and treatment are preferred as failure to fully treat the problem may result in chronic wrist pain from ulnar abutment or chronic elbow pain from radiocapitellar arthrosis. In this article the presentation, relevant anatomy, and management options for ELIs are overviewed, and a summary of outcomes reported in the literature is provided. Additionally, the preferred surgical technique of the senior author is presented, which involves reconstruction of the interosseous membrane with a local pronator rerouting autograft.

Injury

The Essex-Lopresti injury (ELI) involves fracture of the radial head, disruption of the forearm interosseous membrane (IOM), and dislocation of the distal radioulnar joint (DRUJ). In 1931, Brockman recognized axial instability of the forearm in two cases following radial head resection.¹ Fifteen years later, Curr and Coe described a case of acute DRUJ dislocation with concomitant proximal radius fracture-dislocation.² Peter Essex-Lopresti, for whom the eponym is named, is credited with first recognizing the importance of an intact radial head to preventing proximal migration of the radius and subsequent wrist pain.³

Presentation

The mechanism of injury for ELI usually involves an axial compressive load to the forearm with the elbow in an extended position, either from a fall or from high-energy trauma. Initial radiographs are often unremarkable for ELI,^{4–6} and it has been reported that only 20% of these injuries are fully recognized at the time of initial presentation.⁷ Thus, diagnosis of ELI in the acute setting can be challenging, and requires a high index of suspicion. Patients presenting with

radial head fracture should be evaluated for wrist or forearm symptoms, particularly in the presence of high energy.

Other diagnostic imaging modalities may be necessary to confirm presence of IOM disruption. It has been demonstrated that both ultrasound^{8,9} and magnetic resonance imaging^{9–11} are sensitive for the detection of IOM rupture.

Commonly, when ELI is not recognized acutely, patients will present in a delayed fashion. Owing to the longitudinal instability of the forearm, presenting symptoms may be lateral elbow pain from radiocapitellar impingement or ulnar-sided wrist pain from ulnar abutment, particularly if the radial head has been excised.^{6,12,13} Following radial head excision in patients with ELI, the average delay before presentation with ulnar wrist symptoms is 9 months.¹⁴

Several intraoperative dynamic tests for longitudinal forearm instability have been described. It is the preference of the senior author to use the radius pull test, in which 20 lb (9.1 kg) of axial traction is applied to the proximal radius via bone tenaculum, and 3 mm of radial migration is indicative of IOM disruption.¹⁵ Other dynamic fluoroscopic tests have been described using compression force on the radius,¹⁶ radioulnar transverse distraction,¹⁷ and radioulnar translation (radius joystick test).¹⁸ However, all of these tests may remain negative in the case of partial IOM injury or attenuation.¹⁹

received

May 17, 2016

accepted

May 18, 2016

published online

June 20, 2016

Copyright © 2016 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA.
Tel: +1(212) 584-4662.

DOI <http://dx.doi.org/10.1055/s-0036-1584544>.
ISSN 2163-3916.

Anatomy

Forearm Biomechanics

The radial head is the primary longitudinal stabilizer of the forearm, with the IOM and triangular fibrocartilage complex (TFCC) acting as secondary stabilizers.²⁰ Though both the TFCC and IOM contribute to stability, the IOM likely plays a larger role.^{15,21} With the radial head excised, Hotchkiss and colleagues demonstrated that the TFCC is responsible for 8% of forearm stiffness, while the IOM is responsible for 71% of stiffness, and transmits 90% of the axial load of the forearm.²¹

Interosseous Membrane

The IOM consists of five ligaments, including central band, accessory band, distal oblique bundle, proximal oblique cord, and dorsal oblique accessory cord.²² The central band, which is the strongest and most critical to longitudinal stability, originates from the radius at ~57 to 60% of the distance from radial styloid to radial head (distal to proximal) and runs distally, inserting at a 21 to 24 degree angle on the ulna at ~33 to 34% of the distance from ulnar styloid to olecranon tip.²²⁻²⁴ The central band is the thickest portion of the IOM at ~2 mm,^{10,21} and has length and width of 2.7 cm and 1.1 cm, respectively.²⁴

Pathoanatomy

IOM ruptures that occur with axial load injuries usually involve mid-ligament ruptures and less frequently involve avulsions of the ulnar attachment.^{14,25} Though radial head fracture has been thought to be the primary event of the ELI, high-speed video data from simulated axial load injuries in cadavers indicate that the injury may be initiated by transverse radioulnar displacement with IOM disruption, followed by fracture of the radial head.²⁶

When the IOM is disrupted, it is no longer able to transmit force from the radius to the ulna.²⁷ If longitudinal instability exists, excision of the radial head can result in proximal migration of the radius.^{3,6,21,25,28} The magnitude of this proximal migration has been reported to be 7 mm.²⁹ Chronically, this can result in ulnar abutment as forces across the distal ulnocarpal joint increase by ~10% for every 1 mm of proximal radial migration.¹³ Additionally, if the radial head is reconstructed or replaced there may be increased radiocapitellar contact forces which results in radiocapitellar arthrosis.^{25,30}

Management

Radial Head Fracture

There is no widely accepted technique for the surgical management of ELI. However, with current awareness of the importance of the radial head for maintaining stability of the elbow and forearm, most modern techniques involve radial head replacement or open reduction and internal fixation (ORIF), as opposed to excision. Compared with silicone heads, titanium heads are preferable because of their ability to more closely mimic native stiffness, and because of the learned association between silicone heads and particulate degeneration and subsequent synovitis.^{21,25,31-33} Allograft radial head replacements have had minimal success and are not recommended.^{34,35} There is data

to support efficacy of pyrocarbon material radial head replacements for severely comminuted radial head fractures,^{36,37} though these studies did not evaluate efficacy in ELI specifically.

Chronicity

The approach of management to ELI generally involves first recognition of the problem as acute or chronic. Marcotte and Osterman recommend a treatment algorithm whereby acute injuries warrant radial head ORIF or replacement, immobilization of the DRUJ in supination with wires or screws if necessary, and possible reconstruction or repair of the IOM.²⁵ Symptomatic chronic ELI, based on the algorithm, requires ulnar shortening osteotomy (USO), reconstruction of the IOM, and radial head replacement or excision.^{14,25}

Several authors have described managing acute ELI injuries with radial head ORIF or replacement and stabilization of the DRUJ without reconstructing the IOM.^{6,21,31,38} However, there is concern that the IOM may not heal properly even if approximated well, possibly due to interposition of muscle.³⁹ Furthermore, even if USO is performed for ensuing chronic ulnar abutment, the radius may continue to migrate proximally if the IOM is disrupted.

IOM Reconstructive Techniques

Numerous techniques have been described for reconstruction of the IOM, including direct repair when possible,^{8,40} synthetic graft,^{33,41} TightRope tenodesis,⁴² anatomic allograft,⁴³ bone patella tendon bone autograft and allograft,²⁵ flexor carpi radialis autograft,²⁸ semitendinosus autograft,⁴⁴ Achilles allograft,^{27,45} and pronator rerouting.⁴⁶

Several comparative studies have been done to assess the biomechanical results of select IOM reconstructive techniques. Two cadaveric studies demonstrated that reconstruction with flexor carpi radialis autograft effectively restored normal biomechanics and reduced proximal migration of the radius.^{47,48} Three other cadaveric studies collectively evaluated biomechanics of the native IOM, Achilles tendon allograft, bone patellar tendon bone autograft, flexor carpi radialis autograft, and palmaris longus autograft.^{27,45,49} Among these three studies, none of the reconstructive techniques restored the same stiffness of the native IOM, with bone patellar tendon bone graft giving the most stiffness.^{27,45,49}

With regard to graft placement, one study demonstrated that in terms of biomechanical outcome, proximal-distal accuracy of graft important is less important than appropriate angle and tensioning the graft with the forearm in supination.⁵⁰

If longitudinal radioulnar instability persists despite attempts of reconstruction, one option for management is creation of a radioulnar synostosis. Though success has been reported with this procedure,⁵¹ other studies report poor outcomes and high complication rates (Peterson et al, Jacoby et al, Chen et al),⁵²⁻⁵⁴ particularly when the indication is related to trauma.⁵²

Outcomes

Due to the rarity of these injuries as well as challenges with making the diagnosis acutely, studies reporting outcomes following surgical management of ELI are lacking. However,

the literature supports that patients diagnosed acutely have better outcome than those diagnosed in a delayed fashion.⁷ Trousdale and colleagues reported outcomes from 20 patients with injuries involving the radial head fracture and DRUJ. Of the 15 patients whose diagnoses were delayed, all had radial head excisions and went on to develop severe wrist pain with only 20% achieving satisfactory outcomes. All the five patients diagnosed acutely underwent radial head ORIF or replacement and 80% achieved a satisfactory outcome.⁷

Grassman and colleagues reported outcomes following treatment of acute ELI in 12 patients with radial head ORIF, pinning of the DRUJ, and immobilization.³⁸ At 59 months average follow-up, the modified Mayo wrist score was 88.4, the Mayo elbow performance score was 86.7, and Disabilities of the Arm, Shoulder, and Hand (DASH) score was 20.5.³⁸

In a series of 16 patients with chronic ELI, Marcotte and Osterman performed USO and bone patellar tendon bone autograft reconstruction of the IOM and found that at 78 months postoperatively, 15 out of 16 patients had improved pain, and average grip strength improved from 59% to 86% postoperatively.²⁵ However, 25% patients developed persistent pain at the autograft donor site, which prompted the authors to change their technique to use bone patellar tendon bone allograft.¹⁴

When the IOM is not reconstructed for chronic ELI, reported outcomes vary. Heijink and colleagues demonstrated, in a series of patients, that replacement of the radial head alone is not a reliable treatment method, with 5 out of 8 implants failing at a mean of 3 years postoperatively due to loosening or radiocapitellar arthrosis.⁵⁵ Jungbluth and colleagues also followed a series of patients with chronic ELI treated with radial head replacement or excision and neither IOM reconstruction nor USO (though three patients received distal radioulnar arthrodesis).⁵⁶ Mean postoperative DASH score was 55 and postoperative grip strength was 68.5% of the contralateral side.⁵⁶

Whether or not IOM reconstruction is performed for chronic ELI, USO should be performed.^{14,46,57,58} In a series of seven patients with chronic ELI, Venouziou and colleagues report good results following radial head replacement and USO osteotomy.⁵⁸ At 33 months postoperatively, pain score improved from 8.4 to 3.3, range of motion improved significantly, wrist and elbow functional scores were good, and positive ulnar variance improved from +8.0 mm to +3.5 mm.

Surgical Technique

The preferred technique of the senior author has been slightly modified from a previously published technique,⁴⁶ and includes three incisions for (1) radial head replacement, (2) pronator teres graft harvesting and rerouting, and (3) USO and TFCC repair (► Fig. 1). In this technique all three components of longitudinal forearm stability are reconstructed. Pronator rerouting is favored for reconstruction of the central band of the IOM due to the local availability of robust autograft, the conversion of the distal insertion of pronator teres to the proximal attachment of the reconstructed IOM without detachment, and avoidance of remote donor site morbidity.²⁵

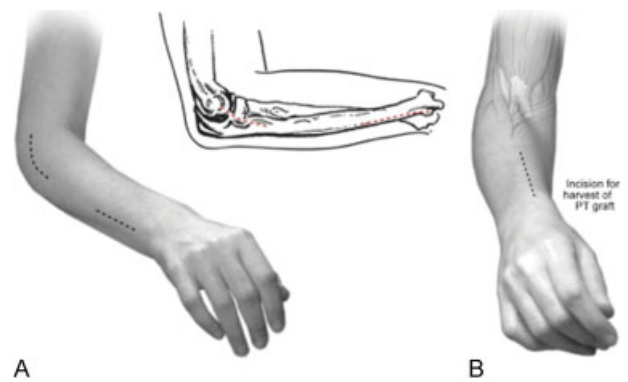


Fig. 1 (A) Standard incisions for radial head replacement and ulnar shortening osteotomy. (B) Pronator teres graft incision. (Reproduced with permission from Chloros et al.⁴⁶)

Radial Head Replacement

Radial head replacement is performed through a Kocher incision and radiocapitellar exposure with the forearm pronated to protect the posterior interosseous nerve. If possible, capsular incision should be made anterior to the lateral ligamentous complex. Curved broaches are used to prepare the neck, taking care to restore radial length. Trialing should be performed and range of motion should be tested in flexion-extension as well as pronosupination, as over-stuffing can ensue via impingement of the prosthesis on the capitellum,⁵⁹ which is particularly relevant in the case of longitudinal forearm instability. Prosthesis placement and positioning are confirmed by fluoroscopy, and the capsule is closed. The lateral ligamentous complex is stressed, and if incompetency is found it is reattached to the lateral epicondyle using suture anchors.

Pronator Teres Graft Harvesting

To reconstruct the IOM, the pronator teres graft is detached proximally, rotated, and inserted distally to the ulna to reconstruct the central band. To release the pronator proximally, a dorsal radial incision is made over the junction of the middle and distal thirds of the forearm. The interval between the extensor carpi radialis longus and brachioradialis is entered, taking care to protect the superficial radial nerve which is retracted medially. Pronator teres is deep to this interval (► Fig. 2). A suture anchor is placed in the radial attachment of pronator teres to keep it firmly anchored. Two Sewell retractors are used to visualize the muscle and trace pronator teres back to its musculotendinous junction, where it is transected taking extreme caution to protect the median nerve as it passes between the two heads of the muscle. Partial detachment of the muscles insertion of the radius may allow for better mobilization to protect the nerve, and also allows for the rotation required for subsequent rerouting.

Ulnar Shortening Osteotomy

USO is performed with the goal of making the wrist ulnar-negative by 2 mm. Intraoperative posteroanterior radiographs may be useful to determine the amount of shortening needed. The ulna is approached subcutaneously, from a distal point 2 cm proximal to the ulnar styloid, with the incision

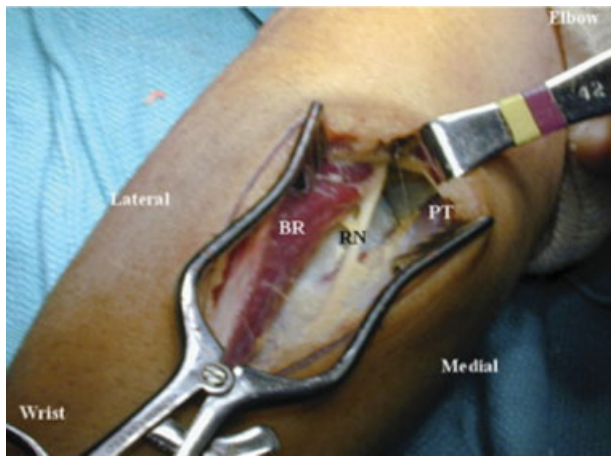


Fig. 2 Surgical exposure of the pronator teres. BR, brachioradialis; RN, radial nerve; PT, pronator teres. (Reproduced with permission from Chloros et al.⁴⁶)

long enough to apply a 6-hole low contact dynamic compression plate (LC-DCP).

The plate is temporarily fixed distally at the flare of the distal ulnar metaphysis (to prevent rotational deformity after osteotomy), and the proximal length of the plate scored with the saw. The osteotomy site is marked and performed at the center of the plate. The length of osteotomy desired should account for the length of bone removed plus two times the width of the saw. The proximal osteotomy cut is made and the bone segment removed and the plate is reattached distally to previously drilled holes (→ **Fig. 3**).

Taking care to restore rotation, the plate is secured to the proximal fragment with serrated reduction forceps, and the osteotomy site is compressed with an AO tensioning device. Magnitude of shortening is assessed radiographically, and if acceptable the remaining three proximal screws are inserted using standard AO technique. If more shortening is needed, the proximal fragment is re-cut prior to screw placement.

Interosseous Membrane Reconstruction

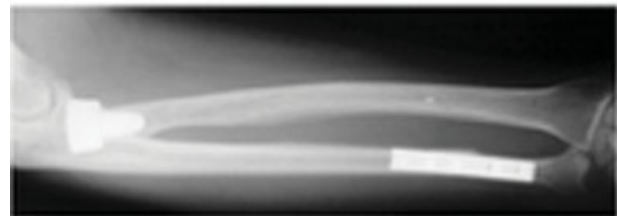
A lamina spreader is placed in the radiocapitellar joint and the radius is distracted ~4 mm. The pronator graft is then rerouted in a distal oblique direction to approach the ulnar shaft at ~20 degrees to recreate the anatomy of the central band.²⁴ It is routed to the dorsal forearm via a tunnel that is dorsal to the IOM and volar to the extensor tendons. The pronator graft is secured to the ulna with the wrist in neutral by suturing it to the LC-DCP plate, or by using two suture anchors (→ **Fig. 4**). In the experience of the senior author, at follow-up for plate removal, there is good healing of the tendon to the periosteum (→ **Fig. 5**). The lamina spreader is then removed.

Triangular Fibrocartilage Complex Repair

To address the TFCC, the ulnar osteotomy incision is extended distally over the fifth dorsal wrist compartment, taking care to protect the dorsal sensory branch of the ulnar nerve. The proximal ulnar half of the extensor retinaculum is reflected radially to visualize the extensor carpi ulnaris and extensor digiti minimi tendons. The TFCC is visualized



A



B

Fig. 3 (A) In most cases, adequate negative ulnar variance (goal 2 mm) is not achieved by reconstructing the radial head alone, and an ulnar shortening osteotomy fixed with a limited contact dynamic compression plate (LC-DCP) is performed. (B) Corresponding radiograph. (Reproduced with permission from Chloros et al.⁴⁶)

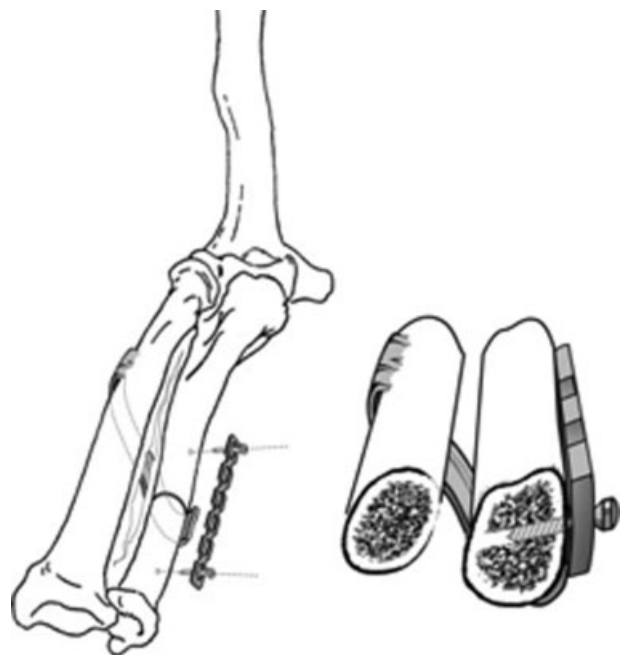


Fig. 4 Principle of IOM reconstruction using a pronator teres graft. (Reproduced with permission from Chloros et al.⁴⁶)



A



B

Fig. 5 (A and B) After removal of the plate, healing of the pronator teres tendon graft to the periosteum of the ulna is observed 2 years after the reconstruction. (Reproduced with permission from Chloros et al.⁴⁶)

via retraction of the extensor digiti minimi which exposes the dorsal aspect of the sigmoid notch of the radius. The components of the TFCC, including the dorsal radioulnar ligaments, the extensor carpi ulnaris sheath, and articular disk are reattached to the ulnar fovea using bone anchors. Stability of the extensor carpi ulnaris sheath is evaluated, and may be augmented by using the retinacular flap created during exposure as a sling.

Wounds are then irrigated and closed over a drain.

Postoperative Care

Postoperatively, patients are immobilized in a sugar tong splint for 2 weeks until suture removal. At this time, a Muenster splint is applied and the patient begins gentle elbow range of motion exercises. At 6 weeks, the Muenster splint is discontinued and active range of motion at the wrist is initiated. Radiographs to evaluate healing at the osteotomy site are performed at 6 weeks, 12 weeks, and 6 months postoperatively.

Conclusion

The ELI is a rare problem that requires a high index of suspicion for diagnosis in the acute setting. Failure to recognize and appropriately treat the full injury may result in chronic symptoms. When considering management options, it is important to understand the pathoanatomy that leads longitudinal instability of the forearm, which involves the proximal radius, IOM, and DRUJ ligaments. In addition to addressing pain related to ulnar abutment or radiocapitellar arthritis, treatment should focus on reconstitution of native forearm biomechanics and stability. The role of regular IOM reconstruction remains uncertain, though several techniques appear promising.

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

Conflict of Interest

None.

References

- 1 Brockman EP. Two cases of disability at the wrist following excision of the head of the radius. *Proc R Soc Med* 1931;24(7):904–905
- 2 Curr JF, Coe WA. Dislocation of the inferior radio-ulnar joint. *Br J Surg* 1946;34(133):74–77
- 3 Essex-Lopresti P. Fractures of the radial head with distal radio-ulnar dislocation; report of two cases. *J Bone Joint Surg Br* 1951; 33B(2):244–247
- 4 Helmerhorst GT, Ring D. Subtle Essex-Lopresti lesions: report of 2 cases. *J Hand Surg Am* 2009;34(3):436–438
- 5 Rodriguez-Martin J, Pretell-Mazzini J, Vidal-Bujanda C. Unusual pattern of Essex-Lopresti injury with negative plain radiographs of the wrist: a case report and literature review. *Hand Surg* 2010; 15(1):41–45
- 6 Sowa DT, Hotchkiss RN, Weiland AJ. Symptomatic proximal translation of the radius following radial head resection. *Clin Orthop Relat Res* 1995;(317):106–113
- 7 Trousdale RT, Amadio PC, Cooney WP, Morrey BF. Radio-ulnar dissociation. A review of twenty cases. *J Bone Joint Surg Am* 1992; 74(10):1486–1497
- 8 Failla JM, Jacobson J, van Holsbeeck M. Ultrasound diagnosis and surgical pathology of the torn interosseous membrane in forearm fractures/dislocations. *J Hand Surg Am* 1999;24(2): 257–266
- 9 Fester EW, Murray PM, Sanders TG, Ingari JV, Leyendecker J, Leis HL. The efficacy of magnetic resonance imaging and ultrasound in detecting disruptions of the forearm interosseous membrane: a cadaver study. *J Hand Surg Am* 2002;27(3):418–424
- 10 McGinley JC, Roach N, Gaughan JP, Kozin SH. Forearm interosseous membrane imaging and anatomy. *Skeletal Radiol* 2004;33(10): 561–568
- 11 Starch DW, Dabezies EJ. Magnetic resonance imaging of the interosseous membrane of the forearm. *J Bone Joint Surg Am* 2001;83-A(2):235–238
- 12 Dodds SD, Yeh PC, Slade JF III. Essex-lopresti injuries. *Hand Clin* 2008;24(1):125–137
- 13 Shepard MF, Markolf KL, Dunbar AM. The effects of partial and total interosseous membrane transection on load sharing in the cadaver forearm. *J Orthop Res* 2001;19(4):587–592

- 14 Adams JE, Culp RW, Osterman AL. Interosseous membrane reconstruction for the Essex-Lopresti injury. *J Hand Surg Am* 2010; 35(1):129–136
- 15 Smith AM, Urbanosky LR, Castle JA, Rushing JT, Ruch DS. Radius pull test: predictor of longitudinal forearm instability. *J Bone Joint Surg Am* 2002;84-A(11):1970–1976
- 16 Davidson PA, Moseley JB Jr, Tullos HS. Radial head fracture. A potentially complex injury. *Clin Orthop Relat Res* 1993;(297): 224–230
- 17 Kachooei AR, Rivlin M, Shojaie B, van Dijk CN, Mudgal C. Intra-operative technique for evaluation of the interosseous ligament of the forearm. *J Hand Surg Am* 2015;40(12):2372–6.e1
- 18 Soubeyrand M, Ciais G, Wassermann V, et al. The intra-operative radius joystick test to diagnose complete disruption of the interosseous membrane. *J Bone Joint Surg Br* 2011;93(10):1389–1394
- 19 Loeffler BJ, Green JB, Zelouf DS. Forearm instability. *J Hand Surg Am* 2014;39(1):156–167
- 20 Morrey BF, Chao EY, Hui FC. Biomechanical study of the elbow following excision of the radial head. *J Bone Joint Surg Am* 1979; 61(1):63–68
- 21 Hotchkiss RN, An KN, Sowa DT, Basta S, Weiland AJ. An anatomic and mechanical study of the interosseous membrane of the forearm: pathomechanics of proximal migration of the radius. *J Hand Surg Am* 1989;14(2 Pt 1):256–261
- 22 Noda K, Goto A, Murase T, Sugamoto K, Yoshikawa H, Moritomo H. Interosseous membrane of the forearm: an anatomical study of ligament attachment locations. *J Hand Surg Am* 2009;34(3): 415–422
- 23 Chandler JW, Stabile KJ, Pfaffle HJ, Li ZM, Woo SL, Tomaino MM. Anatomic parameters for planning of interosseous ligament reconstruction using computer-assisted techniques. *J Hand Surg Am* 2003;28(1):111–116
- 24 Skahen JR III, Palmer AK, Werner FW, Fortino MD. The interosseous membrane of the forearm: anatomy and function. *J Hand Surg Am* 1997;22(6):981–985
- 25 Marcotte AL, Osterman AL. Longitudinal radioulnar dissociation: identification and treatment of acute and chronic injuries. *Hand Clin* 2007;23(2):195–208, vi
- 26 Wegmann K, Engel K, Burkhart KJ, et al. Sequence of the Essex-Lopresti lesion—a high-speed video documentation and kinematic analysis. *Acta Orthop* 2014;85(2):177–180
- 27 Tomaino MM, Pfaffle J, Stabile K, Li ZM. Reconstruction of the interosseous ligament of the forearm reduces load on the radial head in cadavers. *J Hand Surg [Br]* 2003;28(3):267–270
- 28 Skahen JR III, Palmer AK, Werner FW, Fortino MD. Reconstruction of the interosseous membrane of the forearm in cadavers. *J Hand Surg Am* 1997;22(6):986–994
- 29 Rabinowitz RS, Light TR, Havey RM, et al. The role of the interosseous membrane and triangular fibrocartilage complex in forearm stability. *J Hand Surg Am* 1994;19(3):385–393
- 30 Heijink A, Morrey BF, Cooney WP III. Radiocapitellar hemiarthroplasty for radiocapitellar arthritis: a report of three cases. *J Shoulder Elbow Surg* 2008;17(2):e12–e15
- 31 Morrey BF, Askew L, Chao EY. Silastic prosthetic replacement for the radial head. *J Bone Joint Surg Am* 1981;63(3):454–458
- 32 Vanderwilde RS, Morrey BF, Melberg MW, Vinh TN. Inflammatory arthritis after failure of silicone rubber replacement of the radial head. *J Bone Joint Surg Br* 1994;76(1):78–81
- 33 Sellman DC, Seitz WH Jr, Postak PD, Greenwald AS. Reconstructive strategies for radioulnar dissociation: a biomechanical study. *J Orthop Trauma* 1995;9(6):516–522
- 34 Karlstad R, Morrey BF, Cooney WP. Failure of fresh-frozen radial head allografts in the treatment of Essex-Lopresti injury. A report of four cases. *J Bone Joint Surg Am* 2005;87(8):1828–1833
- 35 Szabo RM, Hotchkiss RN, Slater RR Jr. The use of frozen-allograft radial head replacement for treatment of established symptomatic proximal translation of the radius: preliminary experience in five cases. *J Hand Surg Am* 1997;22(2):269–278
- 36 Lamas C, Castellanos J, Proubasta I, Dominguez E. Comminuted radial head fractures treated with pyrocarbon prosthetic replacement. *Hand (NY)* 2011;6(1):27–33
- 37 Ricón FJ, Sánchez P, Lajara F, Galán A, Lozano JA, Guerado E. Result of a pyrocarbon prosthesis after comminuted and unreconstructable radial head fractures. *J Shoulder Elbow Surg* 2012;21(1): 82–91
- 38 Grassmann JP, Hakimi M, Gehrman SV, et al. The treatment of the acute Essex-Lopresti injury. *Bone Joint J* 2014;96-B(10): 1385–1391
- 39 Gong HS, Chung MS, Oh JH, Lee YH, Kim SH, Baek GH. Failure of the interosseous membrane to heal with immobilization, pinning of the distal radioulnar joint, and bipolar radial head replacement in a case of Essex-Lopresti injury: case report. *J Hand Surg Am* 2010; 35(6):976–980
- 40 Ruch DS, Chang DS, Koman LA. Reconstruction of longitudinal stability of the forearm after disruption of interosseous ligament and radial head excision (Essex-Lopresti lesion). *J South Orthop Assoc* 1999;8(1):47–52
- 41 Sabo MT, Watts AC. Reconstructing the interosseous membrane: a technique using synthetic graft and endobuttons. *Tech Hand Up Extrem Surg* 2012;16(4):187–193
- 42 Brin YS, Palmanovich E, Bivas A, et al. Treating acute Essex-Lopresti injury with the TightRope device: a case study. *Tech Hand Up Extrem Surg* 2014;18(1):51–55
- 43 Miller AJ, Naik TU, Seigerman DA, Ilyas AM. Anatomic interosseous membrane reconstruction utilizing the biceps button and screw tenodesis for Essex-Lopresti injuries. *Tech Hand Up Extrem Surg* 2016;20(1):6–13
- 44 Soubeyrand M, Oberlin C, Dumontier C, Belkheyar Z, Lafont C, Degeorges R. Ligamentoplasty of the forearm interosseous membrane using the semitendinosus tendon: anatomical study and surgical procedure. *Surg Radiol Anat* 2006;28(3): 300–307
- 45 Stabile KJ, Pfaffle J, Saris I, Li ZM, Tomaino MM. Structural properties of reconstruction constructs for the interosseous ligament of the forearm. *J Hand Surg Am* 2005;30(2):312–318
- 46 Chloros GD, Wiesler ER, Stabile KJ, Papadonikolakis A, Ruch DS, Kuzma GR. Reconstruction of essex-lopresti injury of the forearm: technical note. *J Hand Surg Am* 2008;33(1):124–130
- 47 Pfaffle HJ, Stabile KJ, Li ZM, Tomaino MM. Reconstruction of the interosseous ligament restores normal forearm compressive load transfer in cadavers. *J Hand Surg Am* 2005;30(2): 319–325
- 48 Pfaffle HJ, Stabile KJ, Li ZM, Tomaino MM. Reconstruction of the interosseous ligament unloads metallic radial head arthroplasty and the distal ulna in cadavers. *J Hand Surg Am* 2006;31(2): 269–278
- 49 Tejwani SG, Markolf KL, Benhaim P. Reconstruction of the interosseous membrane of the forearm with a graft substitute: a cadaveric study. *J Hand Surg Am* 2005;30(2):326–334
- 50 Farr LD, Werner FW, McGrattan ML, Zwerling SR, Harley BJ. Anatomy and biomechanics of the forearm interosseous membrane. *J Hand Surg Am* 2015;40(6):1145–51.e2
- 51 Allende C, Allende BT. Posttraumatic one-bone forearm reconstruction. A report of seven cases. *J Bone Joint Surg Am* 2004;86-A(2):364–369
- 52 Peterson CA II, Maki S, Wood MB. Clinical results of the one-bone forearm. *J Hand Surg Am* 1995;20(4):609–618
- 53 Jacoby SM, Bachoura A, Diprinzio EV, Culp RW, Osterman AL. Complications following one-bone forearm surgery for posttraumatic forearm and distal radioulnar joint instability. *J Hand Surg Am* 2013;38(5):976–982.e1
- 54 Chen F, Culp RW, Schneider LH, Osterman AL. Revision of the ununited one-bone forearm. *J Hand Surg Am* 1998;23(6): 1091–1096
- 55 Heijink A, Morrey BF, van Riet RP, O'Driscoll SW, Cooney WP III. Delayed treatment of elbow pain and dysfunction following Essex-

- Lopresti injury with metallic radial head replacement: a case series. *J Shoulder Elbow Surg* 2010;19(6):929-936
- 56 Jungbluth P, Frangen TM, Arens S, Muhr G, Källicke T. The undiagnosed Essex-Lopresti injury. *J Bone Joint Surg Br* 2006;88(12):1629-1633
 - 57 Duckworth AD, Clement ND, Aitken SA, Ring D, McQueen MM. Essex-Lopresti lesion associated with an impacted radial neck fracture: interest of ulnar shortening in the secondary management of sequelae. *J Shoulder Elbow Surg* 2011;20(6):e19-e24
 - 58 Venouziou AI, Papatheodorou LK, Weiser RW, Sotereanos DG. Chronic Essex-Lopresti injuries: an alternative treatment method. *J Shoulder Elbow Surg* 2014;23(6):861-866
 - 59 Murray PM. Diagnosis and treatment of longitudinal instability of the forearm. *Tech Hand Up Extrem Surg* 2005;9(1):29-34