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TECHNICAL NOTE

Trans-fracture transposition of the radial nerve during the open approach of humeral shaft fractures

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Abstract The radial nerve constitutes a major problem in humeral shaft fractures; it may be injured immediately or during closed reduction or open reduction and internal fixation with plate and screws. After fixation, the nerve always runs directly over the plate without any interposed structure. If a revision surgery is indicated, the nerve is at high risk as it is usually difficult to dissect from surrounding fibrotic scar tissue or callus formation. To avoid these complications, some authors reported transposition of the radial nerve through the fracture line. We present herein the surgical technique of the trans-fracture transposition of the radial nerve during open reduction and internal fixation of humeral shaft fractures, along with our preliminary results in 6 cases and a review of the literature.

Keywords Humeral shaft fracture · Open reduction of humeral fracture · Radial nerve · Radial nerve transposition

Introduction

The radial nerve is in close contact with the humerus as it wraps around it into the spiral groove at the posterior aspect of the humeral shaft; it may be injured at the occasion of humeral fracture or entrapped into the fracture site or damaged during closed reduction maneuvers or open reduction and internal fixation procedure [1–6]. Although causes of postoperative radial nerve paralysis are poorly documented in the literature, they have been attributed to several factors such as stretching and elongation of the nerve during fracture manipulation, extensive dissection of the nerve, and direct compression of the nerve by bone clamps or plate or even because of direct inadvertent injury to the nerve by the surgical blade [1]. Additionally, the position of the nerve over the plate at the end of the operation may cause chronic friction and conflict between the nerve and the hardware with consequent secondary palsy [1, 7]. On the other hand, if nonunion occurs after plate fixation, surgical approach to the site of failed fixation may be deleterious for the nerve because it is usually very hard to be identified and dissected from the surrounding adhesion and fibrous tissue or from callus that has developed around the nerve [2]. In order to avoid these potential threats, some authors advised to perform trans-fracture transposition of the radial nerve during open reduction and plate fixation; only a few numbers of small clinical series and cadaver experiments have been recently published [1–4, 8]. The authors aim at exposing the technical steps of this procedure along with their preliminary experience in a small series and discussing its indications and results with reference to the literature.

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Clinical material

From January 2008 to December 2011, 45 closed humeral shaft fractures were operated in our hospital. In 27 patients, the fractures were fixed with intra-medullary implants (rigid antegrade nail for 11 patients and flexible retrograde nails for 16 patients), while the remaining 18 patients received open reduction and internal fixation with plates and screws. Of these 18 patients, six patients underwent trans-fracture antero-medial transposition of the radial nerve during the open reduction and internal fixation procedure. There were three male and three female patients with a mean age of 45 years (range, 23–72 years). The cause of injury was a sport accident in one case, a fall from height in another case, and a motor vehicle accident in the remaining four cases. In four patients, there was a displaced fracture at the junction between the mid and the distal third of the humeral shaft, with a fracture pattern similar to the type previously described by Holstein and Lewis [9] (Figs. 1a, 2a); on exploration, a large butterfly fragment was present at the medial aspect of the proximal fragment. In two patients, the fracture was located at the mid-shaft with also a large butterfly fragment at the medial aspect of the proximal fragment (Fig. 3a). In three cases, a preoperative radial nerve paralysis was present; they all belonged to the group of the so-called Holstein–Lewis type fracture.

Surgical procedure

All patients were operated in semi-setting position through lateral approach of the humerus by one surgeon, the senior author, and the surgical procedure faithfully followed the technique that has previously been reported by El Ayoubi et al. [1]. A lateral skin incision is made from the tip of the deltoid V to the lateral epicondyle; it can be extended proximally as for a deltopectoral approach if needed. The radial nerve is first identified at its emergence from the lateral intermuscular septum, and dissected anteriorly and distally between brachialis and brachioradialis muscles. The lateral septum is divided to facilitate exposure of the nerve. The brachialis muscle is elevated—as needed—from the distal bone fragment along with dissection of the medial septum. The proximal part of the nerve is then carefully dissected into the spiral groove at the posterior

Fig. 2 Holstein–Lewis type fracture **a** before and **b** after fixation with locking plate and screws

aspect of the proximal fragment; this was better achieved by carefully pulling the proximal fragment with a bone holder and using the tip of the finger to prudently separate the nerve from the bone as they are in close contact at this level. The fracture site is then gently distracted with bone clamps and angulated to allow easy mobilization of the nerve through it from lateral to medial; the nerve is smoothly displaced without any tension toward its new location at the medial aspect of the humerus (Fig. 4a, b, c).

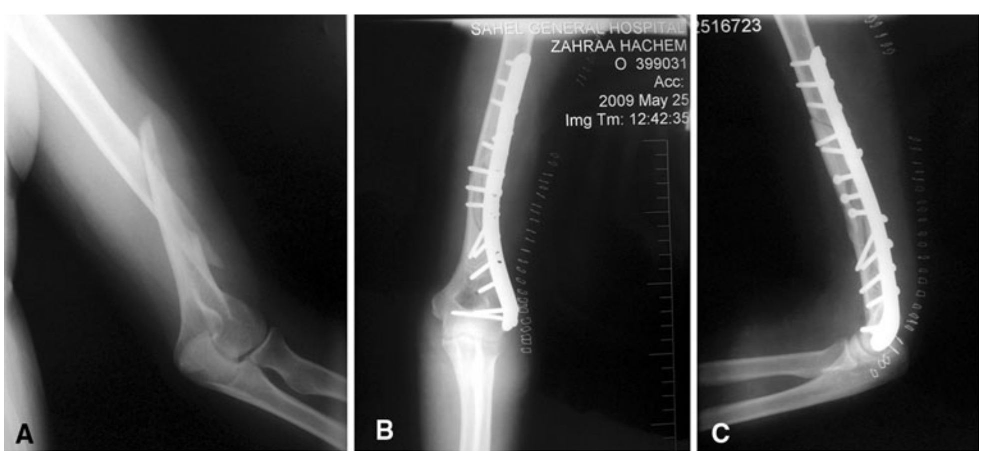

Fig. 1 Holstein–Lewis type fracture **a** before and **b**, **c** after fixation with anatomic prebent plate and screws

Fig. 3 Mid-shaft humeral fracture with proximo-medial large butterfly fragment **a** before and **b** after fixation with conventional large plate and screws

After transposition, the motor branches destined to innervate the long, the medial, and the lateral heads of the triceps are left undisturbed in their original position posterior to the humerus along with the sensory lateral cutaneous branch; the nerve of the brachioradialis follows without tension the displacement of the radial nerve. Decision to transpose the radial nerve was intra-operatively taken by the surgeon; it was based on technical difficulties encountered to achieve anatomic reduction and stable fixation as the nerve was always in the operative field and constantly at high risk during surgical maneuvers. For the three cases with pre-operative radial nerve palsy, the nerve was found entrapped into the fracture site in one patient and impinged with bony fragments in the two others (Fig. 4a); however, the nerve was macroscopically continuous on exploration. After transposition of the radial nerve, reduction and fixation of the fracture with plate and screws were finally achieved according to the AO techniques, and without any threat to the nerve or any conflict between the nerve and the hardware; a conventional broad plate was used in one patient (Fig. 3a, b), an anatomic prebent plate in another one (Fig. 1a, b, c), and a metaphyseal locking plate in the remaining four patients (Fig. 2a, b).

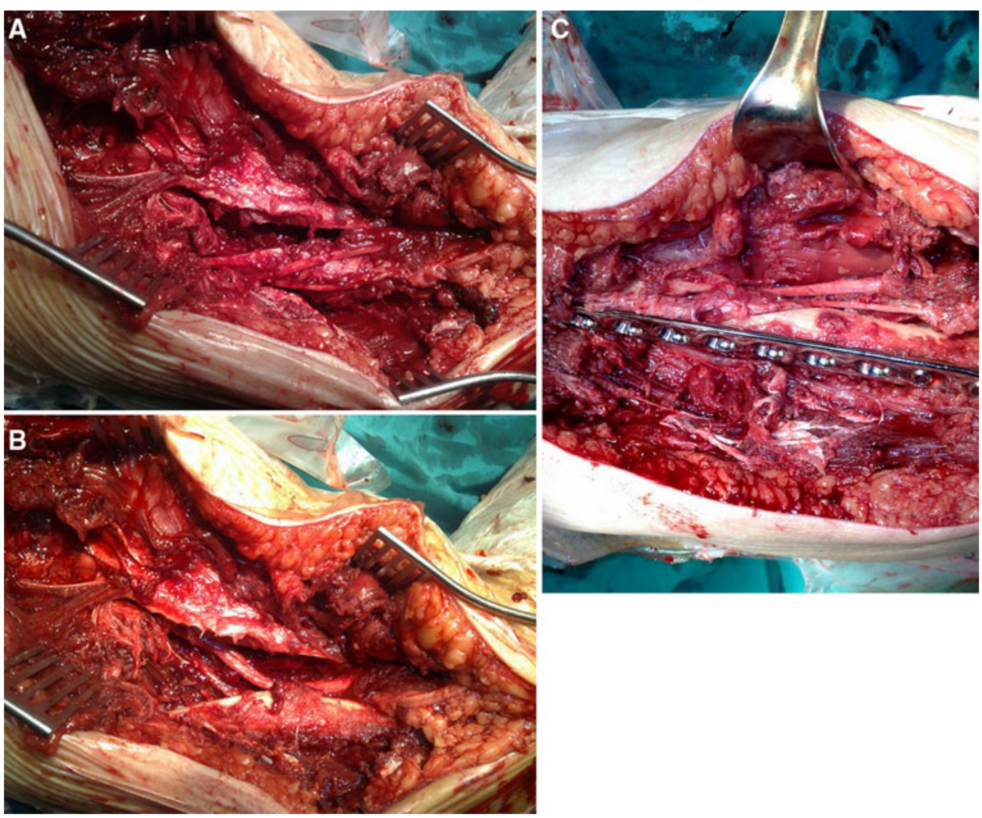

Fig. 4 Intra-operative views for the same patient in Fig. 2 with a Holstein–Lewis fracture. **a** The radial nerve is impinged with the apex of the distal fragment. **b** The radial nerve is dissected and passed through the fracture site to the medial aspect of the humeral shaft. **c** After transposition, the radial nerve runs antero-medial to the humerus. The fracture has been fixed with a plate applied to the lateral aspect of the humerus

Follow-up and results

Immediate postoperative rehabilitation was started in all patients for restoration of shoulder and elbow motion. All patients were monthly followed radiographically and clinically, until full recovery, for the evaluation of bone healing and radial nerve function. No electromyographic assessment was done for the patients with radial nerve paralysis. All fractures healed between three and 5 months postoperatively. No iatrogenic radial nerve paralysis occurred. The three preoperative radial nerve palsies completely recovered within four to 7 months after surgery. In addition, there was no limitation of elbow or shoulder function as compared to the opposite side in any patient.

Discussion

The radial nerve crosses the spiral groove of the humerus as it wraps around this bone from its postero-ulnar to its antero-radial aspect [1–4]. During this path, the nerve has a very close relationship with the posterior aspect of the humerus as it lies directly on it without any interposed layer of soft tissue over a mean distance of 6.5 cm [4, 10]. After traversing the spiral groove, the nerve exits from the lateral intermuscular septum and runs between brachialis and brachioradialis muscles; at this area of emergence, the nerve is relatively fixed to the diaphysis and is therefore more vulnerable [5, 9]. Because of these unique anatomic considerations, the radial nerve may be injured at the occasion of humeral shaft fracture or during closed or open reduction and internal fixation procedure [10–13]. Radial nerve paralysis can immediately occur in 10–18 % of humeral shaft fractures, especially when the fracture is located at the mid-shaft or at the junction between the mid and distal third of the bone, and more particularly when it is initially displaced or follows significant trauma [5, 6, 9, 12–14]. Holstein and Lewis [9] identified a distinct type of humeral shaft fractures with particular predisposition for radial nerve paralysis: “The fracture is in the distal third of the humerus, it is spiral in type, the distal bone fragment is always displaced proximally with its proximal end deviated radialward, the radial nerve is caught in the fracture site, and, if there is a comminuted fragment, it is the oblique surface of the distal end of the proximal fragment that damages the nerve.” Yet one-third of all radial paralyses are iatrogenic [11], this complication can happen in 4–6.5 % of patients who undergo plate fixation [5, 6]. However, spontaneous recovery is observed in 80–90 % of palsies after a few months [5, 6, 13, 15]. Other complications of open treatment are represented by nonunion in 2.8–5.8 % and infection in 1–5 % of cases [6].

For open reduction and internal fixation with plate and screws, the humerus may be approached through either antero-lateral or posterior approach. In both approaches, the radial nerve is directly in the way of fixation in the surgical field and may cause technical and practical problems for the surgeon as it may be at threat during reduction maneuvers, bone clamps and retractors placement, and application of plate and screws. After achievement of fixation, the nerve runs an additional course related to the thickness and width of the plate as it regularly crosses directly over it [1]. Distinctly, tardy paralysis of the radial nerve has been occasionally reported; it was attributed to chronic friction between the nerve and the hardware [1, 7]. To avoid all these problems and difficulties, some authors reported trans-fracture transposition of the radial nerve in a few number of small clinical series [1, 2, 8]; others performed anatomic experiments on cadaver to evaluate the effects of transposition on the length of the nerve [1, 3, 4].

In cadaveric study, El Ayoubi et al. [1] recorded 5-mm stretching—elongation—of the radial nerve after application of lateral plate of 3.2 mm thickness and 13 mm width. They also compared the length of the radial nerve after lateral plate fixation in 10 cadaver specimens without and with trans-fracture transposition of the nerve and noticed a mean gain of length of 11 mm for the transposed nerve [1]. Furthermore, these authors reported their early experience in 6 cases; they stated that the radial nerve transposition should not be performed as a routine procedure but has to be an intra-operative decision when difficulties are encountered to achieve osteosynthesis and also more particularly when preoperative radial nerve paralysis is present [1]. They identified the location of fractures suitable for transposition and in which this technique can safely be done: in the area located from 2 cm proximal to 7 cm distal to the middle of the humerus. In addition, they stated that some local factors can technically facilitate nerve transposition such as presence of comminution at the fracture site and an oblique main fracture line running in the same direction of the spiral groove; nevertheless, this technique can also be done in transverse fractures [1]. Anatomic study by El Ayoubi et al. [1] showed that the motor branches designated to separately innervate the lateral, the medial, and the long head of the triceps, as well as the sensory lateral cutaneous branch are all delivered before the entry of the radial nerve into the spiral groove and run posterior to the humerus; anterior trans-fracture transposition of the radial nerve does not disturb the course of these branches as they remain posterior to the humerus without any tension [1]. On the other hand, the motor nerve of the brachioradialis is delivered by the radial nerve after its exit from the spiral groove and does not limit or bother the transposition [1]. In addition, this anatomic study showed that there are no collateral branches issued from the radial nerve into the spiral groove of the humerus; the last branch delivered by the radial nerve before its entry into the spiral groove is the nerve of the medial head of the triceps, and the first branch after the exit from the spiral groove is the nerve of the brachioradialis [1]. El Ayoubi et al. [1] believe that this procedure is more than a surgical commodity; it avoids intra-operative undue traction and manipulation of the nerve and puts it away from the surgical approach if a re-operation has to be done as in case of nonunion for example. It should be noticed that new generation of plates being used for humeral shaft fractures such as the so-called locking plates are thicker and wider than the plates used by El Ayoubi et al. [1]; these new plates have 5.2 mm thickness and 17.5 mm width for the broad type and 4.6 mm thickness with 13.5 mm width for the narrow type [16, 17]. A newer type of plates so-called metaphyseal locking plates, like those we have used in four of our cases, presents two parts of different thicknesses and widths and allows surgeons to insert screws of 3.5, 4.5, and 5.0 diameters; one part of the plate has 4.2 mm thickness and 13.0 mm width, while the other part has 3.6 mm thickness and 10.5 mm width [16, 17]. Yet Bèzes et al. [12] recommended the use of broad plates for fixation of humeral shaft fractures; the nerve may suffer some tension by the additional bulk of the plate [2, 4], and application of broader plate requires further dissection of the nerve [4]. We do also believe that thicker and wider plates may contribute to more stretch the nerve and hence to jeopardize its functional integrity as it wraps over the plate at the end of the procedure. Olarte et al. [2] reported their experience in 10 patients for whom they transposed the radial nerve medially with lateral plate fixation for humeral fractures and considered this technique reduces the risk of iatrogenic radial nerve injury. They “found that the transposition could be done safely and did not compromise fracture care or neural function” [2]. As previously mentioned by El Ayoubi et al. [1], Olarte et al. [2] also noticed that there is commonly an important stripping associated with fractures that would be appropriate for this procedure as for example in case of very displaced or comminuted fractures. Like these authors [1, 2], we also noticed that despite of presence of stripping, additional dissection was required at the posterior aspect of the proximal fragment and the anterior aspect of the distal fragment to allow safe medial mobilization of the nerve through the fracture site. Yet Olarte et al. [2] pointed that this technique could be criticized because of additional devascularization of bone during dissection; they noticed that “there is significant stripping already present in the fractures that would be best suited for this technique,” and they consider that “the injury that caused dissection is also a contributing factor for nonunion, and therefore, the transposition makes even more sense in such circumstances” [2]. Although Olarte et al. [2] also did not advise routine transposition, they stated that “the use of this technique should be based on the surgeons judgment and experience” and recommended it for fractures in which “the risk of nonunion and the need for revision surgery are high.” In fact as prementioned, if nonunion occurs after lateral plating and revision surgery is deemed, the nerve “is often indistinct and encased in scar, or occasionally within fracture callus” [2]; so primary transposition “avoids these complications, as the nerve is no longer in the operative field” [2], and “the lateral humerus and plate can be exposed directly without the need to dissect the radial nerve” [18]. Lee et al. [8] recently reported in the Korean literature on 6 patients for whom they performed medial transposition of the radial nerve in distal humerus shaft fracture with good results; separately, sporadic reports are also seen in the literature [19, 20]. Bacakoglu et al. [3] performed a cadaveric study with medial transposition of the radial nerve and antero-lateral plate fixation of the humerus. Although they showed that the new trajectory of the nerve was shorter and did “not compromise the nerve or its branches in terms of anatomic location and distance measurements,” the shortening did not reach the 11 mm previously reported by El Ayoubi et al. [1]. These authors concluded “that medial transposition of the radial nerve through the fracture line can be a safe procedure and may be indicated in cases in which antero-lateral plate fixation is indicated” [3]. For Packer et al. [21], the posterior approach is preferred to explore the radial nerve during plate fixation for humeral fracture occurring at the level of the spiral groove with radial nerve palsy. In cadaveric study with posterior approach, Yakkanti et al. [4] consider that “trans-fracture anterior transposition of the radial nerve is only possible in transverse or short oblique fractures involving the spiral groove.” Comparison of plating without and with trans-fracture anterior transposition of the radial nerve during posterior approach showed that more dissection and exposure of the nerve were necessary for transposition; although approximately 2.5-cm dissection of the nerve on each side of the spiral groove was required, this procedure is considered as feasible and safe [4].

In accordance with the limited experience and the very little number of reports in the literature, transposition of the radial nerve during plate fixation of humeral shaft fracture in our small clinical series was an intra-operative decision by the surgeon; it was dictated by the difficulties encountered during surgery. More extensive dissection of the radial nerve to transpose it through the fracture site was necessary, especially when it was entrapped or impinged with the fracture fragments; nevertheless, the dissection did not compromise nerve function nor did the transposition. We believe like others [1–4, 8] that radial nerve transposition during open reduction and internal fixation of humeral shaft fractures is technically feasible, harmless, and safe and has several advantages. From the practical standpoint, this procedure allows wider and better exposure—visualization—of the fracture site, protects the radial nerve during manipulations and reduction, and facilitates application of broader and longer plates. Other significant advantages are represented by the gain of functional length of the transposed nerve, the good quality of muscular mattress of the nerve into its new anatomic location surrounded by the brachialis muscle, and the absence of contact between the nerve and the plate. Moreover, the nerve will be located away from the surgical approach in case a revision surgery is indicated. Finally, it is very important for the patient to be clearly informed and given an official operative note documenting and detailing the transposition of his radial nerve. Although our preliminary results with this technique are encouraging, additional clinical application in larger series is recommended before indorsing its use in wider scales.

Conflict of interest The authors declare that they have no conflict of interest. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

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