Wide Resection of Traction Induced Radial Nerve Injury with Cable Grafting Leads to Full Recovery

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Abstract The specific clinical setting of high-energy open humerus fractures combined with radial nerve transection has typically led to poor final outcomes with respect to recovery of nerve function. Attention has focused on the issue of an expanded zone of nerve injury induced by longitudinal traction. The fundamental principle of nerve grafting is to bypass the zone of injury. If direct repair or short nerve grafts are placed within the zone of injury, limited recovery should be expected, and this is exactly what has been documented. Wide resection of the zone of traction induced injury, particularly from the distal injured nerve trunk and replacement with long cable grafts has the potential for improved outcomes. Complete nerve recovery to 5/5 manual motor power testing and bilaterally equivalent grip strength is reported in two initial cases treated according to the wide resection plan.

Keywords Radial nerve graft · Humerus fracture

Introduction

Most radial nerve palsies associated with humerus fractures resolve without surgery. The specific setting of a high-energy mechanism of injury and an open humerus fracture appears to confer a much more ominous prognosis for recovery of the radial nerve. No recovery was seen following surgical repair in 6/6 patients. [6] Longitudinal traction injury to the nerve was targeted as the responsible

factor with an emphasis on the need for longer cable nerve grafts. Cable nerve grafting for radial nerve transections in general has demonstrated only around a 50% rate of good motor recovery [1, 3, 5, 7]. Identifying traction induced injury to nerve tissue when planning cable nerve grafting is problematic, in particular, the decision of where to place the junction between the cable nerve grafts and the distal injured nerve trunk. The axonal growth cone is not expected to propagate well through injured tissue, but resection of additional potentially damaged nerve tissue mandates the use of greater lengths of cable nerve graft. There is conflicting data regarding the effect of increased length of nerve graft on final outcome [2, 5, 7]. This report concerns two cases that match the specific scenario of a high-energy mechanism of injury with open humerus fracture and complete nerve transection reported on in the other six patients [6]. A specific strategy designed to account for traction induced injury was employed that included significant lengths of cable nerve graft, and resulted in complete motor recovery to strength levels matching the contralateral side.

Case Reports

Case #1

The patient was a 27-year-old male involved in a high-speed rollover truck accident with multiple orthopedic trauma injuries including pelvic and lower extremity long bone fractures as well as a right open humerus fracture treated by debridement and intramedullary nailing (Table 1). He was sent for microsurgical consultation during the third month following injury. Clinical examination and electrodiagnostic studies confirmed complete radial nerve palsy.

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Figure 1 Patient number one demonstrates full-range simultaneous wrist and digital extension. There is no radial deviation with wrist extension.

Surgical exploration at 12 weeks from injury revealed widely separated proximal and distal nerve stumps at 25 cm proximal to the lateral epicondyle. A purely lateral exposure was used that required deep dissection posteriorly with deltoid retraction to expose the proximal stump. A medial axillary exposure was not needed. The proximal stump was trimmed under the microscope to the appearance of healthy fascicles. The distal stump was palpated moving toward the defect with microsurgical forceps for the point at which the consistency of the distal injured nerve trunk became more rigid. The distal stump was transected at this point leaving an 11-cm defect grafted by three sural nerve cables. The patient began to demonstrate initial contractions of the radial wrist extensors at 40 weeks postoperatively, and progressively added motor functions until by 62 weeks from surgery he tested to manual resistance in all groups on the Medical Research Council scale at 5/5 through a full range of motion (Fig. 1). Grip strength on the Jamar dynamometer was 40 kg right, 44 kg left. He was still being followed up by his orthopedic team for a humeral nonunion that persisted at 2 years postinjury. The microsurgical team was then asked to reconstruct the nonunion, and with a long

plate and bone graft achieved a fully healed humerus in 8 weeks. There was no decrement in radial nerve function as a result of that subsequent intervention.

Case #2

The patient was an 11-year-old male involved in a crash during a motocross ramp jump sustaining an open right humerus fracture that was debrided, reduced, and treated with a Sarmiento splint (Table 1). He was sent for microsurgical consultation at 4 months after injury. Clinical examination and electrodiagnostic studies confirmed complete radial nerve palsy. Surgical exploration at 19 weeks from injury revealed widely separated proximal and distal nerve stumps at 18 cm proximal to the lateral epicondyle. A purely lateral exposure was used that required deep dissection posteriorly with deltoid retraction to expose the proximal stump. A medial axillary exposure was not needed. The proximal stump was trimmed under the microscope to the appearance of healthy fascicles. The distal stump was palpated moving toward the defect with microsurgical forceps for the point at which the consistency of the distal injured nerve trunk became more rigid. The distal stump was transected at this point leaving an 8-cm defect grafted by three sural nerve cables. The patient began to demonstrate initial contractions of the radial wrist extensors at 24 weeks postoperatively, and progressively added motor functions until by 31 weeks from surgery he tested to manual resistance in all groups on the Medical Research Council scale at 5/5 through a full range of motion (Fig. 2). Grip strength on the Jamar dynamometer was 26 kg right, 25 kg left.

Discussion

In 2004, Ring et al. [6] published an article on radial nerve palsy associated with high energy humeral shaft fractures. They identified six patients with open humerus fractures, transected radial nerves, and an average age of 27 years old.

Table 1 Patient data.

	Case #1	Case #2
Mechanism of injury	Rollover motor vehicle accident	Motocross ramp jump
Age, gender	27 years old, male	11 years old, male
Open humerus fracture treatment	Intramedullary rod	Debridement – Sarmiento splint
Date of surgery vs. injury	12 weeks	19 weeks
Transection site proximal to lateral epicondyle reference	25 cm	18 cm
Length of cable nerve grafts	11 cm	8 cm
Weeks to achieve maximum motor recovery	62 weeks	31 weeks
Medical Research Council Scale for manual testing of motor recovery	MRC 5/5	MRC 5/5
Grip strength by Jamar vs. contralateral	40/44 kg	26/25 kg

Figure 2 Patient number two demonstrates full-range simultaneous wrist and digital extension. There is no radial deviation with wrist extension.

Five of the six nerves were surgically repaired; none of the six achieved any recovery of nerve function. The authors pointed to an expanded zone of nerve injury induced by longitudinal traction at the surgical nerve junctions as responsible for the lack of recovery. Generalizing from the specific scenario of open humerus fractures to radial nerve injuries as a whole, results have not been outstanding. In a 10-year review from Duke University, Nunley identified 20 radial nerve injuries treated surgically (13 high, 7 at the posterior interosseous nerve level) and found only a 44% overall recovery to M4, primarily contributed to by the more distal injury sites [5]. No differences were noted based on length of the nerve graft. The average grip strength compared to contralateral was 60%. Grip strength represents an excellent measure of radial nerve recovery as the digital flexors cannot generate power in the absence of the stabilizing force provided by the synergistic wrist extensors and, to a lesser degree, the antagonist digital extensors. Three other series of radial nerve grafting in general found useful motor recovery in 38.1%, 57%, and 50% of cases [1, 3, 7]. There are conflicting data regarding the effect of increased length of nerve graft on final outcome. In contrast to the Duke series, two other reports have found better results with shorter nerve grafts, identifying 10 cm as a breakpoint in the data [2, 7]. Whether this is an independent variable or a dependent variable is not clear. One of the most recent 10-year reviews of autologous nerve grafting of upper extremity sites in general found results to be “good” in only 7%, “fair” in 27%, and “bad” in 66%. [4] If the prognosis for recovery by cable nerve grafting in a specific case of radial nerve injury is considered exceedingly poor, a shorter to time to reinnervation can be achieved by nerve transfer of select branches of the median to specific motor branches of the

radial and posterior interosseous nerves [8]. The more traditional reconstructive option that can be performed even later is tendon transfer.

In the specific scenario of radial nerve transection associated with high-energy open humerus fractures, Ring and Jupiter’s assessment of a wide traction induced zone of nerve injury is a reasonable one to accept. The shoulder girdle is the stable reference point compared to which the arm is mobile. As the humerus fractures, it is the distal humeral fragment attached to the mobile arm that is most likely to injure the nerve. The portion of the nerve most likely to be stretched is the segment distal to point of transection rather than the proximal segment. When the patient comes to surgery later and the neuroma and glioma are resected under the microscope, the surgeon is afforded the opportunity to view a nerve stump with viable axons and fascicular turgor in the proximal segment. This is not the case in the distal segment following Wallerian degeneration. Most of the existing techniques for assessing nerve stumps have the distinction of motor from sensory axons as their goal, and are applicable to the proximal stump only. No criteria under frozen section histology of the distal stump have been accepted as a standard that can ensure a favorable endoneurial environment for propagation of the axonal growth cone. The assumption used in the treatment of these patients was that scar tissue blocking the endoneurial tubes following traction induced injury would be palpably firmer than the uninjured segment of the distal nerve using microsurgical forceps. When assessing from distal toward the point of transection, the distal nerve graft junction was selected to occur at the location of palpable change, intentionally resecting the remainder of the distal nerve segment and replacing it with cable nerve graft.

This introduces the question of whether there is a specific advantage or disadvantage for the growth cone to be propagating through the distal segment of an injured nerve trunk vs. cable nerve graft for each centimeter that it must travel. One difference is that the distal nerve trunk retains its original segmental blood supply whereas cable nerve graft must revascularize. The revascularization process is rapid and not necessarily a disadvantage for cable nerve grafts. There is a fundamental difference in the architecture of a trunk vs. multiple cables, but it is uncertain whether this confers an advantage one way or the other. The time clock for endoneurial stenosis has started earlier for the distal injured nerve trunk than for the cable nerve grafts by however many months the patient underwent surgery following initial injury. At this point, it remains unknown if there is an advantage to pursuing a wide resection of traction induced injury to the distal nerve segment specifically in high-energy open humerus fractures associated radial nerve transection. The results seen in these two cases compared to Ring and Jupiter’s six cases will

need to be expanded upon with additional data before this subject can be clarified.

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