

Is early exploration of secondary radial nerve injury in patients with humerus shaft fracture justified?



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ABSTRACT

Background: Radial nerve is commonly injured with a fracture of the shaft of the humerus. Primary radial nerve injury occurs at the time of fracture, and secondary nerve injuries are seen after closed reduction or operative management. Management of these secondary nerve injuries is controversial regarding conservative approach verses early exploration.

Materials and methods: The PubMed, Science Direct, Scopus, and Google Scholar were used to find out relevant studies in the English language from October 2007 to October 2017. After a search of total 114 articles, we excluded 107 articles which did not meet our inclusion criteria, and only seven studies were thoroughly reviewed.

Results: Among the seven studies, three studies by Wang JP, Wang X, and Reichert P have included only secondary radial nerve injuries. Studies by Noaman H, Gouse M, Schwab TR and Bhardwaj A have included both primary as well as secondary radial nerve injury cases. Four studies used a conservative strategy and late exploration was advocated only if no nerve recovery was found within three to five months. Three studies recommended early radial nerve exploration (within the first two weeks) in patients with secondary radial nerve injury.

Conclusions: The pattern and duration of radial nerve recovery in secondary nerve injury was similar to that seen in primary radial nerve palsy. No advantage was seen in the early exploration of the radial nerve in most of these studies. If there is no misplaced instrumentation, macroscopic laceration of nerve or fracture displacement in the postoperative radiograph, secondary radial nerve injury can be treated as a primary radial nerve injury, and we recommend observation for a minimum of four to five months before exploration.

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1. Introduction

The radial nerve is commonly injured with fractures of the shaft of the humerus. These can be divided into three categories depending on its time of occurrence: primary, secondary and late-onset or delayed.¹ The primary radial nerve injury develops at the time of the initial injury, and its incidence was found to be 11.8% in a

meta-analysis comprising of 4517 Humeral shaft fractures. As 70–80% of primary radial nerve injuries recovered spontaneously, expectant management is used initially in most of the cases except in high velocity injuries and compound fractures.^{2–4} From the review of multiple studies, a consensus has formed that three to four months period of watchful waiting is appropriate before surgical intervention is attempted.⁵

Following closed manipulation or closed/open reduction and internal fixation about 10–20% of patient developed radial nerve injury which is defined as secondary nerve injury.⁶ Delayed or late-onset radial nerve injury is noticed slowly as the uniting fracture callus or scar tissues formed around unstable fracture entraps the nerve. Surgical intervention would be done obligatorily because the mechanism of injury appears to be the development of ongoing traction or callus entanglement. Some studies had even included

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late onset radial nerve injury under the heading of secondary nerve injury.

Treatment of secondary radial nerve injury is a controversial subject among orthopaedic surgeons. Some advocate early surgical exploration because of the high frequency of nerve entrapment after manipulation,^{7,8} while others stand for expectant management. The purpose of this study was to make treatment strategy for secondary radial nerve injury and to find out the outcome of various treatment modalities for the same.

2. Materials and Methods

We searched the PubMed, Science Direct, Scopus, and Google Scholar for the available literature. We searched for relevant studies in the English language from October 2007 to October 2017. The search strategy used following terms and Boolean operator: 'secondary' or 'delayed' and 'radial nerve injury' or 'palsy' or 'paralysis' or 'fracture' or 'nonunion' or 'shaft' or 'diaphysis' and 'humerus.' Manual searches of journals were done that were not indexed in the electronic sources, internet searches for grey literature and screening of reference lists of retrieved studies were also done (Fig. 1).

The titles and abstracts of the publications produced by the initial search strategy were evaluated. Following were the inclusion criteria: (1) an original study involving at least five or more secondary radial nerve injuries associated with humerus fracture (2) studies with complete data of the treatment of humeral fracture with radial nerve injury (3) studies published in English language after October 2007 to October 2017 including humeral diaphysis

fracture with secondary radial nerve injury and (4) Prospective or retrospective studies.

Irrelevant studies which did not meet the selection criteria were discarded after a screening of the abstract and titles of the studies. Data were extracted in reference to the inclusion criteria and presented in tabular form from selected studies (study design, participants, essential information, epidemiological data, interventions, and outcomes).

3. Results

One hundred and fourteen articles were retrieved after thorough search in the different database based on our search criteria. Twelve duplicate articles and 62 articles which have not described secondary radial nerve injury were excluded. Fifteen articles were included after reading titles and abstract. Then, by reading the whole paper, we included only seven papers, still having heterogeneity in context.

Among the seven studies, three studies of Wang JP,⁵ Wang X⁹ and Reichert P¹⁰ have included only secondary radial nerve injury in their study. Studies of Noaman H,¹¹ Gouse M,¹² Schwab TR¹³ and Bhardwaj A¹⁴ have included primary as well as secondary radial nerve injury cases. Out of these studies, we have extracted data of cases with secondary radial nerve injury for the study purpose. Four^{5,9,12,13} were retrospective, and three^{10,11,14} were prospective studies.

Various controversies came forward after assessing the included studies. Four studies^{5,9,12,14} favored a conservative strategy and they guided for late exploration only if signs of

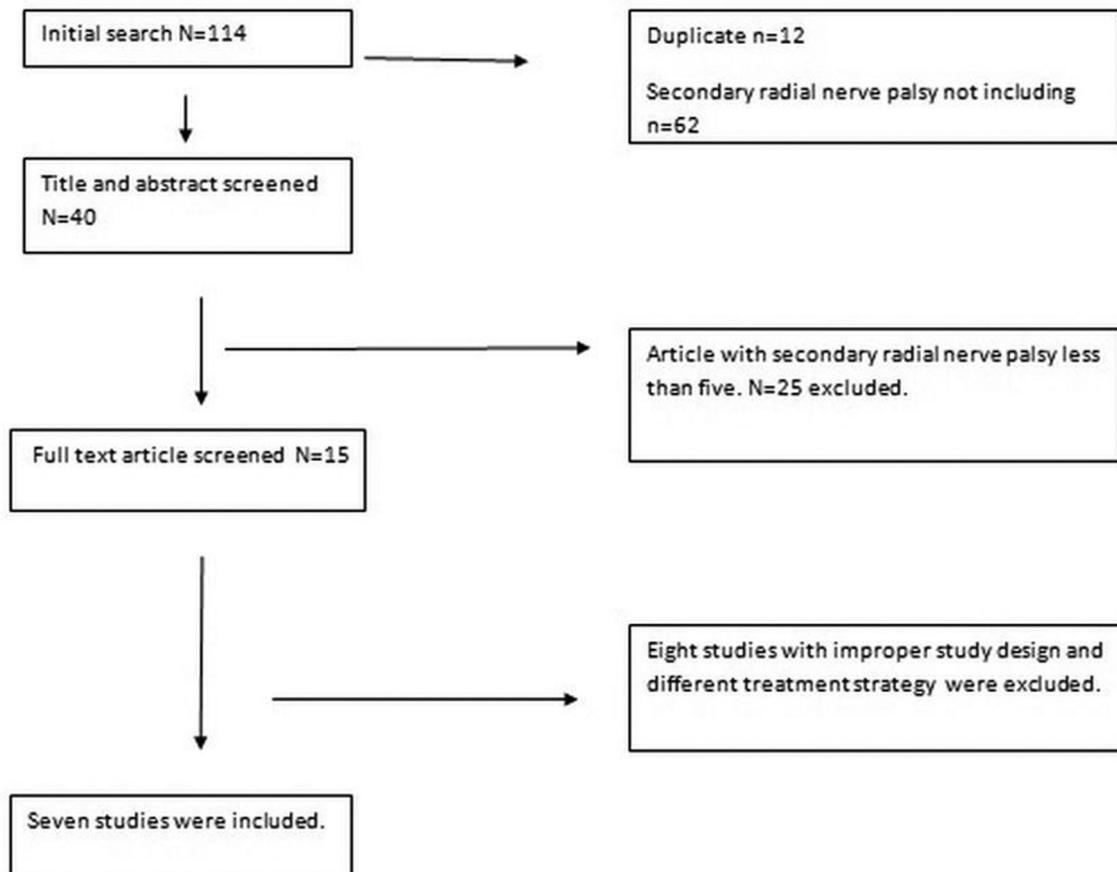


Fig. 1. Flowchart of the selection process of studies/articles.

recovery of nerves are not seen within three to five months. Three studies^{10,11,13} recommended early radial nerve exploration (within the first two weeks) in patients with secondary radial nerve injury.

Data regarding different parameters of included studies are shown in Table 1. A total number of secondary radial nerve injury cases were 119 in seven studies. Six studies found the average age to be 38.91 years. Most of the radial nerve injuries were associated with transverse or oblique fracture of a middle or distal third of humerus diaphysis. Open reduction and internal fixation (ORIF) with narrow dynamic compression plate was the most frequent mode of treatment in most of these studies. The anterolateral approach was used in most of the cases of plating. Only four patients with manipulation without surgery had radial nerve injury described in one study.¹⁰

In a study by Wang JP,⁵ of all 46 cases with secondary radial nerve injury; 39 patients had been treated with dynamic compression plates, three with closed anterograde interlocking intramedullary nails and four with closed retrogradely inserted Ender's nails. In 12 cases, radial nerve was visualized and protected during surgery but in other 34 cases status of nerve was not mentioned. Intraoperative injury of nerve was not mentioned. In every case, radial nerve palsy was recognized within 24 h after the surgery. Postoperative films showed the instrumentation to be in reasonable position, with no displaced fragments or fracture gap that would suggest entrapment of the radial nerve. All fractures united uneventfully. After around 16 weeks of mean time (Range, 5–30 weeks), clinical recovery of nerve was started. In five cases nerve was explored, and there was no macroscopic lesion in any of the cases. The follow-up time ranged from 13 months to 10 years. Of the 46 patients, six reported normal on telephonic follow-up, 36 had complete, and four had functional (partial) recovery on clinical examination.

In a study by Wang X,⁹ they noted six cases of secondary radial nerve injury out of 125 patients operated with internal fixation. ORIF with plating in five cases and nailing was done in one case. On Electromyography, recovery was started on average of 3.5 months (Range 1–5 months) in four cases, initiation of clinical recovery started with mean time of 4.8 months (Range 1–6 months), and the average time to full recovery of wrist and finger extension was 8.5 months (range 3–12 months). As there was no beginning of nerve recovery after three months of internal fixation of a humeral fracture in two patient, exploration of the nerve was done at the request of patients and found no macroscopic lesions of the nerve. Wrist and finger extension recovered to nearly normal in these two cases in two years follow up.

In a study by Gouse,¹² out of 66 patient (37 fresh fractures, 20 nonunion and nine infected nonunion) operated through anterolateral brachialis splitting approach with plating, 11 patient developed secondary radial nerve injury. Ten patient recovered completely without surgery in six months follow up, and one patient lost to followup. In a study by Bhardwaj,¹⁴ five cases with radial nerve injury, exploration did not show any macroscopic lesion, and all recovered completely in 18 weeks period.

In a study by Reichert,¹⁰ out of 33 cases of fracture with secondary radial nerve injury; four were treated conservatively, 16 were operated with ORIF with plating (13 anterolateral and three posterior approaches) and 13 by anterograde CRIF. Eleven cases had nerve entrapment, and 22 had complete transection of nerve. Neurolysis was done in 11 cases, repair in seven cases and nerve graft was done in fifteen cases. A full return of function was observed in 18 patients, and 11 patients achieved a partial return of function. Response from the radial nerve was absent in four patients, and in these cases, a tendon transposition was performed at 12 months after the nerve graft. These patients had satisfactory

results after two years. One of these patients was initially treated conservatively because the injury was in the middle third of the humerus. The three other patients had a mid-shaft spiral fracture with radial nerve neurotmesis treated by use of an intramedullary nail.

In Reichert's study,¹⁰ the results observed for operations performed with less than 6 weeks between the injury and second surgery were significantly better than those observed for operations and performed after 12 weeks (MRC: median 5 vs. 1, $p < 0.001$; DASH: median. 2.25 vs. 75.0, $p = 0.006$). The patients with entrapment of the radial nerve had significantly better results than those with radial nerve neurotmesis (MRC: median five vs. 2, $p < 0.001$; DASH: median 0 vs. 67.05, $p < 0.001$). The results after a direct neurotomy were better than after neurotomy with reconstruction. However, the difference was not statistically significant. Complications after using intramedullary nails were more significant. Tenomyoplasty surgery was required in 3 cases in which intramedullary nails were used.

In Noaman's¹¹ study, nine cases with secondary radial nerve injury; all were managed with plating through a posterior approach, five cases had entrapment, three had compression, and one had loss of continuity of nerve. Neurolysis was done in five cases and repair was done in four cases. All recovered completely in over nine month periods.

In Schwab's¹³ study; among nine cases of secondary radial nerve; locking compression plate was done in seven cases with minimally invasive plate osteosynthesis technique, external fixation in one and CRIF was used in one case. Primary exploration was done in four cases which did not show any macroscopic changes except in one case in which nerve was under plate which was released immediately. Secondary exploration was done in five cases with variable nerve injury; complete transection by distal locking bolt in one case found on the sixth post-op day and then 70 mm sural nerve graft was done on the 13th post-op day. This did not improve in 1.5 years of follow up, so tendon transfer was done. In one case with an External fixation, about 10% of nerve was lacerated with a pin, and this was released at the time of plating, and it recovered completely over 12 months. In other three cases nerve was contused by bone or plate, nerve recovered completely in all except one partial recovery.

In total 119 cases; there were 65 cases of axonotmesis, nine of contusion, three of compression, 17 cases of entrapment, 24 cases of the transection and one lost to followup. Axonotmesis was clinical diagnosis in most of the cases in these retrospective study by presuming that patient with complete radial nerve injury which recovered without any intervention. Regarding the method of treatment; observation was done in 74 (55 unexplored and 19 explored), neurolysis in 17, repair in 11 and nerve graft was done in 16 cases. There was a spontaneous recovery in 91 cases (77.11%) with few cases of neurolysis out of 118 patients and rest were operated by nerve repair or nerve grafting (Fig. 2). There was a complete recovery in 97, partial in 16 and no improvement in five cases. Tendon transfer was done in five patient with failure of repair and reconstruction.

4. Discussion

The problem of radial nerve palsy after conservative or operative management of a humeral fracture is not uncommon.¹⁰ In cases of ORIF; traction, callus formation, reduction maneuvers, compression of the nerve by the plate or screws were the common causes. On the other hand, in cases of MIPPO or CRIF nerve injury can occur at the level of the fracture or while putting the interlocking screw. Other causes include newly formed callus, reaming of the medullary canal, or compression by fracture.^{5,10}

Table 1
Epidemiological datas of selected studies.

Author's name and year of Publication	Wang X 2014	Reichert P 2016	Schwab Tr2017	Wang JP 2009	Bhardwaj A.2012	Noaman H 2008	Gouse M 2016	Total
Study design	RS	PS	RS	RS	PS	PS	RS	
Number of cases	6	33	5	46	5	9	11	119
Mean age	34.5	41	–	40	–	30.3	42.7	
Site of Fracture								
	Proximal						1	
	Middle			37			8	
	Distal			9		9	2	
Pattern of Fracture								
	Transverse	2		32		6		
	Oblique	1	9	14		3		
	Spiral	3	12					
	Comminuted		10					
Method of treatment of fracture								
	Conservative		4				4	
	ORIF		16	7 LCP	39	5	9	11
	Plating							92
	Nailing	1						1
	CRIF-IMIL		13 ante	1	3 + 4*			21
	Ext.fixator			1				1
Surgical Approach								
	Anterolateral	2	13		37		11	63
	Posterior		3		2	9		14
Type of nerve injury								
	Axonotmesis	6		3	41	5	10	65
	Contusion			4	5			9
	Entrapment		11	1		5		17
	Compression					3		3
	Transection		22	1		1		24
Method of treatment of nerve injury								
	Observation (exploration)	4+(2)		(7)	41+(5)	(5)	10	55+(19)
	Neurolysis		11	1		5		17
	Repair		7			4		11
	Nerve graft		15	1				16
Recovery								
	Complete	6	18	7	42	5	9	10
	Partial		11	1	4			97
Mean time of recovery(m)	8.5	6.1		6	5.5	7	6	16
Remarks	4 open fracture	4 not improve	1open fracture	4*Ender's nail			1 lost F/u	

Note: Cases in bracket indicates number of surgically explored cases without any macroscopic nerve damage and no further surgical intervention was done.

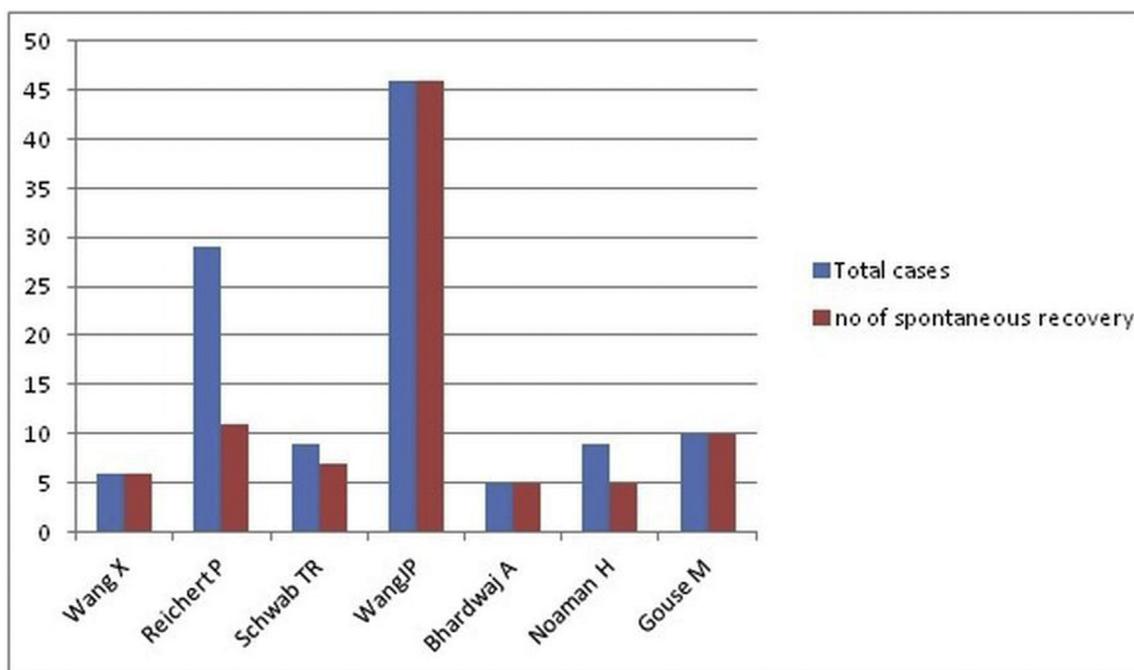


Fig. 2. The number of cases of spontaneous recovery in secondary radial nerve palsy.

In our review, Reichert's study¹⁰ had secondary nerve injury in four cases with conservative management of fracture, but the cause was not explained. Regarding the approach for plating in ORIF and radial nerve injury, 63 cases with anterolateral and 14 cases with posterior approach had secondary radial nerve palsy in our review. The exact cause was not explained in any of the studies but the anatomical course of radial nerve winding around the humerus and "tethered" within the lateral intermuscular septum in the middle and distal third of arm may predispose it to injury during antero-lateral approach.

There is still controversy regarding observation and late exploration versus early exploration for the management of secondary radial nerve injuries associated with fracture shaft of the humerus. The main advantage of the conservative approach is that most of the nerves are macroscopically intact and recover spontaneously, avoids unnecessary second surgery in many patient. In few cases which do not improve, late exploration and needful is done which is almost equally effective as early exploration. The main advantage of early exploration is that it may provide the best opportunity for nerve recovery when a nerve laceration is identified and grafted in a timely fashion.¹⁰

Clinically secondary radial nerve injury can be recognized easily but it could not find out the degree of damage to the nerve. Conservative observatory treatment versus early exploration and needful should be based on the extent of injury to the nerve. If there is a discontinuity of the nerve or gross laceration is present, early exploration and repair/reconstruction should be done.

Seddon has classified peripheral nerve injury into neuropraxia, axonotmesis, and neurotmesis.¹⁵ Partial loss of sensation in the dorsal radial aspect of the thumb/index web space with a present of sweating and muscle dysfunction but without atrophy indicates the radial nerve neuropraxia and such injury recover spontaneously, so such type of injuries are kept under conservative management.¹⁵ A complete loss of sensory and motor power with a strong Tinel sign suggest at least an axonotmesis if not neurotmesis.⁸ At the beginning of few weeks, the axonotmesis and neurotmesis manifest

similar clinical findings but, management protocol was different.¹⁵

Surgical intervention (nerve repair/reconstruction) is almost always required for neurotmesis whereas, in axonotmesis, nerve remains in continuity and nerve function restoration is more likely without surgical intervention.¹⁵ We agreed with Green DP et al.¹⁶ and Seddon¹⁷ who had suggested that the maximum length of time which may be required for motor recovery to first manifestation could easily be calculated by measuring the distance from the fracture site to the point of innervation of the brachioradialis muscle, which is approximately 2 cm above the lateral epicondyle. The maximum time for observation should not be longer than six months.¹⁷ Use of ultrasonography (US) for evaluation of the extent of damage to the radial nerve associated with fracture shaft of the humerus was described by Bodner G et al.¹⁸ His ultrasound findings of five patients with severe injuries of the radial nerve, were completely matched in surgery.

Electrodiagnostic studies like Electromyography (EMG) and Nerve conduction velocities (NCV) do not provide clear-cut guidelines regarding the degree of nerve damage leading to difficulty in decision making. Meta-analysis of 33 articles by Shao YC et al.,⁴ showed the limited role of EMG and NCV even in later days, as reinnervation signs are seen only two to three weeks before the onset of clinical recovery of motion. It also showed that the mean time of onset of recovery to full recovery of primary radial nerve palsy was 7.3 weeks (2 weeks–6.6 months) to 6.1 months (3.4–12 months) respectively. The present study also showed almost similar finding in secondary radial nerve palsy. Based on different data^{5,9,12,14} of conservative treatment, there appears to be little advantage of early exploration of the radial nerve. Unless there was a gross malposition of the implant, poorly reduced fracture or high index of suspicion for radial nerve transection in postoperative cases, early exploration of nerve was postponed, and expectant management was continued.

In cases of exploration of radial nerve injury^{10,11,13} neurolysis and epi-eppi neurium repair had better results for the gap >1 cm treated by using the sural nerve graft.^{19,20} This may be explained as

in entrapment, as only the axon is affected, and Wallerian degeneration appears in the distal part of the nerve only (axonotmesis). Whereas, in case of interruption (neurotmesis), Wallerian degeneration takes place in both antegrade and retrograde directions.^{19,20}

Early exploration was advocated by studies^{10,11,13,21} regarding iatrogenic nerve entrapment, but a review of published series²² and our studies^{5,9,12,14} demonstrated that the rate of spontaneous recovery is comparable to that of primary radial nerve palsy. Early exploration may not be indicated in every case, but it allows for the assessment of the degree of damage apart from entrapment. The advantage of early exploration is; in case of lacerated or transected nerve, quick repair allows tension reduction and promotes healing, and in a case of unrepairable injury (ruptured with a significant defect), nerve grafting or tendon transfer can be used immediately.²³ Most of the studies^{5,9,12,14} favored conservative treatment as in most of the cases nerve remain in continuity and recovers spontaneously within three to five months. Late exploration can allow for the spontaneous return of function, thus avoiding an unnecessary operation. Furthermore it allows the neurilemmal sheath to thicken, which facilitates repair if a neuroorrhaphy is needed.²⁴

Altogether 119 secondary radial nerve palsy patients were evaluated from seven studies; there were no randomized, controlled trials, nor any non-randomised, comparative studies were available. We acknowledge that some data were missed in this study as we could not include studies other than in English language, unpublished studies, and errors in our search strategies. We set the minimum number of patients for eligible studies to be \geq five with a secondary radial nerve injury to secure the minutiae of the data, but this number itself is a subjective decision and could have introduced bias. However, such bias is inevitable in the absence of randomized studies. Clinical decision-making is improved when a direct comparison can be made between different methods of treatment.²⁵

The recovery pattern and period of recovery of radial nerve palsy in secondary nerve injury was almost similar to that seen in primary radial nerve palsy. No advantage was found in the early exploration of the radial nerve in most of these studies. If there is no apparent malreduction or placement of the implant, macroscopic laceration of nerve or fracture displacement in the postoperative radiograph, secondary palsy can be treated as a primary nerve injury and exploration of the nerves advisable after observation for a minimum of four to five months.

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CRedit authorship contribution statement

Raju Vaishya: Conceptualization. **Ishwar Sharma Kandel:** Writing - original draft. **Amit Kumar Agarwal:** Formal analysis. **Vipul Vijay:**

Writing - original draft. **Abhishek Vaish:** Data curation. **Karuna Acharya:** Supervision.

References

1. Abdelgawad AA, Wassef A, Ebraheim NA. Late-onset radial nerve palsy associated with conservatively managed humeral fracture. A case report and suggested classification system. *HSS J.* 2010;6:49–51.
2. Bishop J, Ring D. Management of radial nerve palsy associated with humeral shaft fracture: a decision analysis model. *J Hand Surg Am.* 2009;34A:991–996.
3. Shah A, Jebson PJ. Current treatment of radial nerve palsy following fracture of the humeral shaft. *J Hand Surg Am.* 2008;33:1433–1434.
4. Shao YC, Harwood P, Grotz MR, Limb D, Giannoudis PV. Radial nerve palsy associated with fractures of the shaft of the humerus. *J Bone Joint Surg.* 2005;87B:1647–1652.
5. Wang JP, Shen WJ, Chen WM, Huang CK, Shen YS, Chen TH. Iatrogenic radial nerve palsy after operative management of humeral shaft fractures. *J Trauma.* 2009;66:800–803.
6. Hak DJ. Radial nerve palsy associated with humeral shaft fractures. *Orthopedics.* 2009;32:111.
7. Bleeker W, Nijsten M, Duis H. Treatment of humeral shaft fractures related to associated injuries. *Acta Orthop Scand.* 1991;62:148–153.
8. Lim R, Tay SC, Yam A. Radial nerve injury during double plating of a displaced intercondylar fracture. *J Hand Surg Am.* 2012;37:669–672.
9. Wang X, Zhang P, Zhou Y, Zhu C. Secondary radial nerve palsy after internal fixation of humeral shaft fractures. *Eur J Orthop Surg Traumatol.* 2014;24(3):331–333.
10. Reichert P, Wnukiewicz W, Witkowski J, et al. Causes of secondary radial nerve palsy and results of treatment. *Med Sci Monit.* 2016;22:554–562.
11. Noaman H, Khalifa AR, El-Deen MA, Shiha A. Early surgical exploration of radial nerve injury associated with fracture shaft humerus. *Microsurgery.* 2008;28(8):635–642.
12. Gouse M, Albert S, Inja DB, Nithyananth M. Incidence and predictors of radial nerve palsy with the anterolateral brachialis splitting approach to the humeral shaft. *Chin J Traumatol.* 2016;19(4):217–220.
13. Schwab TR, Stillhard PF, Schibli S, Furrer M, Sommer C. Radial nerve palsy in humeral shaft fractures with internal fixation: analysis of management and outcome. *Eur J Trauma Emerg Surg.* 2017 Mar 9. <https://doi.org/10.1007/s00068-017-0775-9>.
14. Bhardwaj A, SweKMM. Study of incidence and treatment of radial nerve palsy in fracture shaft of humerus. *Int J Collab Res Intern Med Public Health (IJCRIMPH).* 2012;4(5):796.
15. Seddon H. Nerve lesions are complicating certain closed bone injuries. *J Am Med Assoc.* 1947;135:691–694.
16. Green DP, Hotchkiss RN, Pederson WC. *Green's Operative Hand Surgery.* fourth ed. vol. 2. New York: Churchill Livingstone; 1999:1492.
17. Seddon HJ. Nerve grafting. *J Bone Joint Surg [Br].* 1963;45-B:447–461.
18. Bodner G, Huber B, Schwabegger A, Lutz M, Waldenberger P, Fornage BD. Sonographic detection of radial nerve entrapment within a humerus fracture. *J Ultrasound Med.* 1999;18:703–706.
19. Griffin MF, Malahias M, Hindocha S, Wasim SK. Peripheral nerve injury: principles for repair and regeneration. *Open Orthop J.* 2014;8:199–203.
20. Deumens R, Bozkurt A, Meek MF, et al. Repairing injured peripheral nerves: bridging the gap. *Prog Neurobiol.* 2010;92:245–276.
21. Ring D, Chin K, Jupiter JB. Radial nerve palsy associated with high-energy humeral shaft fractures. *J Hand Surg Am.* 2004;29:144–147.
22. Pidhorz L. Acute and chronic humeral shaft fractures in adults. *Orthop Traumatol Surg Res.* 2015;101:S41–S49.
23. Dabezies EJ, Banta II CJ, Murphy CP, d'Ambrosia RD. Plate fixation of the humeral shaft for acute fractures, with and without radial nerve injuries. *J Orthop Trauma.* 1992;6:10–13.
24. Pollock FH, Drake D, Bovill EG, Day L, Trafton PG. Treatment of radial neuropathy associated with fractures of the humerus. *J Bone Joint Surg Am.* 1981;63:239–243.
25. Littenberg B, Weinstein LP, McCarren M, et al. Closed fractures of the tibial shaft: a meta-analysis of three methods of treatment. *J Bone Joint Surg [Am].* 1998;80-A:174–183.