CLINICAL DECISION MAKING AND DIFFERENTIAL DIAGNOSIS IN A CYCLIST WITH UPPER QUARTER PAIN, NUMBNESS, AND WEAKNESS: A CASE REPORT

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ABSTRACT

Background and Purpose: Differentiating between cervical nerve root and peripheral nerve injuries can be challenging. A phenomenon known as double crush syndrome may increase the susceptibility to injury and symptoms at other locations along the course of the nerve. The purpose of this case report is to describe the physical therapy differential diagnosis and management of a cyclist with upper extremity pain, weakness, and paresthesia.

Case Description: The subject was referred to physical therapy with a diagnosis of cervical disc disease. His chief complaints were chronic neck and right shoulder pain as well as a recent onset of right hand numbness and weakness following 100-mile bike ride one month prior. Diagnostic imaging revealed multi-level degenerative changes of the cervical spine. Initial electromyography and nerve conduction studies (EMG/NCS) indicated right ulnar neuropathy at the elbow. The ultimate incorporation of ulnar nerve mobilizations in various positions immediately decreased symptoms. In light of the subject's improvement after ulnar nerve mobilizations, imaging findings, and EMG/NCS findings, the subject's presentation was consistent with a double crush syndrome with C8 nerve root compression and distal ulnar nerve compression at the elbow.

Outcomes: The subject demonstrated full resolution of all symptoms, 0% disability on the Neck Disability Index, 8.3% disability of the Disabilities of the Arm, Shoulder, and Hand questionnaire, normal EMG/NCV findings, and unrestricted return to work and endurance cycling at three months and maintained at one year. He did not require hand surgery.

Discussion: This case report highlights the importance of continual clinical re-examination and re-assessment with ancillary diagnostic testing, especially if chosen interventions are not eliciting desired responses. The identification of key risk factors, such as occupation and recreational activities is imperative in achieving the most efficacious clinical treatment. In this case, the recognition of a double crush syndrome assisted in optimizing the physical therapy plan of care and the subject ultimately achieving full recovery.

Level of evidence: Level 4

Key words: Double crush syndrome, nerve root, radiculopathy, ulnar nerve upper limb tension

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BACKGROUND AND PURPOSE

The peripheral nervous system is composed of a continuum of dynamic neural structures that must withstand a variety of mechanical actions and physiological adaptations to facilitate normal mobility among and across joints, muscles, and connective tissues.¹ Neurodynamics, first described in 1995 by Shacklock et al,² broadly encompasses these interdependent mechanical and physiological changes that occur with both normal and pathological processes related to nerve elongation, angulation, compression, and sliding, as well as local histological and vascular responses that may occur.^{1,2} Peripheral nerve compression and entrapment commonly presents clinically with sensory deficits within the affected nerve distribution, followed by muscle weakness.^{3,4} Additionally, pain at the entrapment site is not uncommon.³ Neurophysiologic abnormalities can be detected using electromyography and nerve conduction studies (EMG/NCS), however diagnostic testing alone is not sufficient in diagnosis of peripheral neuropathies and often is limited in detecting acute neural changes or mild radiculopathy.⁵ In the upper extremity, compression of the median nerve at the wrist is the most common site of entrapment affecting approximately 1-7% of the general population.⁶⁻⁸ Ulnar nerve entrapment most commonly occurs at the cubital tunnel at the elbow, whereas radial nerve compression is extremely rare.^{4,9}

In addition to peripheral mononeuropathies, Upton and McComas¹⁰ introduced the concept of a condition called double crush syndrome, and proposed that neural impairments at a more proximal location increase the susceptibility to injury and symptoms at more distal locations along the course of the nerve due to impaired axial flow. It has also been hypothesized that a distal site of compression could make the more proximal nerve susceptible to secondary compression, described as a reverse double crush syndrome.¹¹ With the potential to occur at points anywhere along the course of the nerve, one must consider the presence of double crush syndrome in relation to evaluation of patients with diagnoses of cervical radiculopathies and upper extremity neuropathies. One must be aware of the variability in explanations for the mechanisms associated with double crush syndrome. In 2011, a Delphi study by Schmid et al¹² explored the views of experts in the field and

concluded that a consensus agreement has not yet been reached regarding the mechanisms leading to double crush syndrome. Although compression of the ulnar nerve at Guyon's canal among cyclists is well documented, cyclists with clinical diagnoses of ulnar neuropathy may also present with proximal dysfunction suggesting an increased prevalence of double crush syndrome in this population.^{13,14}

Upper extremity pain, numbness, and weakness can be challenging to treat due to many possible diagnoses and sources of tissue involvement. Careful history taking and clinical examination is essential to understanding the site of compromise in order to properly treat the underlying cause.¹⁵ Neuroimaging and neurophysiological studies are often used to confirm or refute a clinical diagnosis once established, however, are not always needed in treatment of upper quarter neurological symptoms.¹⁶⁻¹⁸ The purpose of this case report is to describe the physical therapy differential diagnosis and management of a cyclist with upper extremity pain, weakness, and paresthesia.

CASE DESCRIPTION: SUBJECT HISTORY AND SYSTEMS REVIEW (FIGURE 1)

The subject was a right-handed 54-year-old Caucasian male referred to an outpatient, sports focused physical therapy clinic. He had a medical diagnosis of cervical disc disease and a referral with specific instructions for use of cervical traction. He was a practicing dentist and an avid recreational road cyclist, riding approximately 100-200 miles weekly. He also participated in weight training with a personal trainer twice a week.

The subject consented to physical therapy treatment. He presented with a chronic history of right cervicothoracic paraspinal pain, right periscapular pain, and associated muscle tightness in these regions. These complaints had intensified approximately four weeks prior, following an unremarkable 100-mile bike ride. In addition to an exacerbation of these preexisting symptoms, the subject also complained of a concurrent, novel onset of right hand numbness on the dorsal and palmar surfaces of his right fifth digit and medial one-half of his right fourth digit. The subject described these distal symptoms as constant and unchanging regardless of activity or

Figure 1. Time Line from initiation of symptoms to one-year follow-up.

position, and unaccompanied by pain. Additionally, he complained of intermittent, self-described “zings” at the posteromedial aspect of his right elbow, which occurred occasionally with sneezing, but otherwise was unrelated to any activity and not reproducible, despite many attempts per his account. Subsequently, the subject became increasingly concerned secondary to decreased grip strength and difficulty manipulating instruments during his work as a dentist and when donning socks. Since the initial 100-mile bike ride, further cycling and weight-training activities had not affected his current complaints, but he had ceased participation on the recommendation of his physician. The subject continued to work as a dentist, but cited increased difficulty secondary to decreased strength in his right hand. Finally, the subject reported a long-standing history of bilateral hand and finger osteoarthritis.

Treatment over the four weeks prior to the initiation of physical therapy included massage therapy and chiropractic treatments, which had reduced his right sided cervical and thoracic pain, but had no effect on his right hand and elbow symptoms. He reported a long history (over several years and at varying frequencies) of massage and chiropractic treatment for his cervical and thoracic complaints focusing on cervical adjustments and massage. The subject's goals were to eliminate his hand numbness and weakness so he could perform his job duties as a dentist, return to cycling, and perform weight training exercises without restriction.

A review of systems revealed no complaints of constitutional symptoms, changes in bowel or bladder habits, weight fluctuations, or changes in appetite.

The subject was an otherwise healthy adult male with a significant medical history of osteoarthritis in bilateral hands, which he managed with over the counter nonsteroidal anti-inflammatory drugs (NSAIDs) to decrease pain in the evenings. He was currently taking ibuprofen 400-800mg as needed. He denied any preexisting numbness and/or tingling, deficits in hand strength, or difficulty performing work duties prior to the present complaints.

Diagnostic Testing

Prior to his initial physical therapy examination, the subject had obtained radiographs (Figure 2) and magnetic resonance imaging (MRI) (Figure 3) of his cervical spine ordered by his referring physician. The radiologist's reports of these tests indicated multilevel degenerative changes and bilateral neural foraminal narrowing C4-C5/C5-C6, as well as disc osteophytes at C5-6/C6-7. The subject was also referred to a hand surgeon who ordered EMG/NCS which was scheduled for one week following the initial physical therapy evaluation.

CLINICAL IMPRESSION #1

The subject's primary problem involved right upper extremity pain, paresthesia, and weakness which were affecting his activities of daily living, job duties, and athletic participation. Information gathered during the history and systems review led to a differential diagnosis of cervical nerve root radiculopathy versus distal ulnar nerve involvement. Review of EMG/NCS results was identified as potentially useful in assisting to clarify the potential pathology and tissue structures involved and thus the subject was asked to bring those results in for review once the

Figure 2. Frontal and sagittal plane cervical radiographs. The radiologist's official findings were disc space narrowing present at C3-4, C5-6, and C6-7, facet arthropathy and uncovertebral overgrowth present at C4-C5 and C5-C6 bilaterally, as well as bilateral neural foraminal narrowing.

Figure 3. Sagittal T2 weight Magnetic Resonance Image (MRI) without contrast. The radiologist's official findings from the MRI were C3-C4 uncovertebral joint hypertrophy and facet arthropathy with resultant mild bi-foraminal stenosis, C4-5 evidence of mild right neural foraminal stenosis, C5-6 a broad disc-osteophyte complex with resultant mild degree of central canal stenosis with no cord compression, C6-7 a broad disc-osteophyte complex with resultant mild central canal stenosis with no compression, C7-T1 no significant disc protrusion evident.

testing had been completed. Planning for the examination, included standard cervical clearing tests, basic range of motion, strength (myotomal), and sensation (dermatomal) assessments for the cervical spine would be performed. In addition, the test item cluster for cervical radiculopathy and Upper Limb Neural Tensioning Testing would be performed to discern the likelihood of cervical radiculopathy versus peripheral nerve involvement.¹⁹ Understanding the differential diagnosis of these conditions is essential in identifying the best treatment options and plan of care. This is particularly important with at risk populations for cervical radiculopathy and/or peripheral neuropathy such as dentists and cyclists.^{13,14,20-22}

EXAMINATION #1 (TABLES 1 AND 2)

Upon observation, the subject presented with increased kyphosis in the upper and mid thoracic spine and a forward head posture. Gross observation and examination of the cervical spine revealed decreased active end range of motion (ROM) with cervical flexion and right cervical rotation (due to time constraints goniometric or inclinometer measurements were not performed). For cervical flexion, the subject was unable to touch his chin to his chest, but this was not limited by pain nor did it

Table 1. Patient Reported Outcomes			
Measurement	Initial Visit	Visit 8	Visits 12 & 13
Global Rating of Function	Question not asked	85%	95%
Perception of Right Hand Numbness	Constant	90% reduced	100% reduced
NDI	12%	Not Administered	0%
DASH	Not Administered	Not Administered	8.3%
NDI = Neck Disability Index DASH = Disabilities of the Arm, Shoulder and Hand			

elicit pain. However, end-range right cervical rotation resulted in provocation of his elbow symptoms. Active shoulder and elbow ROM were within normal limits and produced no changes in symptoms with over pressure in all planes of range of motion. Testing of cervical joint mobility revealed hypomobility with both side-glide and posterior to anterior joint mobilizations of C3-C7. Further examination revealed increased tone of the right upper and middle trapezius, rhomboids and sub-occipital muscles with myofascial restrictions that were palpable and regions of sensitive muscle spasms. Palpation and observation revealed mild atrophy at the right hypothenar eminence as compared to the left.

An upper quarter neurologic screen was performed.²³ Examination of sensation and neurovascular integrity indicated decreased sensation to light touch at the dorsal and palmar surfaces of the right fifth digit, medial one-half of the right fourth digit, and hypothenar eminence, consistent with the ulnar nerve distribution. Right upper extremity sensation, distal perfusion, and radial pulse were otherwise intact with no apparent temperature or integumentary changes. Strength testing of the cervical spine, shoulder, elbow and wrist demonstrated strong (5/5) and painless contractions. However, strength testing of the right hand intrinsic muscles indicated decreased strength with abduction and adduction of the 4th and 5th digits and decreased right thumb abduction, all rated 3/5. Deficits in right hand grip strength were measured with the use of a hand dynamometer with the upper extremity in 0 degrees shoulder abduction/flexion and 90 degrees elbow flexion with three trial averages of 23.6 kg on the left and 20.3 kg with the right hand (Table 2). These scores were classified as weak bilaterally.²⁴

The following clearing and provocation tests were performed with unremarkable results: vertebral

artery testing for vertebral artery insufficiency [Sensitivity: 0.00 to 0.31; Specificity: 0.39 to 0.86; + Likelihood Ratio: 0.00 to 0.59; -Likelihood Ratio: 1.16 to 2.30],^{25,26} axial cervical compression,^{19,27} cervical quadrant testing ("Spurling Test") [Kappa: 0.40 to 0.77; Sensitivity: 0.40 to 0.60; Specificity: 0.86 to 1.0; + Likelihood Ratio: 3.5; -Likelihood Ratio: 0.58],^{19,28} cervical distraction [Kappa: 0.50 to 0.88; Sensitivity: 0.40 to 0.50; Specificity: 0.86 to 1.0; + Likelihood Ratio: 4.4; -Likelihood Ratio: 0.62],^{19,27,28} and Adson's test [Specificity: 0.18 to .087; Sensitivity: 0.94; Positive Predictive Value: 0.85; Negative Predictive Value: 0.72].^{13,29} Performance of Roos test for thoracic outlet syndrome [Sensitivity: 0.84; Specificity: 0.30; Positive Predictive Value: 0.68; Negative Predictive Value: 0.50]^{13,29} was negative for changes in sensation or provocation of symptoms, but continued performance resulted in decreased ability to actively extend and open and close his right hand when compared to his left. The subject had a negative Hoffmann's sign [Sensitivity: 0.58; Specificity: 0.78].^{28,30} Testing of ulnar, radial, and median nerves utilizing Tinel's sign [Sensitivity: 0.50; Specificity: 0.77] at the elbow and wrist (Guyon's canal and Carpal tunnel) failed to produce symptoms.^{27,31} Passive Upper Limb Neural Tensioning Testing for median nerve (Upper Limb Tension Test A or ULTT-A) [Kappa: 0.54 to 0.76; Sensitivity: 0.97; Specificity: 0.22]^{19,32} and for ulnar nerve (Ulnar Upper Limb Tension Test or Ulnar ULTT) [Kappa: 0.36]³² failed to elicit symptoms as well (Table 2).³³ At this point the subject did not demonstrate any positive tests for the test item cluster for cervical radiculopathy.¹⁹

The subject was initially administered the Neck Disability Index (NDI) by the clinic's front desk personnel as his referral indicated a cervical problem. Depending upon the associated neck condition, the NDI has adequate to high ICC values (ICC: 0.50 to 0.96),^{34,35} Minimally clinically important difference

Table 2. Clinical Examination Findings						
Measurement	Initial Visit		Visit 8		Visits 12 & 13	
Cervical Testing						
	Right	Left	Right	Left	Right	Left
Vertebral Artery Insufficiency Testing	Negative	Negative	NT	NT	NT	NT
Right Cervical Rotation	Reproduction of right elbow pain		Pain Free		Pain Free	
Cervical Compression	N		N		N	
Cervical Distraction	N		N		N	
Spurling Test	N		N		N	
Thoracic Outlet Testing and Neurologic Testing						
Adson's Test	Negative	Negative	NT	NT	NT	NT
Roos Test	Negative*	Negative	NT	NT	NT	NT
Light Touch Sensation	P [†]	WNL	P [†]	WNL	WNL	WNL
ULNTT	WNL	WNL	WNL	WNL	WNL	WNL
Ulnar	WNL	WNL	P [‡]	WNL	WNL	WNL
Radial	WNL	WNL	WNL	WNL	WNL	WNL
Media	WNL	WNL	WNL	WNL	WNL	WNL
Tinel's Sign	N	N	NT	NT	NT	NT
Hoffman's Sign	N	N	NT	NT	NT	NT
Strength Testing						
Finger abduction/adduction (MMT)	3/5	5/5	4/5	5/5	4/5	5/5
Thumb abduction strength (MMT)	3/5	5/5	4/5	5/5	4/5	5/5
Grip Strength (kg)	20.3	23.6	NT	NT	NT	NT
P = Positive N = Negative NT = Not Tested WNL = Within Normal Limits ULNTT = Upper Limb Neural Tensioning Testing *Reported decreased ability to actively extend and open and close his right hand when compared to his left †Decreased sensation to light touch at the dorsal and palmar surfaces of the right fifth digit, medial one-half of the right fourth digit in ulnar nerve distribution ‡Reproduction of UE symptoms.						

has been reported from 3.5 to 8.5 points,^{36,37} and minimal detectable change from 8.4 to 13.4 points.^{37,38} The subject's NDI score was 6 points (12%) indicating minimal disability related to his neck (Table 1).

CLINICAL IMPRESSION #2

The clinical examination did not confirm the presence of cervical radiculopathy or peripheral nerve involvement. Additional clinical examination led to a working diagnosis of decreased lower cervical spine mobility and poor cervical and upper extremity postural control and awareness with consideration of potential of cervical nerve root radiculopathy and secondary distal ulnar nerve involvement. However, the likelihood of cervical radiculopathy could be ruled out with 97% confidence secondary to a negative finding on the ULTT-A test of the cervical radiculopathy test item cluster.¹⁹ The decision was made to initiate treatment focused on the primary impairments noted above focused on improving spinal mobility. However, the inconclusive clinical examination findings necessitated continual

re-examination and re-evaluation of subject symptoms throughout treatment. Evaluation of the EMG/NCS would provide potentially valuable information pertaining to the subject's symptoms and related interventions. The initial physical therapy sessions were planned for twice a week to focus on manual techniques and postural cueing with continual re-evaluation of symptoms and progress. In addition, formal testing of the periscapular muscles would be performed to further evaluate the potential impact of scapular and postural control on the subject's symptoms. Formal re-evaluation of initial testing procedures was planned after four weeks of treatment.

INTERVENTION

Initial Plan of Care and Physical Therapy Interventions (Table 3)

Visits 1-4

The discussion of the interventions from visits 1-4 in this case report are to provide a global perspective of the subject's overall treatment but are not the

Table 3. *Sequencing and Timeline of Selected Interventions*

Interventions	Visits 1-4	Visits 5-8	Visits 9-13
Postural Education	✓		
Strengthening Ex*	✓	✓	✓
Soft Tissue Mobilization †	✓	✓	
Mechanical Traction	✓		
Cervicothoracic Mobilization‡	✓	✓	
Ulnar Neural Mobilization		✓§	✓
Periscapular Neuromuscular Control Training¶			✓
Bike Fitting			✓
§ No changes or improvement in upper extremity symptoms were noted until visit 5 with the initiation of the ulnar nerve mobilizations. The subject reported substantial reduction of elbow symptoms following initiation of these techniques.			
* Strengthening exercises focused on the following: deep neck flexors (visits 1-4), periscapular musculature (visits 5-13), hand intrinsic (visits 9-13).			
† Soft tissue mobilization techniques used included deep pressure and myofascial trigger point release techniques focused on cervical paraspinals, right upper trapezius, right levator scapulae, right anterior scalene, and right rhomboids.			
‡ Mobilizations included C3-C6 side glides, manual cervical distraction, thoracic spine thrust, first rib mobilization.			
¶ Including prone non-weight bearing exercises progressing to weight bearing and upright exercises using unstable surface and resistance.			

primary focus of this case report (Table 3). Initial interventions (visits 1-4) primarily targeted restoration of normal, symmetrical cervicothoracic joint and soft tissue mobility for improved function with the goal of reducing both cervicothoracic pain and elbow/hand symptoms. More specifically, manual mobilization techniques were utilized and included side glide techniques (grades III and IV) to C3-C6, manual cervical distraction, thoracic spine thrust techniques and first rib mobilizations. Soft tissue mobilization was performed on the cervical paraspinals, right upper trapezius, levator scapulae, and rhomboids employing techniques focused on deep pressure and myofascial trigger point release. Basic scapular retraction and deep cervical flexor endurance exercises were utilized to address poor postural tendencies. In addition, the subject was also educated on postural control and awareness with emphasis on workplace ergonomics and positioning, as the subject reported an increase in symptoms on days in which he saw patients in a clinical setting. During this initial phase of treatment, the subject reported an improvement in periscapular discomfort; however, no change in his distal upper extremity symptoms were reported otherwise. In addition, secondary to several requests from the referring physician, mechanical traction was initiated on the third visit. No changes in symptoms resulted from the mechanical traction, so it was not continued.

Between the second and third physical therapy sessions the EMG/NCS were performed as previously ordered by the hand surgeon (Tables 4, 5, and 6). The testing physician's impression was an "abnormal study" with "findings and clinical picture [being] most consistent with a right mild axonal ulnar neuropathy at the elbow" with "no evidence of cervical radiculopathy." Following the EMG/NCS, the medical recommendation by the hand surgeon was for a nerve release at the elbow. However, the subject declined this intervention and opted to continue physical therapy. A follow-up EMG/NCS was scheduled approximately six weeks later.

Visits 5-8

Secondary to minimal changes in distal UE symptoms during visits 1-4, reassessment using the Ulnar ULTT was performed at visit 5.³⁹ At this point, repeated performance of this test reproduced symptoms at the elbow and hand in contrast to the subject's initial physical therapy visit. Based on the provocation with this testing at this time, ulnar nerve glides directed at neural mobilization and decreasing the mechanosensitivity of the ulnar nerve and surrounding tissues was initiated.^{33,40} Passive and active mobilization of the right ulnar nerve was performed at the point of symptom provocation and reduction, with the subject in supine. The shoulder was externally rotated and abducted to a point of symptom provocation. Nerve

Table 4. Electromyography Studies

Muscle	Nerve	Root	October 13 th							November 23 rd						
			Fibs	PSW	MUP	Insert	Spont	Poly	Recruit	Fibs	PSW	MUP	Insert	Spont	Poly	Recruit
1 st Dorsal	Ulnar	C8-T1	1+	1+	Nml	NR	NR	0	Dec	NR	NR	Nml	Nml	None	NR	Nml
Biceps	Musculocutaneous	C5-6	Nml	Nml	Nml	NR	NR	0	Nml	NR	NR	Nml	Nml	None	NR	Nml
Triceps	Radial	C6-7-8	Nml	Nml	Nml	NR	NR	0	Nml	NR	NR	Nml	Nml	None	NR	Nml
Pronator Teres	Median	C6-7	NR	NR	NR	NR	NR	NR	NR	NR	NR	Nml	Nml	None	NR	Nml
Deltoid	Axillary	C5-6	Nml	Nml	Nml	NR	NR	0	Nml	NR	NR	NR	NR	NR	NR	NR
Abductor Digiti Minimi	Ulnar	C8-T1	1+	1+	Nml	NR	NR	0	Dec	NR	NR	Nml	Nml	None	NR	Nml
Flexor Carpi Ulnaris	Ulnar	C8	Nml	Nml	Nml	NR	NR	0	Nml	NR	NR	Nml	Nml	None	NR	Nml
Extensor Indicis	Radial	C7-8	Nml	Nml	Nml	NR	NR	0	Nml	NR	NR	Nml	Nml	None	NR	Nml
Paraspinals	Rami	C3-T1	Nml	Nml	Nml	Nml	NR	0	NR	NR	NR	NR	Nml	None	NR	NR

Selected Electromyography study results from available physician reports dated on October 13th and November 23rd. Dec = Decreased; Insert = Insertional Activity; Fibs = Fibrillating Potentials; MUP = Motor Unit Potential; NR = Not reported; Nml = Normal; Poly = Polyphasic Potentials; PSW = Positive Sharp Waves; Recruit = Recruitment; Spont = Spontaneous Activity.

Examination Findings:

- **October 13th:** Electromyography of the right upper limb is significant only for 1+ positive sharp waves and fibrillations in the right ulnar innervated hand muscles.
- **November 23rd:** No abnormalities in any of the areas tested in the right upper limb and corresponding perispinal muscles with no evidence of cervical radiculopathy or brachial plexopathy. Normal EMG/NCS of the right upper limb. No evidence of ulnar or entrapment neuropathy.

Table 5. Nerve Conduction Studies - Motor

	Norm Onset (ms)	Norm Velocity (m/s)	October 13 th		November 23 rd	
			Onset (ms)	Velocity (m/s)	Onset (ms)	Velocity (m/s)
<i>Right Median Motor (APB)</i>						
Wrist	<4.3	>45	3.6	51.9	3.7	55
Elbow			8.6			
Elbow - Wrist						
<i>Right Ulnar Motor (ADM)</i>						
Wrist	<4.0	>53	2.7		2.6	
Below Elbow		>53	6.6			
Above Elbow			8.0			
Below Elbow – Wrist				53.8		60
Above Elbow – Below Elbow				64.3		61

ADM = Abductor Digiti Minimi; APB = Abductor Pollicis Brevis; Norm = Normative; ms = milliseconds; m/s = meters per second

Examination Findings:

- **October 13th:** The absence of focal slowing on nerve conduction studies suggest the absence of significant demyelination.
- **November 23rd:** Normal EMG/NCS of the right upper limb. No evidence of ulnar or entrapment neuropathy.

Table 6. Nerve Conduction Studies - Sensory Left/Right Comparison

	October 13 th				November 23 rd			
	Left Latency (ms)	Right Latency (ms)	Left Amplitude (μV)	Right Amplitude (μV)	Left Latency (ms)	Right Latency (ms)	Left Amplitude (μV)	Right Amplitude (μV)
<i>Dorsal Cutaneous Sensory</i>	3.5	3.3	43.0	22.0	NR	3.6	NR	20

ADM = Abductor Digiti Minimi; APB = Abductor Pollicis Brevis; Norm = Normative. Normative Sensory Amplitude = $\geq 20\mu V$; ms = milliseconds; m/s = meters per second; μV = microvolts; NR = Not reported

Examination Findings:

- **October 13th:** Normal radial, median, and ulnar sensory distal latencies are normal with normal amplitudes. Normal left ulnar sensory distal latency with normal amplitude. Normal left dorsal ulnar cutaneous distal latency with normal amplitude. Normal right dorsal ulnar cutaneous distal latency with relative decrease in amplitude compared to the left.
- **November 23rd:** The right median and ulnar nerve conduction studies within normal limits.

sliding was initiated with concomitant wrist extension and right cervical side-bending followed by wrist flexion and left cervical side-bending.¹² Repetitions were performed until the subject reported a decrease in elbow symptoms during this technique (Table 3). As symptoms at the elbow decreased, mobilization of the ulnar nerve was progressed by adding elbow flexion and extension. Elbow flexion occurred with wrist extension and right cervical side-bending, and elbow extension occurred with wrist flexion and left cervical side-bending. Repetitions were again performed until the subject reported a reduction in symptoms with this neural sliding technique. The subject was subsequently educated on independent performance of seated active right ulnar nerve mobilization techniques to be performed at home three to five times daily starting with wrist flexion/extension and cervical side bending as previously described. The subject was instructed to perform as many repetitions as were needed to reduce symptoms, up to 30 times in a row. At the conclusion of this treatment session, for the first time since his initial complaints of right elbow pain he reported a substantial decrease in complaints in right elbow symptoms with right cervical rotation.

Subsequent to the initiation of ulnar nerve mobilization in the clinic and instruction on performance of active ulnar nerve mobilization techniques independently at home, the subject reported continued decrease in elbow symptoms and fluctuating symptoms within the ulnar distribution at his right hand, with periods of significant relief. Treatment continued to focus on ulnar nerve mobility across multiple joints of the neck and upper extremity, guided by provocation or alterations in symptoms. Ulnar nerve glides were progressed in sitting and performed with movement of the wrist, elbow, and shoulder at the same time as the cervical spine as previously described. The focus was movement that ultimately reduced symptoms. Additionally, as an adjunctive intervention, manual grade III and IV joint mobilization of the lower cervical spine, upper thoracic spine, and first rib were continued, focusing on improving joint mobility. At this time, the subject was instructed to continue the performance of ulnar nerve gliding techniques independently and observe any changes in his symptoms with plans to return to physical therapy in 12 days, following a vacation.

Upon return from vacation and reported diligent adherence to his home program, the subject reported a decrease in the frequency and intensity of his neurological symptoms, with distal numbness present approximately 10% of the time, rare occurrences of symptoms at the elbow, yet continued complaints of upper trapezius tightness. Reassessment after eight physical therapy visits over four weeks indicated improved right hand intrinsic strength, subject reported 85% improvement in right hand paresthesia and subjective improvements in grip strength at work as a dentist (Table 1). At the time of re-evaluation, the subject presented with improved symptoms, however, deficits in thoracic and cervical posture persisted. Formal testing of the lower trapezius and rhomboids revealed 4/5 strength with manual muscle testing (MMT).

CLINICAL IMPRESSION #3

Following continued clinical reassessment, symptom improvement following ulnar nerve mobilizations, and the MRI and EMG/NCS results, the diagnosis and assessment was modified to be suspicious of a double crush syndrome with C8 nerve root compression and distal ulnar nerve symptoms and compression at the elbow. Ulnar nerve mobilizations were the primary intervention and focus of treatment and were performed as symptoms continued to decrease. Following visit eight, the frequency of formal physical therapy treatment sessions was decreased secondary to subject improvement, independence with interventions, and the subject traveling.

INTERVENTION

Final Plan of Care and Physical Therapy Interventions (Table 3)

Visits 9-13

Although not the primary focus of this case report, in this final phase of treatment, physical therapy interventions concentrated on supportive activities focused on postural control, endurance, and return to prior level of function, specifically participation at work and return to cycling (Table 3). Visits 9-11 focused primarily on periscapular exercises to promote optimal posture, control, and muscular endurance for his activities of choice (e.g. dentistry and

endurance cycling). Prone bilateral upper extremity extension, abduction, and scaption were initially prescribed based on his periscapular MMT results and observed posture.^{41,42} The dosage and prescription of these interventions was focused on performance until fatigue or the loss of appropriate technique was demonstrated. Verbal, visual, and tactile cueing were used to promote appropriate technique as needed. As the subject was able to demonstrate appropriate control and endurance, neuromuscular re-education progressed through the use of increasing unstable surfaces and resisted neuromuscular control exercises to facilitate improved dynamic control and endurance.^{41,42} Between physical therapy sessions 11 and 12 follow-up EMG/NCS testing was ordered by the hand surgeon. The testing physician's impression at this time was "normal EMG/NCS of the right upper limb. No evidence of ulnar or other entrapment neuropathy seen today." No additional EMG/NCS were scheduled (Tables 4, 5, and 6).

On visit 12, the subject participated in a static bike fitting assessment by the primary treating physical therapist. This was conducted in order to evaluate his positioning on the bike to potentially decrease stress on the right ulnar nerve and address any faulty posture which may have contributed to his injury, prevent future injury, and to improve performance. It was determined that no specific changes to the bike were warranted during the fitting assessment. However, extensive education was performed during the session. This education was focused on improving the subject's awareness of his cervical, thoracic, and upper extremity positions in order to minimize sustained forward head posture, limit shoulder protraction, and optimize hand position throughout long rides.

In addition to physical therapy interventions, the subject had resumed participation in personal training sessions 2-3 times weekly and cycling on the weekends. He reported that he was currently free of all symptoms 95% of the time and was able to self-manage his symptoms when present through the performance of ulnar nerve mobilization techniques. He continued to receive regular chiropractic manipulations and massage, as he had done prior to this episode of symptoms, as he felt those treatments were helpful in managing his upper back and

neck tightness. The subject and therapist agreed that no need for skilled physical therapy intervention remained and that the subject was to return in three weeks for reassessment regarding any change in symptoms or presence of functional limitations. Upon follow-up (visit 13), the subject reported a full return to prior level of function with nearly complete resolution of symptoms.

OUTCOMES

Formal outcome measures were obtained at visits 8 and 13. At visit 8 (4 weeks of treatment) the subject reported that his hand numbness was reduced by 90%, he had 85% overall improvement, and no elbow pain. Objectively he had no elbow symptoms with end range right cervical rotation and increased finger abduction/adduction strength, now graded as a 4/5 with MMT. He also denied exacerbation of symptoms with the ulnar nerve tension test. At visit 13, the subject reported nearly complete resolution of all symptoms with only periodic hand numbness one to two times approximately every two weeks that resolved quickly with his nerve gliding techniques. Further, he had returned to full and unrestricted job duties and continuation of cycling. His follow-up EMG/NCS results indicated as "normal" with "no evidence of ulnar nerve involvement." During his last visit he scored 0% disability on the NDI and was also administered the Disabilities of the Arm, Shoulder, and Hand (DASH). Depending upon the upper extremity condition, the DASH has adequate to high ICC values (ICC: 0.54 to 0.99),^{43,44} minimally clinically important difference reported from 10 to 10.2 points,^{45,46} and minimal detectable change from 10 to 12.2 points.^{45,46} The subject reported 8.3% disability on the DASH which he attributed to his hand osteoarthritis. The lack of a baseline DASH score does limit the understanding regarding the magnitude of improvement related to this tool and in retrospect this questionnaire should have been administered sooner in the subject's care. However, considering the low level of disability recorded on the final treatment DASH score, the marked improvement in both the subject's self-reported symptoms and function, as well as the EMG/NCS results, the lack of baseline DASH score has minimal impact in understanding and appreciating the subject's overall outcomes and improvement. Finally, at a one-year follow-up the

subject reported no symptoms and continued work as a dentist as well as cycling.

DISCUSSION

In this case report, a subject with substantial risk factors for double crush syndrome including long distance road cycling and working full time as a dentist was described with a primary focus on illustrating his outcomes following ulnar nerve mobilizations. EMG/NCS confirmed the diagnosis of ulnar nerve entrapment at the elbow. Even though EMG/NCS was negative for cervical radiculopathy, MRI findings were indicative of multilevel cervical foraminal narrowing. However, narrowing at the C7-T1 segment was not shown via MRI. Further, although the subject did demonstrate decreased cervical rotation and flexion, he did not present with the a positive test item cluster (ULTT-A, distraction test, Spurling test) indicative of cervical radiculopathy.¹⁹ Notably, Wainner et al¹⁹ evaluated the diagnostic accuracy of cervical flexion and rotation range of motion related to cervical radiculopathy and showed that less than 55° of cervical flexion and less than 60° of involved cervical rotation had Sensitivity values of 0.89, Specificity values from 0.41 to 0.49 respectively, +Likelihood ratios of 1.5 to 1.8 respectively, and -Likelihood ratios from 0.27 to .023 respectively for potential cervical radiculopathy.¹⁹ Unfortunately, as previously noted due to time constraints, specific goniometric cervical range of motion measurements were not taken. However, the authors do not feel that the omission of goniometric measurements negatively impacted the initial treatment plan.

Initial interventions focused on improving cervical and thoracic mobility deficits while symptom provocation and improvement with the Ulnar ULTT did not present until visit five. By combining the results of the MRI and EMG/NCS findings and continual clinical re-examination and subject response to treatment (specifically ulnar nerve mobilization techniques) the final working diagnosis was double crush syndrome involving the C8 nerve root and ulnar nerve. In this case, it would seem highly likely that the subject's ulnar nerve was placed at increased risk of injury secondary to potential compression at the C8 nerve roots, which was only clinically apparent with end-range right cervical rotation. This potential low-level compression, which was able

to reproduce symptoms of elbow pain, may have increased the vulnerability and compromise of the ulnar nerve distally.

Entrapment of the peripheral nerves of the upper extremity is frequently associated with work related factors in specific occupations, especially those with increased forces, use of hand grips and vibratory tools, and the performance of repetitive manual tasks.^{47,48} Several authors have associated these and other such ergonomic factors with an increased risk of carpal tunnel syndrome and other repetitive motion disorders specifically in the field of dentistry.²⁰⁻²² For example, 9.2% of dentists reported receiving a medical diagnosis of a repetitive motion disorder with more than 40% of those resulting in shortened work hours.^{20,21} Further, ulnar neuropathy is also the most frequent upper extremity peripheral nerve injury to occur to cyclists due to compression at either the cubital tunnel or Guyon's canal, and is often termed "cyclist's palsy."^{13,14} For example, proximal dysfunction at the thoracic outlet has been demonstrated in up to 43% of cyclist with diagnosed distal ulnar neuropathy, suggesting that double crush syndrome was present.¹³

Discussion of clinical decision-making and interpretation of examination procedures

Continual clinical re-examination and reassessment during the initial sessions of physical therapy was a key factor in determining both the proximal and distal nerve involvement. First line testing for any complaints of upper extremity neuropathy should be an upper quarter neurologic screen including dermatomal and myotomal testing.²³ This testing found dermatomal changes and myotomal changes indicative of potentially both C8 nerve root and ulnar nerve compromise. Although cervical quadrant testing did not elicit symptoms, end-range right cervical rotation was found to reproduce symptoms at the subjects elbow, but not into the hand. Although imaging and EMG/NCS did not indicate a C8 nerve root compression nor radiculopathy it would seem plausible that the end-range right cervical rotation was able to compress the C8 nerve root enough to elicit clinical signs and symptoms. The subject did not have full cervical ROM, so mobility testing was performed to determine which levels of the cervical spine were causing the gross limitation in ROM. Palpation to

upper back and cervical musculature needed to be included to rule in/out trigger point referrals in the soft tissue, and although increased muscle tone and trigger points were established as subject impairments, these did not change the subject's distal UE symptoms.

Key to this subject case is the continual reassessment of the subject's progress. The limited progression at visit five led to the reassessment of neurodynamics. Even with a negative result with Upper Limb Neural Tension at initial evaluation, the Ulnar ULTT was repeated several times at visit five to ensure its exclusion of potential involvement. With repeated testing, the Ulnar ULTT was found to be positive for eliciting the subject's distal symptoms. At this point, the physical therapist was able to create a secondary working diagnosis and begin treatment on both proximal and distal upper quarter structures.

Analysis of initial interventions & outcomes

It has been well accepted that a subject's clinical presentation, in collaboration with electrodiagnostic tools such as EMG/NCS, provide reliable results to assist in the diagnosis of upper extremity neuropathies, however, evidence on treatment approaches are currently limited. A systematic review by Wong et al⁴⁹ found that 83% of subjects had nearly full resolution of symptoms with conservative treatment (e.g medication, heat, ultrasound, massage, traction, electrical stimulation, neck mobilization, collar use, postural rehabilitation, and progressive resistive exercises). Unfortunately, the decision making, dosage, sequencing, and other details regarding these interventions is not described further. It is suggested is suggested that conservative treatment should be attempted first for all subjects without central cord involvement; however, there is limited literature on treatment types.²³ The use of mechanical traction, manual therapy, and therapeutic exercise individually and in combination has been shown to improve functional outcomes in the short term in patients with cervical radiculopathies. However, even though these forms of interventions were initially used in the treatment of the subject of this case report their inclusion demonstrated minimal effect on improving the subject's symptoms. Treatment of isolated peripheral nerve entrapment often includes stretching, soft tissue mobilization, corrective exercises, and

neural mobilizations.^{50,51} Related to this case report, incorporation of neural mobilizations of the ulnar nerve demonstrated substantial changes in the subject's symptoms, function, and ultimate outcomes.

Evidence continues to support applying the knowledge of neurodynamics and investigating the role of neural mobilization as a treatment technique.^{33,40} A study of cadavers demonstrates that upper limb neural tensioning techniques increase tensions across the course of the nerve.⁴⁰ Similarly, additional neural mobilization techniques, often called nerve glides and nerve slides have been shown to cause changes in neural excursion without significant increases in tension.⁴⁰ Based on the treating physical therapist's clinical reasoning and the consideration of the acuity, mechanism of injury, and the response to treatment, applying a neural sliding technique was successful in the treatment of this subject's upper extremity neuropathy and the restoration of normal neurodynamics.

There is minimal evidence demonstrating optimal treatment techniques and intervention dosage for the subject of this case report. Thus, initially the treating physical therapist decided to treat impairments that were directly related to the subject's functional limitations. As a dentist, this subject inherently is required to be able to sustain prolonged periods of cervical flexion. Such sustained postured requires both adequate joint mobility and appropriate endurance of his deep cervical neck flexors muscles and cervical/thoracic extensor muscles. Joint mobilizations to both thoracic and cervical spine were performed to improve mobility and therefore cervical flexion range of motion, and deep neck flexor activation and strengthening interventions were performed to improve maintenance of neutral spine posture with prolonged positions. Scapular strengthening interventions were also aimed to improve subject's scapulothoracic mechanics, endurance, and posture both statically and dynamically. Future research should focus on identifying types of subjects or subgroups who are most likely to benefit from neural mobility interventions as well identifying the dose response to such interventions.

CONCLUSION

This case report presents a subject with strong risk factors and clinical signs and symptoms suspect of a

double crush phenomenon to his C8 nerve root and ulnar nerve. The subject made a full and unrestricted recovery to work and cycling following physical therapy despite recommendations from other health care providers for more invasive interventions. This was supported by subject reported outcomes, clinical examination, and diagnostic testing (EMG/NCS) results. This case highlights the need for continual assessment and re-evaluation of subjects' signs and symptoms especially if current interventions are not eliciting desired responses.

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