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Radial nerve palsy associated with fractures of the shaft of the humerus

A SYSTEMATIC REVIEW

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The management of radial nerve palsy associated with fractures of the shaft of the humerus has been disputed for several decades. This study has systematically reviewed the published evidence and developed an algorithm to guide management. We searched web-based databases for studies published in the past 40 years and identified further pages through manual searches of the bibliography in papers identified electronically. Of 391 papers identified initially, encompassing a total of 1045 patients with radial nerve palsy, 35 papers met all our criteria for eligibility. Meticulous extraction of the data was carried out according to a preset protocol.

The overall prevalence of radial nerve palsy after fracture of the shaft of the humerus in 21 papers was 11.8% (532 palsies in 4517 fractures). Fractures of the middle and middle-distal parts of the shaft had a significantly higher association with radial nerve palsy than those in other parts. Transverse and spiral fractures were more likely to be associated with radial nerve palsy than oblique and comminuted patterns of fracture ($p < 0.001$). The overall rate of recovery was 88.1% (921 of 1045), with spontaneous recovery reaching 70.7% (411 of 581) in patients treated conservatively. There was no significant difference in the final results when comparing groups which were initially managed expectantly with those explored early, suggesting that the initial expectant treatment did not affect the extent of nerve recovery adversely and would avoid many unnecessary operations. A treatment algorithm for the management of radial nerve palsy associated with fracture of the shaft of the humerus is recommended by the authors.

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Radial nerve palsy associated with fractures of the shaft of the humerus is the most common nerve lesion complicating fractures of long bones.[1,2] There are considerable differences of opinion regarding the treatment of choice.

Advocates of early exploration of the radial nerve claim a variety of advantages. Early exploration is technically easier and safer than a delayed procedure. Direct examination of the injured nerve clarifies the diagnosis and the extent of the lesion. Reduction of the open fracture helps lessen the risk of further neural damage from mobile bone ends. Shortening the humerus to facilitate nerve repair is better done before healing of the fracture is complete. Early stabilisation of the fracture reduces the chance of the nerve being enveloped by scar tissue and callus.[3-6]

However, opponents of early exploration have observed a high rate of spontaneous recovery and have advised a policy of expectancy,[7-14] believing that this approach mitigates unnecessary complications attendant upon 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. They suggest that recovery of the nerve is just as good with either early or late repair.

Most of these papers describe small numbers of patients and all are uncontrolled retrospective case series. We have systematically pooled data from previous clinical studies in order to provide more powerful recommendations on the treatment of choice.

Materials and Methods

Criteria for eligibility. There were no randomised, controlled trials or non-randomised, comparative studies and the formal meta-analysis had to be undertaken as a systematic review of the literature. The criteria for eligibility for selection of a paper were: published within the last 40 years (1964 onwards); inclusion of more than ten patients with radial nerve palsy; published in the English or German language; most of the detailed data should be extractable.

Identification of the studies. The medical search engines employed in this study included PubMed, Datastar and the Cochrane Database. The following terms and Boolean operators were used in each search: 'humeral' or 'humerus' or 'shaft' or 'diaphysis' or 'fracture' or 'radial nerve' or 'palsy' or 'paralysis', with limitation of 'title/abstract' and 'human' when possible. The bibliography of each paper identified electronically was searched manually for further potential references.

Extraction of data. Relevant information regarding the site of the fracture, type of fracture, the method of treatment, the nature, treatment and result of the injured nerve, and any grading of subdivision of these aspects, were carefully extracted. In order to reduce bias, the subgroups for each parameter were carefully defined and classified when possible. The data were extracted and double-checked (YCS, PH), and any disagreements resolved (PVG).

Primary radial nerve palsy was assumed when signs of such injury were present from the time of the accident or when a patient with polytrauma recovered consciousness. Patients who had undergone exploration of the nerve were categorised according to the method of treatment of the injury. Those with 'intact' and/or 'contused' nerves were combined into one group when no procedure was carried out on the nerve itself. Release of the nerve was assumed to have occurred naturally if it was entrapped in the fracture fragments. Neurolysis was assumed to have been carried out when the nerve was reported to be engulfed by callus or buried in scar tissue, or when neurolysis or intrafascicular neurolysis were described. The patients whose radial nerve was damaged too severely to be repaired were combined into a group of 'leave'. Early exploration was defined as operation within three weeks of injury.

Analysis of data. This was performed and recorded using Microsoft Excel 2000 (Microsoft Corp, Redwood, Washington). Since different authors provided relevant information differently, it was not always possible to calculate each parameter with data from all 35 studies. The number of pooled studies for each parameter was recorded.

Statistical analysis was performed using SPSS 12.0 for Windows (SPSS Inc, Chicago, Illinois) and Stata 8.0 (Statacorp, College Station, Texas). The data were compared using the chi-squared test, or Fisher's exact test wherever there were numbers less than 5. Heterogeneity between initial expectancy and early exploration was tested using the Mantel-Haenszel method. Statistical significance was defined for overall α error at $p < 0.05$ level. The power calculation for future randomised, controlled trials was carried out using the Power and Sample Size Program version 2.1.30, 2003 (Biostat, Engelwood, New Jersey).

Results

Literature search. We identified 391 citations of which 44 were found to be eligible for further consideration. However, two of the 44 appeared to be similar series,[15,16] and seven other papers did not have sufficient information for critical analysis.[17-23] Thus, 33 published studies[4-14,24-45] and two published abstracts[46,47] met the inclusion criteria; four were written in German.[42-45]

Characteristics of the studies. From the 35 studies, 1079 patients with radial nerve palsy were identified, of which 1045 (96.8%) had been followed up. All were observational studies. Of the 35, nine favoured early exploration,[4-6,24,29,42,44,45,47] and 21 did not.[7-14,25,26,31-39,43,46] The other five either had a conditional strategy or did not state a clear preference.[27,28,30,40,41] Sixteen included paediatric patients,[4,7,9,10,12-14,25,27,30,31,34,35,40,42,45] 11 clearly excluded children[5,6,24,28,29,33,36-39,41] while the remaining eight did not mention this.[8,11,26,32,43,44,46,47] Seven studies recorded their criteria for the evaluation for recovery of radial nerve palsy,[7,8,13,25,34-36] but only three presented a grading system for recovery and gave a definition of non-recovery, partial recovery and complete resolution.[8,13,35]

General information. Of the 25 studies, 21[6,7,10,11,14,24,26,29,31-34,36-39,41-45] described a total of 4517 fractures of the shaft of the humerus and 532 radial nerve palsies, giving an overall prevalence of radial nerve palsy of 11.8%, which is very similar to that noted by Pollock et al.[10] Only a few of the authors analysed their cohorts according to the site or type of fracture. When the length of the shaft was divided into three,[29,34,36,39] the prevalence of radial nerve palsy was 1.8% (one of 57) proximally, 15.2% (27 of 178) in the middle, and 23.6% (37 of 157) distally. If a five-part classification was adopted,[26,31,33,38,45] the respective data were 3.4% (three of 89) proximally, 10.5% (6 of 57) middle-proximally, 21.9% (48 of 219) middle, 20.0% (32 of 160) middle-distally, and 10.5% (eight of 76) distally. Thus, the middle and middle-distal fractures were most commonly associated with nerve injury ($p < 0.05$). As to types of fracture, transverse (47 of 222, 21.2%) and spiral fractures (19 of 96, 19.8%) had a significantly higher occurrence of radial nerve palsy ($p < 0.001$) than oblique (15 of 179, 8.4%) and comminuted fractures (26 of 382, 6.8%).[29,36,37,45] The incidence in closed (137 of 929, 14.8%) and open (51 of 280, 18.2%) fractures was not statistically significant ($p > 0.05$).[6,24,26,31,34,37]

Of a total of 1045 patients with radial nerve palsy, 921 recovered, providing an overall rate of recovery of 88.1%. The difference in the rate of recovery between primary (632 of 713, 88.6%) and secondary radial nerve palsy (121 of 130, 93.1%) was not significant ($p > 0.05$),[4-7,9-14,24-26,28-34,36-45] while the differences between complete (225 of 290, 77.6%) and incomplete (53 of 54, 98.2%) fractures,[4,5,10-13,25,28,29,33,38,40] and those which were closed (101 of 104, 97.1%) or open (30 of 35, 85.7%)[5,6,9,10,14,31] are all statistically significant ($p < 0.05$).

Initial expectant treatment and early exploration. Thirty papers described patients with radial nerve palsy sufficiently well to be classified according to treatment policy. Group A in Table I represents the patients treated with an expectant policy who spontaneously recovered. Of 581 patients, 411 recovered spontaneously (70.7%). Of the remaining 170

Table I. Results of initial expectant management and early exploration

	Total radial nerve palsy				Primary radial nerve palsy			
	A	B	A+B	C	D	E	D+E	F
	Ini, sr*	Wait op*	Ini, fr*	Early op*	Ini, sr	Wait op	Ini, fr	Early op
Radial nerve palsy	581	149	581	314	435	104	435	222
Recovered	411	98	509	276	315	72	387	188
Rate (%)	*70.7*	*65.8*	*87.6*	*87.9*	*72.4*	*69.2*	*89.0*	*84.7*
Chi-squared test			(A+B)/C = 0.899				(D+E)/F = 0.116	
Heterogeneity test			p = 0.3880				p = 0.9209	
Total number of studies	30				27			
References	4-7, 9, 10, 12-14, 24-35, 37-43, 46, 47				4-7, 9, 10, 12-14, 24-26, 28-35, 37-39, 41-43, 46			

* Ini, sr: initial expectant, spontaneously recovered; Wait op: operated on more than eight weeks after injury; Ini, fr: initial expectant and final resulted; Early op: operated on within three weeks after injury

Table II. Recovery rate of different managements of the nerve injury

	Recovery rate after different managements								
	Ini, sr*	Total operated	Intact or contused	Extrication†	Neurolysis	Neurorrhaphy	Nerve graft	Leave‡	Tendon transfer
Radial nerve palsy	534	397	184	53	67	51	27	15	26
Recovered	397	327	169	48	60	27	23		
Rate (%)	*74.3*	*82.4*	*91.9*	*90.6*	*89.6*	*52.9*	*85.2*		
Total number of studies	25	23	16	11	13	16	6	10	9
References	4,6,7,9,10,12-14, 25-28,30-35, 37-40,43,44,46	4-7,9,10,12-14, 25-28,30,32-35,38, 40,42, 44,46	5-7,9, 12,14,25-29,34,35,40,42,46	5,9, 12,25,27,29,30, 33,34,40,42	8-10,12,14,27,30,33, 34,38,40,42,44	5-7,9,10,12, 13, 25-28,34,38,40,42,44	5,8,13,30,32,35	5-7,9,12,13, 28,29,32,40	4-7,9,13,29, 32,40

* ini, sr: initial expectant, spontaneously recovered

† freeing the radial nerve from entrapment by fracture fragments

‡ the nerve was damaged too severely to be repaired

Table III. Overall mean times for a radial nerve palsy associated with fracture of the shaft of the humerus

	Follow-up	ROTsr*	FRTsr†	$MLET_{first}$‡
Mean	30.1 mths	7.3 wks	6.1 mths	4.3 mths
Range	5.5 to 80 mths	2 wks to 6.6 mths	3.4 to 12 mths	1 to 15 mths
Patients	323	101	110	98
Studies	11§	5	5	11
References	6,9,13,14,29,32,34,35,40,42,44	7,10,12,27,28	7,10,12,27,28	4,7,8,10-13,25,32,33,40

* ROTsr, recovery onset of spontaneously recovered cases

† FRTsr, full recovery time of spontaneously recovered cases

‡ $MLET_{first}$, mean late exploration time of the first exploration

§ five other papers provided data that cannot be analysed, such as > 2 years; these were: [5,8,25,26,28]

cases, 149 (group B) had a late exploration after a variable period of time. Of these, 98 (65.8%) recovered (group B). Group (A+B) represents the final results of the waiting and expectant groups, while group F represents patients who underwent early exploration. No significant difference was seen in the rate of recovery between the two groups. Although caution needs to be taken in interpreting these figures, it appears that the chance of eventual recovery was very similar whether a policy of early exploration or an initial expectant strategy was employed. The data were further subdivided according to the cause of radial nerve palsy. As shown in Table I, the same trend could be seen in primary radial nerve palsy, but the data were insufficient for the analysis of secondary radial nerve palsy.

Treatment and prognosis. In Table II, patients were grouped according to the management of the associated nerve injury, regardless of the time of operation and the original neurological status. The treatments varied among groups, and it was not possible to reach any firm conclusion through statistical comparison. Nevertheless, we attempted to retrieve some information contained in these data. Of the 397 patients who underwent surgical exploration, in 184 (46.3%) the nerve was intact or merely contused, in 53 (13.4%) the nerve was trapped within the fracture fragments and needed to be extricated, a neurolysis was carried out in 67 (16.9%) and in 93 (23.4%) the radial nerve was severed. Of the 93 severed nerves, 51 underwent neurorrhaphy, 27 were grafted and in 15 the damage to the nerve was so severe or there was a prohibitively long nerve defect such that repair was not possible.

Mean times to recovery. As shown in Table III, 11 papers (323 patients) gave the duration of follow-up following the nerve injury, the overall mean time being 30.1 months (5.5 to 80). Five other studies provided incalculable time data,

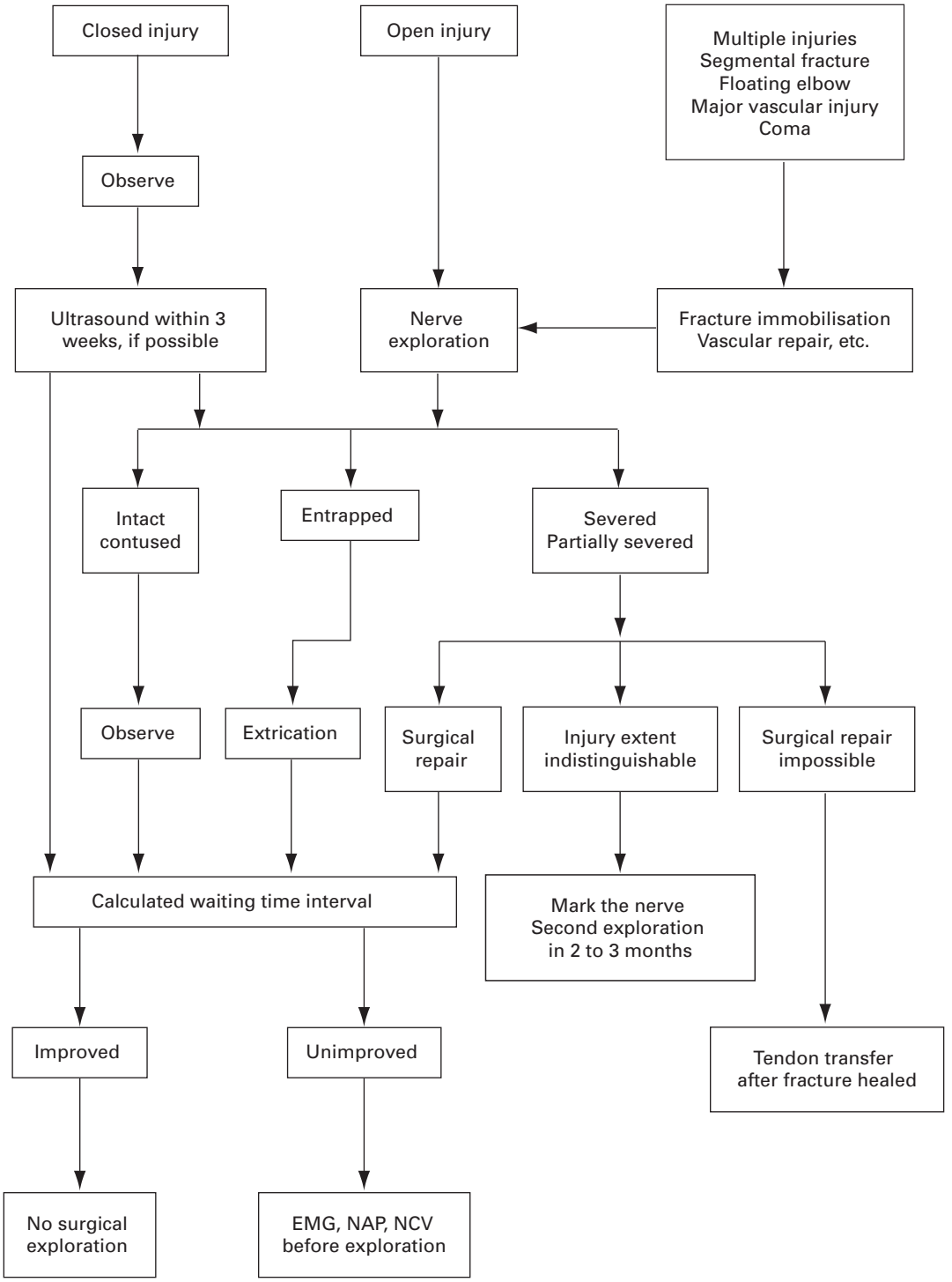

Fig. 1

Treatment algorithm for a radial nerve palsy associated with a fracture of the shaft of the humerus (the role of ultrasound has yet to be properly determined) (EMG, electromyogram; NAP, nerve axonal physiology; NCV, nerve conduction velocity).

such as more than 12 months, or at least two years. Five studies reported the spontaneous recovery onset time in a total of 101 patients. The mean time to the onset of recovery was 7.3 weeks (2 weeks to 6.6 months). We considered this mean recovery onset time important in making a decision as to the period of waiting when following an expectant policy. In five papers,[7,10,12,27,28] the mean time to full recovery in 110 patients who recovered spontaneously was 6.1 months (3.4 to 12). When evaluating the mean time before late exploration for the first time ($MLET_{first}$), three

patients in two papers[4,12] were excluded because of an extremely long period of waiting of 18, 21, and 36 months respectively. The $MLET_{first}$ of 98 patients in 11 series was 4.3 months (1 to 15). These mean times might represent the common view of authors who believed in a waiting policy.

Power calculation. Groups (D+E) and F in Table I represent the final results of all the patients with primary radial nerve palsy who were managed by two different policies of treatment. The rates of recovery of these two groups were analysed by the Power and Sample Size Program. When using a dichotomous calculation for a future independent prospective study, setting $p < 0.05$ and power = 80%, the result was 969, indicating that a future randomised, controlled trial needs at least 969 patients for each arm with a total of 1938 patients. Then, if a difference does exist, there will be a 80% chance of identifying it. Such a study would present immense logistical problems.

Discussion

Clinical decision-making is enhanced when direct comparison can be made between methods of treatment.[48] Unfortunately, not all clinical material can be studied in such an ideal way. Meta-analysis is a statistical procedure which integrates the results of several independent studies which are considered to be combinable. It therefore increases the statistical power for defined end-points and subgroups, and systematically analyses conflicting reports.[49]

Quality of the literature and limitations of the analysis. Although a total of 1045 radial nerve palsy patients were pooled from 35 studies, there were no randomised, controlled trials, nor any non-randomised, comparative studies available. We acknowledge that failure to include studies written in languages other than English and German, unpublished studies and errors in our search strategies could all have resulted in missing data. We limited our literature review to the last 40 years as publications before then are very difficult to retrieve. We set the minimum number of included radial nerve palsy patients for eligible studies to be ≥ 10 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 randomised studies.

We were not able to separate children from the cohorts described, but we could identify that the total number of paediatric patients was very small.

Analysis of the results. The crucial question is whether to treat a radial nerve palsy conservatively or surgically, and if conservatively, at what point should exploration of the nerve be considered. Table I shows no significant difference in the rate of recovery between groups of (A+B)/C and (D+E)/F, indicating that whether the nerve is explored early or not, a limited period of waiting has no effect on the final recovery. Considering the advantages of initial expectancy, and in order to avoid unnecessary surgery, we recommend that a policy of initial expectancy must be considered.

How long should one wait for a nerve to show signs of recovery before exploration? In Table III, of 98 patients in 11 papers, the mean delay to first exploration ($MLET_{first}$) was 4.3 months (1 to 15). In 101 cases treated expectantly at first, the mean spontaneous recovery onset time was 7.3 weeks, which may indicate the minimum waiting time before exploration. However, the optimum period of waiting is still a subject of debate. Some authors agreed on two, three or four months, others preferred to explore within six months. Based on this analysis, we were unable to make a statistically effective recommendation as there were too many factors which might have affected the final outcome. However, we agree with Green, Hotchkiss and Pederson,[50] who stated that assuming a nerve regenerates at the rate of approximately 1 mm a day, and adding 30 days (as Seddon[51] had suggested), the maximum length of time which may be required for motor recovery to first manifest itself could easily be calculated. This is achieved by measuring the distance on the radiograph from the fracture site to the point of innervation of the brachioradialis muscle, which is approximately 2 cm above the lateral epicondyle. The overall waiting time should not be longer than six months.

There were only two papers offering data on the so-called Holstein-Lewis fractures in which the radial nerve may be trapped between the fragments of a spiral fracture of the distal third of the humerus.[29,38] We consider that the special relationship between this fracture and radial nerve palsy is not as strong as the original authors suggested.[3] Based on this study, it appears that the region at risk extends from the midshaft to the level of the typical Holstein-Lewis fracture.

We could not make any effective analysis of the role of electrophysiological examination from the data available. However, serial examination does appear to be important[9,25,30] and Bodner et al[30,52] have described an attractive technique using high-resolution ultrasound to evaluate the injured nerve.

Based on the results of current meta-analysis and expert opinions from several other authors[1,40,53] we have derived the algorithm shown in Figure 1 as a recommendation for the treatment of a radial nerve palsy associated with a fracture of the shaft of the humerus.

Supplementary Material

A further opinion by Mr Simon Lambert is available with the electronic version of this article on our website at www.jbjs.org.uk

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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