A New Single Volar Approach for Both-Bone Fractures of the Forearm: The Mediolateral Windows Approach Extended

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Abstract: Fractures of the forearm are common injuries in adults. Particularly, both-bone fractures of the radius and ulna are frequently encountered by orthopedic surgeons. To date, these fractures are typically treated with open reduction and internal fixation, because of the propensity for malunion of the radius and ulna and the resulting loss of forearm rotation. We propose a modification of the classic double approach for both-bone fractures of the distal radius and ulna. Indeed, we described a minimal and anatomic approach to prevent complications such as the heterotopic ossification of the interosseus membrane and vascular-nervous lesions. By a single anterior incision, we utilize 2 windows to expose the medial and lateral compartments of the forearm. In this way, we avoid the handling of the interosseous membrane, and we protect the ulnar, median, and radial nerves from the surgical approach. This technique is indicated for complex distal radius and ulna fractures. We exclude open fractures, and Monteggia, Galeazzi, or Essex-Lopresti lesions. In this report, we describe the surgical anatomy, surgical approach, and complications regarding this approach.

Key Words: volar approach, both-bone fractures, forearm, single access

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Fractures of both the radius and ulna are common. Typically, they may result from high-energy trauma, and, occasionally, from ground-level falls with an axial load applied to the forearm through the hand. The diagnosis may be given by the obvious deformity of the limb. However, surgical planning requires a careful neurovascular and skin examination of the limb to rule out respectively acute compartment syndrome or neurovascular lesions of the forearm and open fractures.[1] Subsequently, orthogonal radiographs of the forearm, wrist, and elbow are mandatory to get a complete evaluation of the trauma, and, usually, advanced imaging may be necessary in case of articular fractures.[2] A variety of solutions have been proposed to manage both-bone fractures of the forearm. Open reduction and internal fixation (ORIF) with plates and screw, intramedullary (IM) nails, and external fixation is indicated in several different conditions. It has been widely demonstrated that even minimally displaced both-bone forearm fractures are prone to displacement, malunion, and nonunion.[3] For these reasons, nonsurgical management has been considered unacceptable due to the loss of forearm rotation crucial for positioning the hand in space.[4] Considering the likelihood of loss of function after these fractures, ORIF with plates and screws is used to manage most both-bone forearm fractures.[5] IM nails are characterized by a stress-sharing behavior that facilitates secondary periosteal callus formation in case of comminuted fractures.[6] In contrast, external fixation is indicated in cases of severe soft tissue injury or open fractures. Usually, ORIF of such fractures is carried out through 2 separate incisions of the forearm. The radius may be exposed through either the dorsal (Thompson) or the volar (Henry) approach. This decision is based on the location of the fracture and/or the presence of traumatic wounds that could limit the surgical incision. The ulna is exposed through a separate incision over its subcutaneous border to avoid the involvement of the interosseous membrane.[7] After ORIF, patients may undergo several complications such as refracture after the removal of the implant, infection, nonunion, malunion, synostosis of the radius and ulna, and heterotopic ossification of the interosseous membrane.[8] The interosseous space may be thought of as an articulation that permits rotation of the radius around the ulna. Indeed, anatomic restoration of this "joint," is crucial to effective positioning of the hand in space, and it is among the primary goals of the treatment. Postoperative synostosis of the radius and ulna is rare; however, when it occurs, it may determine pain and lack of forearm rotation.[9] The aim of our technique was to expose both the radius and ulna through a single straight anterior incision of the forearm. In this report, we describe the surgical anatomy, surgical approach, and indications for this exposure.

ANATOMY

The muscles of the forearm are split into 4 compartments: the superficial volar, the deep volar, the extensor, and the mobile wad. The median nerve passes between the 2 heads of the pronator teres. It travels between the flexor digitorum superficialis (FDS) and the profundus. The median nerve is accompanied by the median artery during this course.[10] Thereafter, about 5 cm above the flexor retinaculum at the wrist, it emerges between the FDS and the flexor carpi radialis (FCR) into the hand. By our approach, the median nerve and the median artery are not at risk from surgery, because they lie below the flexor digitorum, superficially protected by the superficial and deep volar compartments. The ulnar nerve enters the anterior compartment of the forearm between the 2 heads of flexor carpi ulnaris (FCU), and it lies along the lateral border of the FCU with the ulnar artery. It runs between the flexor digitorum profundus (laterally) and FCU medially. At the wrist, it courses superficial to the flexor retinaculum of the hand, but is covered by the volar carpal ligament. During the reduction and plate fixation of the ulna, the ulnar nerve and artery might be damaged. It is imperative to carefully explore the ulnar nerve. The surgeon needs to show the surgical assistant how to place and hold the hand-held retractor and to pull on the tissues to show the fracture. Therefore, the assistant should be careful to pull the retractor only as much as is needed to expose the surgical site. In regard to the posterior interosseous nerve, it has been established that careful dissection between the heads of the supinator muscle is mandatory during the dorsal Thompson approach for proximal fractures. Through our anterior approach, none of the complications of this nerve have been reported because it runs far from our surgical field. In contrast,

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during reduction and plate fixation of the radius, the superficial branch of the radial nerve lies deep to the brachioradialis (BR) in the midforearm, and care should be taken to safely retract the nerve radially with the radial artery and overlying muscle. The lateral antebrachial cutaneous nerve should be protected where it emerges underneath the BR. During this phase, as stated above, the surgeon needs to show the surgical assistant how to place and hold the hand-held retractor to avoid iatrogenic injuries.

INDICATIONS AND CONTRAINDICATIONS

We reserved this technique for both-bone fracture of the distal and middle third of the forearm (Fig. 1). We excluded proximal both-bone fractures because it will be necessary for a relevant arrangement of soft tissues. Indeed, it must be taken into consideration that, when going proximally, the tendons give way to the main muscle mass of the forearm. For these reasons, it is easy to understand that it will be more difficult to reach the bones. Moreover, the surgical time will be longer, along with an increased risk of infection and neurovascular lesions. The Gustilo-Anderson classification has become the most commonly used system for classifying open fractures in relation to the exposure of bone and the severity of the associated soft tissue injuries.[11] Open fractures that are classified as Gustilo-Anderson Grade I, II, or IIIA could be treated with irrigation, debridement, and antibiotic therapy followed by ORIF with our single anterior access. In contrast, in accordance with the literature, fracture types IIIB and IIIC are treated by damage-control through irrigation, debridement, antibiotic therapy, and external fixation. The plating will be carried out after soft tissue stability and after ruling out any reasonable risk of infection.[12] We excluded Galeazzi, Monteggia, and Essex-Lopresti lesions because they are not shaft fractures of both forearm bones.[13] It is important to consider that both-bone fractures of the forearm need to be approximately at the same level to get both bones with a limited incision.

SURGICAL APPROACH

The patient is positioned supine under regional anesthesia. A tourniquet is placed on the upper limb, and a sterile field is set up. The tourniquet, is not usually used, unless in case of excessive bleeding. The patient's forearm is placed supine, and the incision is made directly over the palmaris lungus (PL). The incision is made 1 cm proximal to the wrist flexion crease, and radial to the PL. It extends proximally, parallel to this tendon, and it ends just lateral to the PL. The length of the incision depends on the location of fractures. After dividing the fascia, the interval between the FCR and PL is exposed. By a single incision, we utilize 2 windows to expose the radio and ulna: the medial or ulnar window and the lateral or radial window. The medial or ulnar window allows direct reduction of the ulnar fragment. Conversely, the lateral or radial window permits the optimal positioning of the plate on the radius.[14] We need to consider that the forearm must be considered a unit, including the elbow and radiocarpal joint. Both-bone forearm fractures require the necessity of exact anatomic reposition, which is essential for the unrestricted pronation and supination.[15] Despite most long bone shaft fractures requiring an elastic osteosynthesis, the forearm fracture is still fixed in a rigid technique, using compression plates with or without lag screws.[16] Rigid fixation with compression plates creates a near-zero strain environment, causing new bone to form via primary healing without callus formation. In this way, the strain of the forearm is not considered to be sufficiently effective to build up callus.[4] Although many simple both-bone forearm fractures can heal with this method, strain theory suggests that severely comminuted fractures are best managed with elastic fixation, even though there might be the risk of formation of a bridging callus with disturbance of pronation and supination.[4] Nowadays, an ongoing discussion exists whether volar or dorsal plating is the appropriate technique for internal fixation of radius and ulna fractures. Studies showed contradictory results regarding complication rates.[17] However, Disseldorp et al[17] reported more cases of tendinitis in patients with dorsal radius plate. In addition, an ulnar plate placed too far dorsally may cause irritation to the extensor carpis ulnaris tendon. In contrast, a plate placed volarly and distal could cause impingement if placed too radially.[18] For these results, and considering our surgeon's experience, we apply the plates on the volar side of the radius and ulna, resulting in an optimal soft tissue coverage. According to OA indications, if both bones have been fractured, the reduction is first performed on the bone

FIGURE 1. A and B, Anteroposterior and lateral view of both-bone fractures of the forearm (type 22, A3). C and D, Final fluoroscopic control is carried out to assess optimal fracture reduction and internal plating. E, Surgical scar after 3 months from surgery.

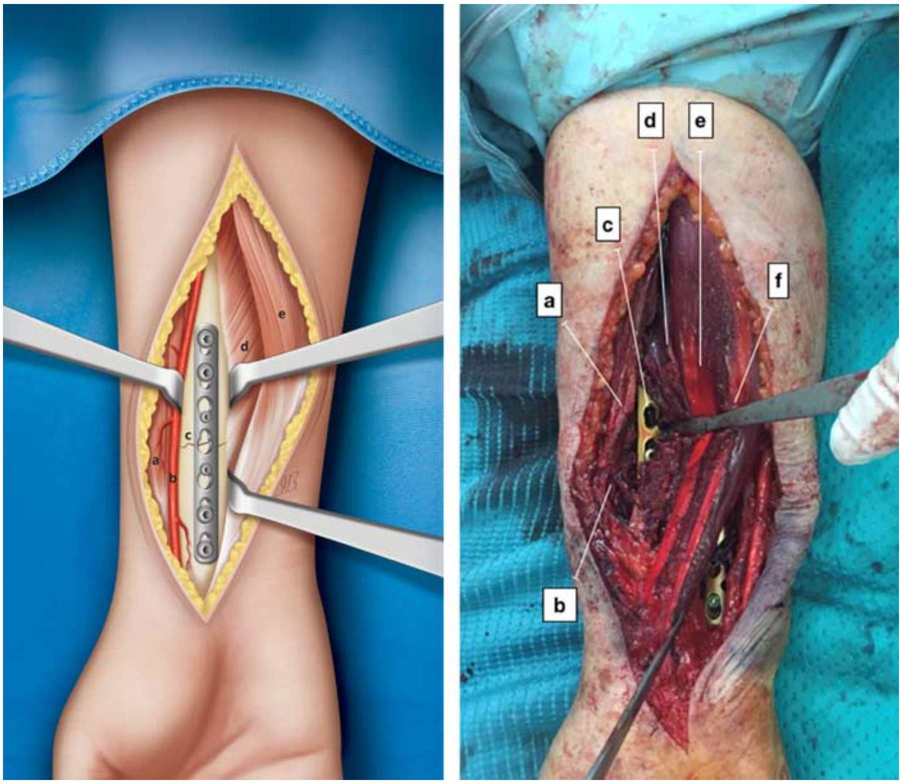

FIGURE 2. The lateral radial window: brachioradialis (a), radial artery (b), radius (c), flexor pollicis longus (d), flexor carpi radialis (e), palmaris longus (f).

with the fracture characterized by less comminution to regain the length of the bones, good opposition, and alignment without any malrotation.[16,19]

The Lateral or Radial Window

The FCR tendon sheath is opened, and the tendon is retracted radially with the radial artery and the BR by retractors. The FDS and the flexor pollicis longus muscle are carefully retracted ulnarly to cover and protect the median nerve by soft tissue (Fig. 2). Thereafter, the pronator quadratus muscle was released from the radial shaft. With the necessity of proximal exposure of the radius, the FCR muscle might be retracted ulnarly, and the dissection might continue between the pronator teres and the BR along the radius shaft. Proximally, the forearm might be pronated to visualize the insertion of the pronator teres, which can be elevated to achieve full access to the radius in case of proximal fractures.

The Medial or Ulnar Window

The median or ulnar window uses the interneural interval between the FCU and FDS innervated respectively by the ulnar and median nerve. This interneural plane allows adequate bone exposure and prevents muscle denervation. The FDS and flexor digitorum profundis are released along their ulnar border, and then they are raised radially to avoid denervation (Fig. 3). At this point, it is mandatory to reach and isolate the ulnar neurovascular bundle that appears underneath the FCU. The surgeon needs to show the surgical assistant how to place and hold the hand-held retractor to avoid neurovascular injuries. The ulnar artery and nerve with FCU are carefully drifted ulnarly to cover and protect the medial antebrachial cutaneous nerve.

Anatomic reduction of the main fragments was achieved by minimal epiperiosteal exposure of the fracture ends, so that the blood supply was not hampered in that area. The fractures of the radius and ulna are stabilized by titanium dynamic compression plate (3.5 mm LC-DCP) or the titanium one third tubular, small-fragment plate. A minimum of 4, but preferably 6 cortices in the 2 main fragments of the fracture, was fixed with screws. Interfragmentary compression lag screws and bone graft might be used if necessary.

Postoperative Management

After wound closure, a volar brace is adopted for 2 weeks. The drainage is removed the day after surgery. Directly after surgery, the patients are encouraged to move the shoulder, elbow, and fingers to decrease swelling and prevent stiffness. Not active or passive movements of the wrist are allowed for the first 2 weeks. After suture removal, the patient is encouraged to perform flexion and extension movements of the wrist. After 40 days from the surgery, pronation and supination movements are allowed.

PEARLS AND PITFALLS

The radial or ulnar artery may be inadvertently damaged respectively in the lateral and medial window due to sharp retraction. However, the risk of injury of the radial artery in our approach reflects theoretically that of the volar (Henry) approach due to the similarities between them. In contrast, the ulnar neurovascular bundle might hypothetically be damaged by the internal fixation of the ulna. This represents an important difference from the classic and most used direct approach of the ulna, because, in this way, the ulnar nerve and artery are away from the surgical field. However, we believe that our technique is less

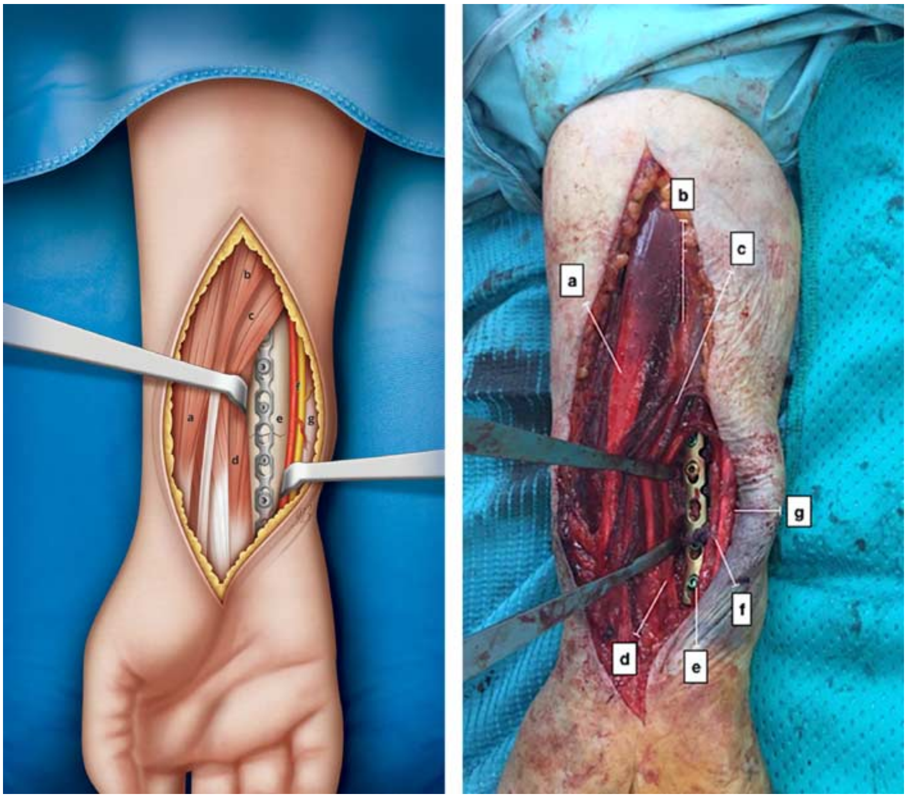

FIGURE 3. The medial ulnar window: flexor carpi radialis (a), palmaris longus (b), flexor digitorum superficialis (c), flexor digitorum profundus (d), ulna (e), ulnar artery and nerve (f), flexor carpi ulnaris (g).

demanding, and the surgeon might be able to protect the neurovascular bundle with the retractor with a low risk of complications. Dissecting subperiosteally too distally along the volar aspect of the radius can potentially disrupt the volar wrist ligament. Damaging of the palmar cutaneous branch of the median nerve (PCBMN) might occur if the incision is made distally to the wrist crease. From our approach, if the ulnar plate is placed distal and volar, it might cause impingement if placed too radially. However, the ulnar window allows an excellent vision of the surgical field, and, with the aim of the C-arm fluoroscopy, the surgeon will be able to set the plate correctly. It has been well established that postoperative infection following fixation of closed both-bone forearm fractures is rare.[20] We believed that our approach might contribute to lower infection rates due to an only single anterior incision. Moreover, the muscles of the forearm cover the volar plates constituting a barrier to infections. Despite the true incidence of forearm compartment syndrome being difficult to determine, it has been well established that both-bone fractures of the forearm are associated with forearm compartment syndromes.[21] In our experience, we do not have cases of compartment syndromes using our approach. Indeed, we do not usually use a tourniquet; patients with both-bone forearm fractures are operated within 24 hours; at the admission, we administered a high dose of steroid for 1 to 2 weeks (0.2 mg/kg/d dexamethasone); with our single anterior incision, we similarly replicate the volar compartment fasciotomy of the forearm.[22]

EXPECTED OUTCOMES

In accurately selected cases, this new single volar approach allows the surgeon to fix both-bone fractures of the forearm with only a single incision. This might be reflected in the minimal surgical time with a consequent lower risk of infection. Indeed, in our case series, we did not observe any neurovascular lesions, heterotopic ossification of the interosseus membrane, and compartment syndromes.

COMPLICATIONS

In addition to the classic complications of anterior approach and volar plating, such as infection, damage flexor tendons, radio-ulnar synostosis, and ossification of the interosseus membrane, one risk of this approach is represented by a lesion of the PCBMN. Dissection must preserve the antebrachial fascia and not extend over the bistyloid line, wherein the PCBMN appears distally. In addition, the surgeon needs to pay attention to protect the ulnar neurovascular bundle during the plating of the ulna. Obviously, prospective randomized studies with long follow-up are mandatory to add further evidence about the effectiveness of our technique. However, it represents a novel approach that might be used when the classic approach of the ulna is prevented by soft tissue injuries. With careful handling, this surgical technique is relatively safe and reproducible with a short learning curve.

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