EDITORIAL

Radial nerve

Tarek El Madhoun, MD,¹ and Rajiv Midha, MD, MSc, FRCSC²¹Department of Clinical Neurosciences, Division of Neurosurgery, Cumming School of Medicine at the University of Calgary; and ²Department of Clinical Neurosciences, Hotchkiss Brain Institute, University of Calgary, Alberta, Canada

By definition, proximal radial nerve injuries are lesions of the radial nerve distribution that occur within the infraclavicular brachial plexus up to the axillary level. If the injury occurs at the divisional to the posterior cord level then they can be categorized as “cord injuries,” and if they extend distally to the radial nerve then they have been categorized as “cord-to-nerve” injuries.⁷ The incidence of proximal radial nerve or posterior cord injury is infrequently discussed in the literature and its epidemiology is largely unknown. Isolated injuries to the triceps branches may be a result of humeral fractures. Occasionally, this may happen during shaft repair as well. However, stretch injuries remain the most frequent cause of posterior cord or proximal radial nerve injuries.⁷ Gunshot wounds and other penetrating injuries are among the uncommon causes of infraclavicular injuries and are less frequently reported in the literature. This lack of information makes the experience and recent data from a large-volume center highly relevant. In this article, Bertelli and Ghizoni report on 13 patients with proximal radial nerve injuries, which resulted from high-velocity stretch mechanisms; all patients were injured in motorcycle accidents and many had concomitant musculoskeletal injuries, and several had injuries to other brachial plexus elements.³

The prevalence of proximal radial nerve injuries is still unknown, unlike the detailed knowledge about the risk of radial nerve palsy due to humeral shaft fractures. The prevalence of radial nerve palsy due to humeral shaft fractures is 11.8%; however, when the shaft length is divided into thirds, only 1.8% of the proximal third fractures are associated with radial palsy, whereas a 15.2% incidence is associated with middle shaft fractures and 23.6% with distal third shaft fractures.¹³ On the other hand, Wang et al. reported iatrogenic radial nerve palsy in 30 of 707 surgically treated patients with humeral shaft fractures (an incidence of approximately 4.2%) over a period of 10 years.¹⁴ Shoulder girdle injuries are usually associated with multiple nerve palsies including the radial nerve. De Laat et

al., in a study that involved 101 patients with shoulder dislocation and humeral neck fracture, reported axonal loss (i.e., at least an axonotmetic injury) on electromyographic evaluation of the radial nerve in 22% of cases, whereas 29% had axonal loss in the suprascapular nerve and 37% in the axillary nerve.⁵

For patients with confirmed radial laceration due to open injuries as well as for those who had no signs of nerve recovery within 3–4 months after the injury, surgical exploration is usually performed. The surgical options vary from simple decompression and neurolysis to nerve grafting. Other authors advocate select distal nerve transfers if the radial nerve injury is extensive and very proximal.¹¹ There remains some controversy about the timing of intervention, especially for the patients who have radial palsy associated with closed humeral shaft fractures. Some advocate early exploration,⁹ whereas others recommend waiting 16–18 weeks.⁸ Several studies have reported spontaneous recovery from the injury for more than 75% of patients after 3 months,^{1,13} so in most patients with typical humeral shaft-associated radial nerve injuries, we recommend waiting 4 months, with serial clinical and electrophysiological follow-up prior to exploration. However, for the proximal radial nerve injuries associated with severe stretch mechanisms, as in the series reported herein,³ we too would recommend exploration by 3–4 months, with intention for nerve grafting.

One of the largest series of surgically treated patients with posterior cord to radial nerve stretch injuries was from the Kline experience at Louisiana State University Health Sciences Center (LSUHSC). In that study, researchers reported performing neurolysis or grafting in 65 individuals.⁷ Pan et al. reported on 44 surgically treated patients with proximal radial nerve injury at the infraclavicular level over a 17-year period.¹⁰ Results of grafting for proximal radial nerve in the literature are variable. Acciarri et al. reported only a 50% recovery rate after a long follow-up of 2 patients with reconstructed and trans-

posed radial nerves.² On the other hand, Henry⁶ reported complete recovery of radial nerve function in 2 cases with lengthy proximal injuries managed with early cable nerve grafting. The outcome was excellent (Medical Research Council [MRC] Grade 5/5) for both patients, in a follow-up period of 31 weeks in one and 62 weeks in the other. In a larger case series of patients with posterior cord to radial nerve stretch injuries, 32 individuals underwent graft repair at LSUHSC, and the recovery average, using a composite radial nerve score, was graded at 2.7.⁷

The largest case series of graft repair of the proximal radial nerve was reported by Pan et al.¹⁰ They studied 244 cases for whom radial nerve grafting was performed due to nerve injury at different levels. Among them, 44 patients had injury to the radial nerve at the infraclavicular level. At 21.5 months, 80% of them recovered wrist extension to MRC Grade 3 or 4, irrespective of the level of injury, whereas thumb and finger extension recovered only for those patients with injury of the very distal radial nerve at the posterior interosseous nerve (PIN) level. Those results underscore the authors' contention³ regarding the need for a long follow-up period and clear demarcation of MRC Grade 3 versus 4 recovery in wrist extension to properly evaluate the outcome. The fact that only a minority of patients achieve Grade 4 or better wrist extension function (considered to be clinically useful extension) despite graft repair underscores the need for careful follow-up and early consideration of a nerve (or tendon) transfer to augment wrist extension function.

The authors³ describe the surgical approach well; their descriptions are supported by illustrative photos taken during the surgeries. However, the presented photos are not specific for cord or cord-to-nerve lesion, and 6 of 13 patients had preserved triceps. In essence the authors are presenting a series of heterogeneous cases of proximal radial nerve palsy, and given this heterogeneity and small sample size, the data regarding graft length are not so meaningful. However, they do challenge the concept of nerve grafting alone if the target is the wrist, and particularly thumb and finger extension, all of which can be achieved with reasonable success by nerve or tendon transfers. Indeed, the authors' discussion is relevant and very detailed, particularly in the manner they present the cons and pros of nerve transfer versus tendon transfer for thumb and finger extension restoration. This is the main value of the paper.

There is considerable controversy about the use of nerve versus the more accepted use of tendon transfers for restoration of wrist and finger extension function. Defenders of nerve transfer from the median nerve branches for the purpose of reanimating the PIN branches note the advantage of this method for the potential of restoration of near normal radial nerve function, including independent finger motion.^{4,11} The opponents of this method see that in case of failure of the nerve transfer, the use of the flexor carpi ulnaris (FCU) tendon transfer is compromised because the radialis has been paralyzed. Restoration of thumb and finger extension is possible using the FCU tendon, which can be transferred to reanimate the extensor pollicis longus (EPL) and extensor digitorum communis (EDC).¹² As yet there is no Class I literature evidence favoring tendon

over nerve transfers, but both options are reasonable. The authors' recommendation of combining nerve grafts with early nerve and tendon transfers seems appropriate for cases with truly proximal radial nerve palsy, especially when associated with impaired elbow extension (triceps palsy). Although this method has already been adopted by many peripheral nerve and upper-extremity reconstructive surgeons, this article is further verification toward the best practice in this evolving field.

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Disclosure

The authors report no conflict of interest.

Response

Jayme Augusto Bertelli, MD, PhD, and
Marcos Flávio Ghizoni, MD, MSc

Department of Neurosurgery, Southern University of Santa Catarina [Unisul], Avenida José Acácio Moreira, Tubarão, Brazil

For injuries of the radial nerve caused by a closed humeral fracture, direct interventions for palsy reconstruction consist of either neurolysis if the nerve is continuous with no evidence of any macroscopic lesion or a nerve graft if the nerve is either ruptured or visibly damaged.¹¹ The urgency of surgery is determined by evidence that early nerve grafts yield better results.²² If, on the one hand, early nerve grafts provide better results, on the other hand, full spontaneous recovery is quite common with radial nerve lesions.¹⁵ This makes the decision about when to operate very difficult.

Following current guidelines for the management of radial nerve palsies after a humeral fracture,²⁰ Korompilias et al.¹⁴ operated on 12 of 25 patients who had failed to recover within 4 months of the injury. The investigators identified a nerve lesion in only 2 of these 12 patients; the remaining 10 patients underwent neurolysis exclusively and progressed to full recovery. Neurolysis is known to accelerate recovery in nerves that ultimately would spontaneously recover.⁵ However, there is no clinical or experimental evidence that a lesion with the potential for spontaneous recovery would fail to do so without neurolysis. Consequently, it is possible that these 10 patients reported by Korompilias et al.¹⁴ (80% of their cases) underwent unnecessary surgery.

In grafted proximal injuries of the radial nerve, as reported here, the results tend to be acceptable in fewer than half of patients. Provided that the delay between injury and tendon or distal nerve transfer surgery is less critical than with nerve grafting, and that tendon and nerve transfers ensure equal to better results than nerve grafts, the urgency to operate earlier cannot be overstressed.

Closed nerve injuries that are associated with axonal loss while the connective tissue layers are preserved tend to recover spontaneously within weeks to months of trauma, and are classified as an axonotmetic type of nerve lesion.⁸ Experimentally, the time to nerve recovery depends on the extent of the nerve affected by the axonotmetic lesion. For instance, after a localized crush injury of the median nerve, rats initiate recovery by Day 8.⁴ However, when the crush injury is accompanied by a segmental stretch injury, recovery begins on Day 12.¹⁶ When radial nerve palsy is associated with high-energy trauma (e.g., a motorcycle accident), an extended lesion of the radial nerve is to be expected, so that the delay before spontaneous recovery should be longer. Based on the fact that spontaneous recovery of a stretched radial nerve may take longer, and that viable alternatives for reconstruction via later surgery are available, we now wait at least 6 months before operating on a closed injury of the radial nerve. In addition, we believe that electrophysiological studies are of limited value as a screening tool for spontaneous recovery. For instance, Bumbasirević et al.⁷ observed that 8 of 14 patients with a radial nerve palsy who exhibited no electromyographic evidence of recovery 4 months after

injury ultimately progressed to full recovery. The scenario is different if other nerves besides the radial nerve are affected, because extended lesions with nerve ruptures are to be expected, as observed in our study.

Although our patients had different types of radial nerve palsy, some with and some without triceps palsy, the homogeneity of our sample stems from the radial nerve's proximal stump lying proximally to the humerus in all cases. Hence, it was far from both the wrist and finger extensor motor endplates. Ours is a small series, but proximal lesions of the radial nerve are rare and have rarely been reported. Pan et al.¹⁸ reported the largest series (39 patients), but failed to distinguish between M3 and M4 levels of recovery. There is general agreement that radial nerve grafting is associated with good results. However, many surgeons report wrist extension scoring M3 as a good result.^{13,19} Conversely, we consider nothing less than M4-level wrist extension strength to be a good result, because less than M4 is associated with a weakened grasp. Of interest is that approaches other than nerve grafting—like tendon or nerve transfer—can consistently yield M4 wrist extension recovery.^{6,9,10,17}

Among our 13 patients, 5 had adequate results (i.e., wrist extension scoring M4 and thumb and finger extension scoring M3 or M4), with elbow extension being predictably restored after radial nerve grafting. Based on these results, we have changed our practices. For proximal radial nerve injuries, we no longer consider nerve grafting as a single procedure. For uncomplicated lesions, the radial nerve can be explored and grafted, accompanied by a tendon or nerve transfer for wrist extension. In more severe lesions, in which surgical dissection of the brachial plexus might be complicated, if the triceps is paralyzed and the latissimus dorsi is functioning, we have preferred to transfer the thoracodorsal nerve directly to the triceps medial and long head motor branches. This yielded M4 elbow extension recovery in 7 of 8 patients with a high radial nerve injury.²¹

Alternatively, the nerve to the brachialis muscle might be used as a donor for transfer.² Concerning orthopedic procedures, elbow extension is most commonly reconstructed by means of posterior deltoid or biceps muscle transfer to the triceps.¹² Contrary to the results for reconstruction of wrist and finger extension, muscle transfers for elbow extension reconstruction rarely yield recovery to an M4 level of strength. In extended lesions of the radial nerve or posterior cord, as reported herein, the posterior deltoid muscle might be paralyzed and unsuitable for transfer. Alternatively, the biceps might be transferred to the triceps. However, because of the radial nerve lesion, the supinator muscle is paralyzed; if the biceps is used for transfer, supination will be lost.

For wrist extension reconstruction, our preference is to transfer the pronator quadratus motor branch to the extensor carpi radialis brevis (ECRB) motor branch.⁴ This was associated with M4-level recovery in 23 of our 24 patients with C5–8 brachial plexus palsy, and with M4 in all 7 of our patients with a radial nerve palsy.³ With radial nerve or posterior cord palsies, as opposed to lesions of the brachial plexus, the pronator quadratus motor branch is fully functional, which ensures a better outcome.

Thumb and finger extension reconstruction is still a matter of debate within our department. Flexor carpi radialis (FCR) motor branch transfer to the posterior interosseous nerve (PIN) produced less than ideal results in 8 patients with isolated radial nerve injuries followed for an average of 11 months postoperatively (M0 in 2, M3 in 4, M4 in 2). All patients scoring M3 flexed their wrist to 20° for full finger extension, denoting weakness of thumb and finger extensors (our unpublished observations). However, these are preliminary results warranting further evaluation. Alternatively, for finger extension reconstruction, the FCU tendon might be used for transfer. If performed at the same time as the nerve repair, this provides not only immediate thumb and finger extension reconstruction, but also some wrist extension.¹¹ If the radial nerve is grafted or not explored, thereby allowing for spontaneous reinnervation of the EDC and EPL, previous tendon transfers do not preclude full thumb and finger extension.

The drawback of tendon transfers is the need for some wrist flexion for thumb and finger extension, with full thumb/finger and wrist extension not possible. Moreover, independent motion of the fingers and thumb is impossible; however, this is also difficult to achieve following nerve transfers to the PIN.¹ It is possible that the best results for nerve transfer for thumb and finger extension reconstruction supplant those for tendon transfers. However, for radial nerve palsies, in our experience, tendon transfers are more predictable for thumb and finger extension reconstruction. An important issue with distal nerve transfers for thumb and finger extension reconstruction is that the PIN is divided, eliminating any potential reinnervation stemming either from spontaneous recovery or from a grafted radial nerve. This dilemma is absent with distal nerve transfers for wrist extension reconstruction because only the ECRB is targeted; therefore, the extensor carpi radialis longus (ECRL) remains available for reinnervation by axons travelling along the radial nerve.

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