EARLY SURGICAL EXPLORATION OF RADIAL NERVE INJURY ASSOCIATED WITH FRACTURE SHAFT HUMERUS

HASSAN NOAMAN, M.D.,* ABDEL RAHMAN KHALIFA, M.D., MOHAMED ALAM EL-DEEN, M.D., and ANIS SHIHA, M.D.

The series included 36 patients, predominantly male, mean age 30.3 years. The most common cause of injury was motor car accident in 20 patients. Postreduction radial nerve injury occurred in nine cases. Open fracture humerus with radial nerve injury in seven cases. The fractures were situated in the middle or distal third of the humeral shaft. Most were transverse fractures. Twelve patients had surgery on the day of injury and the other 24 at a mean of 8 days later (3–14). Narrow dynamic compression plate was generally used for fixation. Exploration of the radial nerve demonstrated compression at the lateral intermuscular septum in 19 cases, entrapment in the fracture site in nine cases, and loss of its continuity in eight cases. Neurolysis was required in 20 cases, epineurorrhaphy in nine cases, interfascicular nerve grafts in five, and first-intention tendon transfer in two. Results of nerve surgery were assessed with the MRC (Medical Research Council) at a mean follow-up of 8.2 years. Outcome was rated good to excellent in 28 patients, fair in 1, and poor (failure) in 3. First-intention tendon transfers were performed in 2 patients and 2 patients were lost to follow-up. Mean delay to recovery was 7 months after neurolysis and nerve repair and 15 months after nerve grafts. The fracture was united in all cases. The mean time of union was 5 months. © 2008 Wiley-Liss, Inc. Microsurgery 28:635–642, 2008.

A radial nerve injury associated with a humeral shaft fracture is an important injury pattern among trauma patients.[1] It is the most common peripheral nerve injury associated with fracture of long bones.[2–4] As our understanding of the pathoanatomy of the humerus and surrounding neurovascular structures has evolved, surgeons have adapted their strategies to improve outcome. There are differences in opinion regarding the treatment of choice. Early exploration of the radial nerve claims a variety of advantages. It is technically easier and safer than the delayed procedure. Direct examination of the nerve clarifies the diagnosis and the extent of the lesion. Early stabilization of the fracture reduces the chance of the nerve being enveloped by scar tissue and callus. Reduction of the open fracture helps lessen the risk of further neural damage from mobile bone ends. Shortening of the humerus to facilitate nerve repair is better done before healing of the fracture is complete.[5–8] However, opponents of early exploration have observed high rate of spontaneous recovery and have advised a policy of expectancy,[9–16] believing that this approach mitigates an unnecessary complications attendant on exploration. Thickening of the neurilemmal sheath while waiting helps to define the extent of nerve damage and facilitates repair. It is easier to treat the nerve when the fracture is healed. Most of these articles describe small numbers of patients and all are uncontrolled retrospective case series. Although treatment for this injury pattern is a controversial subject among upper-extremity surgeons, certain principles of management need to be applied in all cases. We limited our analysis to posthumeral fracture radial nerve palsies, which were operated due to the presence of neurological deficits after the fracture. We recorded the type of fracture, treatment used to achieve bone healing, surgical approach, and type of radial nerve surgery.

PATIENTS AND METHODS

Between April 2001 and April 2007, 36 patients with fractures of the shaft of the humerus with palsy of the radial nerve were treated by early exploration of the radial nerve and internal fixation by narrow dynamic compression plate (DCP) plate (Table 1). Twenty two were males and 14 females, with a mean age of 30.3 years (8–53 years). The most common cause of injury was motor car accident in 25 patients, falling from height in five patients, fire arm injury in four patients, and machine injury in two cases. A lesion of the radial nerve had occurred at the time of injury in 27 patients, seven of these patients had open fracture, and postreduction injury occurred in nine cases. The fracture patterns were varied. The most common pattern of fracture was transverse pattern involved the distal third occurred in 16 cases, oblique fracture in the distal third (Holstein-Lewis fracture),[5] in seven cases, spiral fracture involved the middle third in eight cases, transverse fracture involved the middle third in three cases, and oblique fracture involved the junction of middle and upper third of the humerus in two cases. Twelve patients had surgery on the day of injury and the other 26 at a mean of 8 days later (3–14). The mean follow-up was 28 months (9–72). The anesthesia was general, the position was lateral and the approach was posterior. Exploration of the radial nerve demonstrated compression at the lateral intermuscular septum in

Orthopaedic Department, Sohag Faculty of Medicine, Sohag University, Sohag, Egypt

*Correspondence to: Hassan H. Noaman, M.D., Orthopaedic Department, Sohag Faculty of Medicine, Sohag University, Sohag 82524, Egypt.
E-mail: hassan_h@mailcity.com

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Table 1. Demographic Data of Our Patients with the Mechanism of Injury and the Level and Pattern of Their Fractures

	Age	Sex	Cause	Type of fracture	Pattern	Level of fracture
1.	27	M	MCA	Open	Transverse	Middle
2.	32	M	MCA	Post reduction	Transverse	Distal
3.	8	M	MCA	Post reduction	Transverse	Distal
4.	16	F	MCA	Simple	Oblique	Distal
5.	43	F	FAI	Open	Spiral	Middle
6.	26	M	MCA	Post reduction	Transverse	Distal
7.	20	F	Falling	Open	Spiral	Middle
8.	36	M	Machine	Simple	Transverse	Middle
9.	25	M	MCA	Simple	Transverse	Distal
10.	30	M	MCA	Simple	Transverse	Distal
11.	17	F	Falling	Simple	Transverse	Middle
12.	23	F	MCA	Post reduction	Oblique	Distal
13.	19	M	MCA	Simple	Transverse	Distal
14.	28	M	Machine	Open	Spiral	Middle
15.	31	M	MCA	Simple	Oblique	Distal
16.	26	F	Falling	Simple	Transverse	Middle
17.	36	M	MCA	Post reduction	Transverse	Distal
18.	25	M	MCA	Simple	Oblique	Distal
19.	42	F	FAI	Open	Spiral	Middle
20.	53	M	MCA	Simple	Transverse	Distal
21.	37	F	MCA	Post reduction	Transverse	Distal
22.	24	F	FAI	Open	Oblique	
23.	21	M	MCA	Simple	Transverse	Distal
24.	28	M	FAI	Open	Spiral	Middle
25.	41	M	Falling	Simple	Transverse	Distal
26.	29	F	MCA	Simple	Spiral	Middle
27.	18	F	MCA	Post reduction	Transverse	Distal
28.	44	M	MCA	Simple	Spiral	Middle
29.	23	M	MCA	Simple	Transverse	Distal
30.	44	F	Falling	Simple	Spiral	Middle
31.	20	M	MCA	Post reduction	Oblique	Distal
32.	16	M	MCA	Simple	Oblique	Distal
33.	33	F	MCA	Simple	Transverse	Distal
34.	26	M	MCA	Simple	Oblique	Distal
35.	50	F	MCA	Post reduction	Oblique	Distal
36.	48	F	MCA	Simple	Transverse	Distal

19 cases (see Fig. 1), entrapment in the fracture site in nine cases (see Fig. 2), and loss of its continuity in eight cases (see Fig. 3). Neurolysis was required in 20 cases (see Fig. 4), epineurorrhaphy in nine cases, nerve grafts in five, and first-intention tendon transfer in two. Narrow DCP was generally used for fixation (see Fig. 5).

OPERATIVE TECHNIQUE

The radial nerve was explored through the posterior approach under general anesthesia and the position of the patient was lateral. A longitudinal incision was made in the midline of the posterior aspect of the arm, from 8 cm below the acromion to the olecranon fossa. The deep fascia of the arm was incised in line with skin incision (see Fig. 6). The gap was identified between the lateral and long heads of the triceps muscle. The interval between the two heads was proximally developed by blunt dissec-

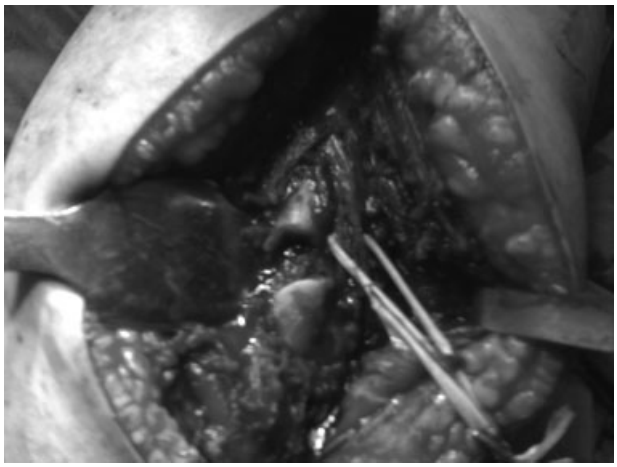

Figure 1. Exploration of radial nerve with entrapment of the radial nerve at the lateral intermuscular septum.

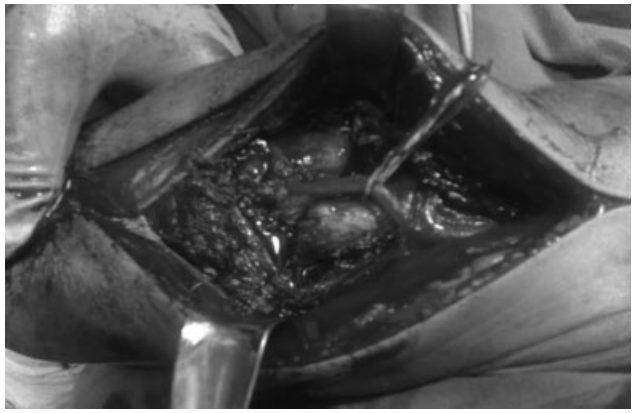

Figure 2. Entrapment of the radial nerve between the fracture fragments.

Figure 3. Fracture humerus with discontinuity of the radial nerve.

Figure 4. Radial nerve after neurolysis and fixation of the fracture by plate.

Figure 5. Plate fixation of the humeral fracture after neurolysis of the radial nerve.

tion, retracting the lateral head lateral, and the long head medially. Their common tendon was distally split along the line of the skin incision by sharp dissection. The radial nerve and the accompanying profunda brachii vessels were identified. The radial nerve leaves the axilla to run through the spiral groove transversely separating the lateral head from the medial (deep) head of the triceps, then passes laterally to enter the lateral intermuscular septum. It passes through the lateral intermuscular septum to come anteriorly in the groove between the brachialis muscle medially and coracobrachialis muscle laterally 7 cm above the elbow joint. The ulnar nerve can be mistaken by the radial nerve especially in the proximal part of the humerus but it goes straight downward on the medial aspect of the humerus and does not accompanying by large vessels as the profunda brachii. The medial head of the triceps was incised in the midline. The muscle was striped off the bone subperiosteally. The fracture will then be exposed and fixed. We used narrow DCP in all cases. The number of holes depends upon the geometry of the fracture. The plate was put on the posterior surface of the humerus anterior to the radial nerve especially in its proximal part. The radial nerve was explored in every case from proximal to distal to emerge from the lateral intramuscular septum. Exploration of the radial nerve demonstrated compression at the lateral intermuscular septum in 19 cases, entrapment in the fracture site in nine cases, and loss of its continuity in eight cases. Neurolysis was required in 20 cases. The function of the nerve was tested by intraoperative electrical nerve stimulation and also by the quality of nerve detected by its normal glistening whitish color, soft in consistency with normal nerve sheath contained longitudinal blood vessels. We also used the operative microscope to examine the fascicular arrangement of the nerve and to detect any abnormality of the nerve structure. The microsurgical procedures of nerve surgery facilitate the identification of healthy nerve tissue from the injured, inflamed, and edematous nerve tissues. The radial nerve was repaired in nine cases. The method of repair was epineurorrhaphy by 9/0 ethilon suture. We did grafting for the radial nerve in five cases, bridged by interfascicular cable nerve graft, sutured by 10/0 ethilon suture. The mean number of grafts was 3, average from 2 to 4. The mean length of the graft was 6 cm, average from 4 to 12 cm. The donor nerve was the sural nerve. First-intention tendon transfer was done in irreparable two. Closure of the wound was done from deeper to superficial. The triceps muscle was sutured by 2/0 vicryl. We used 16-gauge hemosuction for

Figure 6. Posterior approach for exploration of the radial nerve and fixation of the humeral fracture.

drainage for 36–48 hours postoperative. The skin was sutured by 3/0 silk. Postoperative immobilization by broad arm sling or u-shaped slab for 2 weeks (Table 2).

RESULTS

Results of nerve surgery were assessed using the MRC (Medical Research Council) at a mean follow-up of 28 months (Tables 3 and 4). Outcome was rated good to excellent in 28 patients (Figs. 7 and 8), fair in 1, and poor (failure) in 3 (Table 2). First-intention tendon transfers were performed in two patients and two patients were lost to follow-up. Mean delay to recovery was 5 months after neurolysis, 8 months after nerve repair, and 15 months after nerve grafts. The fracture was united in all cases. The mean time of union was 5 months. No cases of posterior arm compartment syndrome were present in our series.

DISCUSSION

Lesions of the radial nerve occurred between 1.8 and 18% of cases with fracture of humeral shaft with a mean of ~11%.[17] Some recommend conservative treatment of the fracture in these cases since in more than 80% the nerve will recover function spontaneously.[12] However, others advise immediate surgical exploration of the nerve and internal fixation of the fracture.[12,18]

In the middle third of the humerus, the radial nerve is still not fixed by the intermuscular septum and there is a greater protective layer of soft tissue between the nerve and the shaft of the humerus. Traumatic lesions of the radial nerve at this level are generally because of neuropraxia and have a high potential for spontaneous recovery.[19] In the distal third of the humerus, the nerve is fixed by the lateral intermuscular septum and is in close contact with the diaphysis.

Acute lesions or those which develop during conservative management of a fracture at this level are because of contusion or entrapment of the radial nerve. Spiral or oblique fractures have a greater propensity toward causing this type of nerve lesion making spontaneous recovery impossible, improbable, or unpredictable.[5,6,18,19]

In our patients, the most common pattern of fracture was transverse pattern involved the distal third occurred in 16 cases, oblique fracture in the distal third (Holstein-Lewis fracture) in seven cases, spiral fracture involved the middle third in eight cases, transverse fracture involved the middle third in three cases, and fracture involved the junction of middle and upper third of the humerus in two cases. Our experience and data in the literature suggest that several factors could be involved in persistent radial palsy after humeral shaft fracture. The greatest risk of radial nerve injury or absence of recovery after the primary lesion is encountered after fracture of the lower third of the humerus, spiral fracture, and plate fixation. Particular features observed in our series were compression in the intermuscular septum and transverse fracture of the distal third humerus.

The risk of laceration or division is increased in open injuries of the humerus. Therefore, exploration of the radial nerve at the time of initial debridement of open fracture and subsequent repair or grafting is generally accepted.[7] Seven of our patients had open fracture. Nerve repair was done in three of them. Nerve graft was done in two patients and first-intention tendon transfer was performed in two patients because the fracture was open grade III and the radial nerve was avulsed from the posterior cord.

Postacchini and Morace[20] reported 42 cases treated with either observation or early or late surgical exploration. Of the 14 cases treated nonoperatively, 12 (86%) recovered fully. All 18 cases treated with early nerve exploration (within 30 days of injury) recovered; however, only 6 (33%) were found to have a lesion that clearly benefited from surgical exploration (nerve trapped in fracture callus, nerve laceration). In comparison, all 10 late

Table 2. The Intraoperative Findings for Each of Our Patients and the Procedure Done with the Final Follow Up Period and Result

	Pattern	Level of fracture	Type of nerve injury	Nerve procedure	Follow up (ms)	Results
1.	Transverse	Middle	Loss of continuity	Repair	28	Excellent
2.	Transverse	Distal	Entrapment	Repair	35	Excellent
3.	Transverse	Distal	Entrapment	Repair	9	Excellent
4.	Oblique	Distal	Compression	Lysis	13	Excellent
5.	Spiral	Middle	Loss of continuity	Tendon transfer	22	Fair
6.	Transverse	Distal	Entrapment	Lysis	15	Excellent
7.	Spiral	Middle	Loss of continuity	Repair	27	Good
8.	Transverse	Middle	Compression	Repair	38	Excellent
9.	Transverse	Distal	Entrapment	Lysis	46	Excellent
10.	Transverse	Distal	Entrapment	Repair	12	Good
11.	Transverse	Middle	Compression	Lysis	44	Excellent
12.	Oblique	Distal	Entrapment	Lysis	26	Excellent
13.	Transverse	Distal	Compression	Lysis	18	Good
14.	Spiral	Middle	Loss of continuity	Tendon transfer	34	Good
15.	Oblique	Distal	Compression	Graft	56	Good
16.	Transverse	Middle	Entrapment	Lysis	22	Good
17.	Transverse	Distal	Compression	Repair	19	Excellent
18.	Oblique	Distal	Entrapment	Lysis	22	Excellent
19.	Spiral	Middle	Loss of continuity	Graft	36	Good
20.	Transverse	Distal	Compression	Lysis	19	Poor
21.	Transverse	Distal	Compression	Lysis	27	Excellent
22.	Oblique		Loss of continuity	Graft	48	Good
23.	Transverse	Distal	Compression	Lysis	35	Excellent
24.	Spiral	Middle	Loss of continuity	Graft	72	Excellent
25.	Transverse	Distal	Compression	Lysis	21	Excellent
26.	Spiral	Middle	Compression	Lysis	18	Excellent
27.	Transverse	Distal	Entrapment	Lysis	61	Excellent
28.	Spiral	Middle	Compression	Lysis	22	Excellent
29.	Transverse	Distal	Compression	Repair	32	Good
30.	Spiral	Middle	Compression	Lysis	25	Poor
31.	Oblique	Distal	Loss of continuity	Repair	25	Excellent
32.	Oblique	Distal	Compression	Lysis	34	Excellent
33.	Transverse	Distal	Compression		46	Excellent
34.	Oblique	Distal	Compression	Lysis	33	Poor
35.	Oblique	Distal	Compression	Lysis	24	Excellent
36.	Transverse	Distal	Compression	Lysis	19	Excellent

Table 3. The Medical Research Council Muscle Grading System

Observation	Muscle grade
No contraction	0
Flicker or trace of contraction	1
Active movement with gravity eliminated	2
Active movement against gravity	3
Active movement against gravity and resistance	4
Normal power	5

Table 4. The Final Results in Relation to the Final Muscle Power

Muscle grade	Result
≤ 2	Poor
3	Fair
4	Good
5	Excellent

British medical research council (1943). Aids to the investigation of peripheral nerve injuries. His Majesty's stationary office: London.

explorations (greater than 4 months after injury) had a lesion that required surgical intervention; however, functional recovery was noted in only 50%. The authors concluded that the decision whether to perform an early or late nerve exploration should be based on four criteria: 1) the fracture level, 2) the degree of displacement, 3) the nature of the soft tissue injury (open fracture), and 4) the degree of neurological deficit.

Other authors recommend surgical exploration 3 or 4 months after injury if there is no evidence of neurologic recovery.[4] Pollock et al.[12] reported 24 humeral fractures associated with varying degrees of radial nerve deficit. Initial treatment was closed in all but 1 patient in whom debridement of an open fracture revealed a lacerated radial nerve. All 24 patients had complete return of radial nerve function. Only two patients required radial nerve

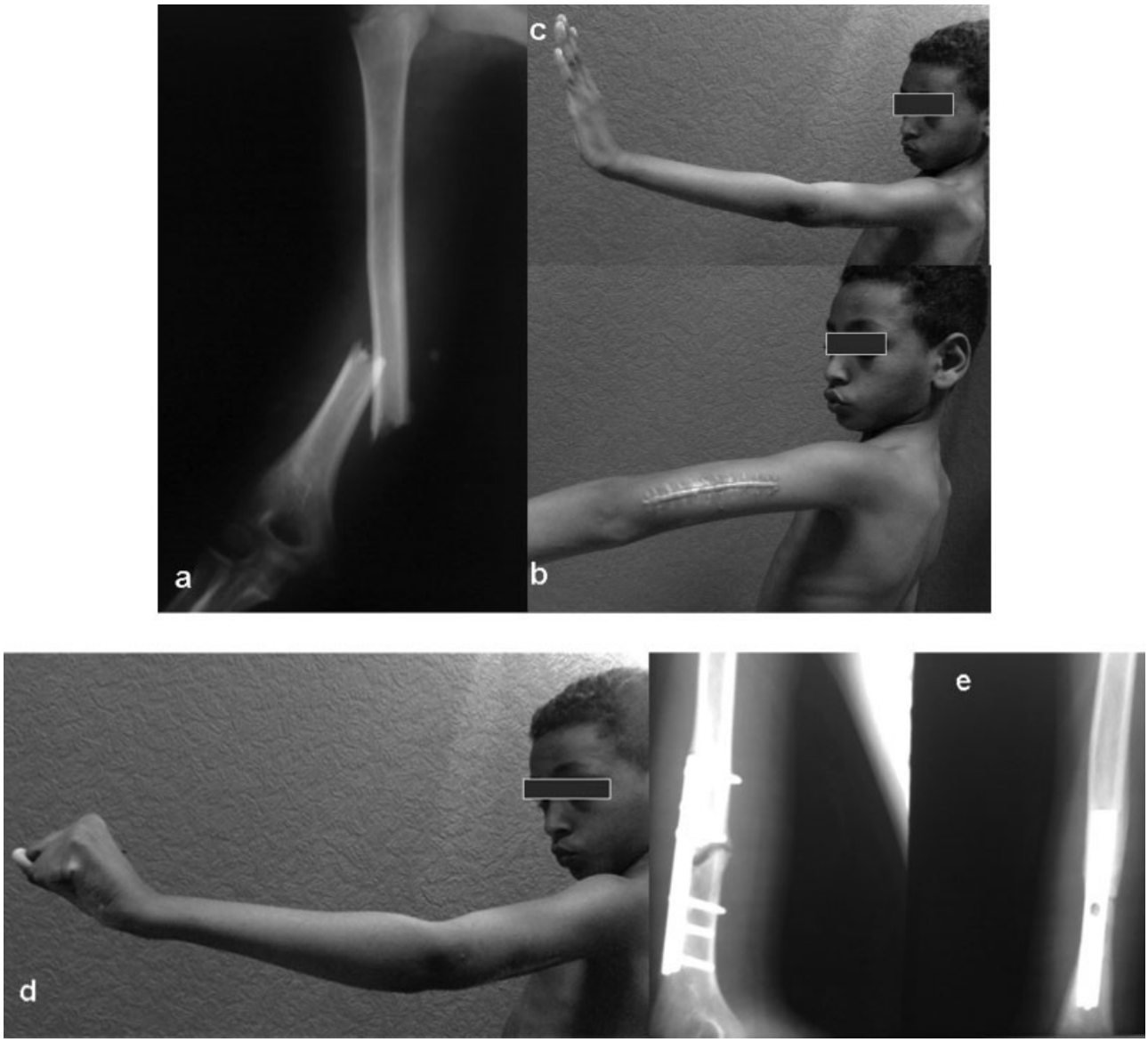

*Figure 7. (**a**) Preoperative plain X-ray with transverse fracture at the junction of the middle and distal thirds of the humerus. (**b**) Postoperative scar of the exploration. (**c**) Clinical photo showing full active extension of wrist and fingers. (**d**) Normal hand grip. (**e**) Follow-up X-ray showing union of the fracture.*

exploration, 1 at 14 weeks for nerve entrapment in fracture callus and the other at 6 weeks for repair of the lacerated radial nerve. They suggested that lack of neurologic improvement at 3 to 4 months after injury was an indication for nerve exploration.

Amillo et al.[15] reported 12 patients who underwent surgical exploration of radial nerve injuries after humeral shaft fracture. Patients follow-up averaged 6 years; the mean time to full recovery was 19 months. The mean interval between the fracture and surgical exploration of the associated nerve injury was 6 months. Perineural fibrosis was observed in four patients, and three nerves were found to be trapped in callus. Partial lacerations were identified in two cases and complete lacerations in three cases. The techniques employed for nerve repair or reconstruction were microsurgical reconstruction with interfascicular nerve grafting using sural nerve (six cases), neurolysis (five cases), and tendon transfers (one case). Good to excellent results were obtained in 11 patients (91%). They recommended nerve exploration if there are no clinical or electrophysiological signs of nerve recovery after 3 months.

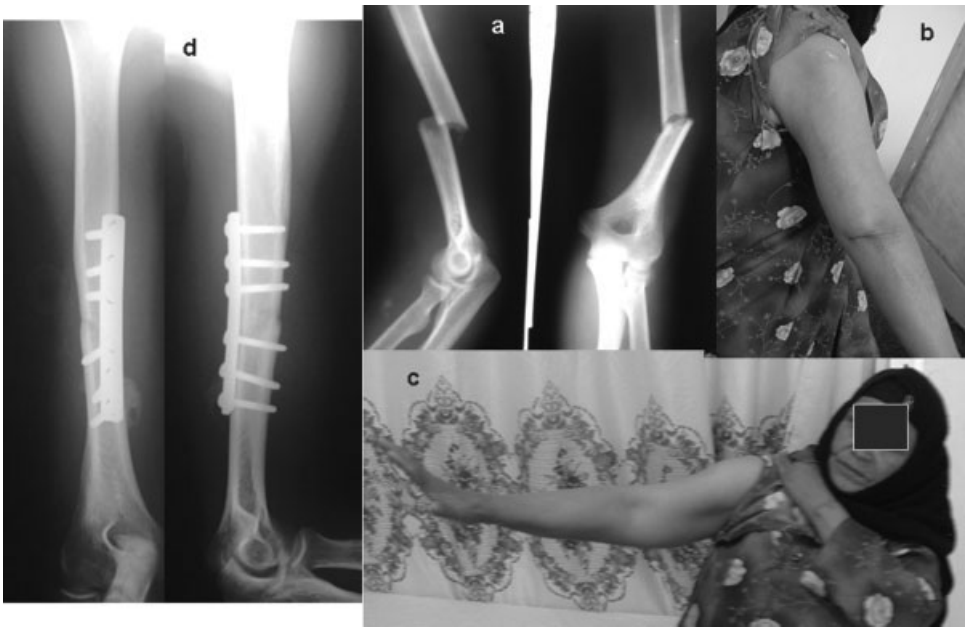

*Figure 8. (**a**) Preoperative plain X-ray showing transverse fracture in the middle third of the humerus. (**b**) Nice postoperative scar for posterior approach. (**c**) Active wrist and fingers extension. (**d**) Follow-up X-ray showing union of the fracture.*

Foster et al.[7] reported 14 patients with associated radial nerve palsy after open humeral shaft fracture. The average patient age was 29 years. In nine of the patients (64%), the radial nerve was either lacerated or interposed between the fracture fragments. There was an equal incidence of radial nerve laceration versus entrapment regardless of the degree of soft tissue injury (grade I, II, or III). Epineural radial nerve repair performed primarily or secondarily provided satisfactory return of radial nerve function at a minimum of 1 year follow-up. The authors concluded that radial nerve palsy in association with an open humerus fracture should have a nerve exploration at the time of initial fracture surgery.

In our patients, there was no negative exploration. Exploration of the radial nerve revealed compression at the lateral intermuscular septum in 19 cases, entrapment in the fracture site in nine cases, and loss of its continuity in eight cases. Neurolysis was performed in 20 cases, epineurorrhaphy in nine cases, and nerve grafts in five cases. First-intention tendon transfer was performed in two cases because the fracture was open grade III and the radial nerve was nearly avulsed from the posterior cord. Outcome was rated good to excellent in 28 patients, fair in 1, and poor (failure) in 3. First-intention tendon transfers were performed in two patients and two patients were lost to follow-up. Mean delay to recovery was 5 months after neurolysis, 8 months after nerve repair, and 15 months after nerve grafts. The fracture was united in all cases. The mean time of union was 5 months.

CONCLUSION

The classic indication for early radial nerve exploration with humeral shaft fracture is the postreduction radial nerve injury; however, we recommend early radial nerve exploration (within the first 2 weeks) with fractures of the humerus in patients with open fractures of humerus with radial nerve injury, fractures of distal third of humerus either transverse or oblique, radial nerve injury in Holstein–Lewis fracture and in postreduction radial nerve injury.

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