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Guyon Canal Syndrome: lack of management in a case of unresolved handlebar palsy

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Objective: *To present the clinical diagnostic features including management of Guyon canal syndrome in a case with unresolved sensory deficits in a young female cyclist.*

Clinical Presentation: *After 14 days of cycling across Canada, a 23-year old female experienced sensory loss, followed by atrophy and a "claw" hand appearance of her left hand.*

Intervention and Outcome: *Treatment included cervical chiropractic manipulation, soft tissue therapy and the use of cycling gloves. Seven years after the initial injury a lack of sensation in the ulnar nerve distribution of her left hand has persisted.*

Discussion: *This case demonstrates that a lack of proper management can lead to permanent sensory loss and is worth highlighting. Various therapists evaluated the patient's symptoms and provided minimal care. No diagnosis was given, nor were appropriate measures taken for her to understand the risks of continuing to ride.*

Summary: *Although treatment for Guyon Canal Syndrome can be as easy as cessation from cycling until symptoms subside, other treatment options could be*

Objectif : *Présenter les caractéristiques de diagnostic clinique, dont le traitement du syndrome du canal de Guyon dans un cas de déficits sensoriels non traités chez une jeune cycliste.*

Tableau clinique : *Après 14 jours de vélo à travers le Canada, une femme de 23 ans a souffert une perte sensorielle, suivie par une atrophie et l'aspect d'une « main en griffe » à sa main gauche.*

Intervention et résultats : *Le traitement comportait la manipulation chiropratique cervicale, le traitement des tissus mous et le port de gants de vélo. Sept ans après la blessure initiale, un manque de sensation dans la distribution du nerf cubital de la main gauche a persisté.*

Discussion : *Ce cas démontre que le manque de traitement approprié peut entraîner la perte sensorielle permanente et mérite qu'on s'y attarde. Différents thérapeutes ont évalué les symptômes de la patiente et lui ont fourni des soins minimaux. Aucun diagnostic n'a été fait, ni des mesures appropriées n'étaient prises pour lui faire comprendre les risques de continuer à faire du vélo.*

Résumé : *Bien que le traitement du syndrome du canal de Guyon soit aussi simple que l'arrêt de la pratique du vélo jusqu'à la disparition des symptômes, d'autres options thérapeutiques pourraient être utilisées pour*

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utilized to help manage ulnar nerve compression injuries in cyclists.

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aider à traiter les lésions de compression du nerf cubital chez les cyclistes.

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MOTS CLÉS : observation, paralysie du guidon, syndrome du canal de Guyon, chiropratique

Introduction

Ulnar nerve compression in cyclists, also known as Guyon Canal Syndrome (GCS), was first reported by Eckman et al in 1975.[1] Other common terms used in the literature include: ulnar tunnel syndrome, cyclist's palsy, or handlebar palsy. Stresses over Guyon's Canal in other sports including racket sports, karate and wheelchair activities can also lead to this type of ulnar nerve injury.[2,3]

The anatomic region of Guyon's canal is approximately 4–4.5 cm in length and can be subdivided into three zones: 1) proximal to the pisiform bone (the area where the ulnar nerve bifurcates); 2) a deep ulnar (motor) compartment; 3) a superficial (sensory) compartment (see Figure 1).[4,5] Guyon's canal is bordered by the pisiform medially and the hook of the hamate laterally, with the pisohamate ligament forming the floor of the canal and the roof composed of the palmar carpal ligament.[2,4-7] The ulnar nerve lies within the confines of this anatomic region and can be easily compressed by pressure of the extended wrist on the handlebars of a bicycle. Other common causes ulnar nerve compression at Guyon's Canal include but are not limited to the presence of ganglion cysts, lipomas, anomalous muscles, or a hypoplastic hamulus.[2,3] As the ulnar nerve courses through Guyon's canal, it divides into two terminal branches, the deep motor branch of the ulnar nerve and the superficial ulnar nerve (Figure 1). The deep ulnar nerve is responsible for motor control of intrinsic hand function through innervation of the dorsal and palmar interossei, the lumbricals of fourth and fifth digits, the hypothenar muscles (abductor, flexor and opponens digiti minimi), adductor pollicis muscle and the deep head of flexor pollicis brevis.[6] The superficial ulnar nerve supplies sensation over the hypothenar eminence and through two common palmar digital nerves over the palmar aspect of the fifth finger and the adjacent sides of the fourth and fifth fingers.[6] Authors have attempted to classify the type of Guyon Canal Syndrome into Type I (mixed motor and sensory loss), Type II (motor loss), and Type III (sensory).[8,9] This classification may not be important in guiding our treatment, however it can help to understand the anatomy involved and to monitor progress and outcomes. In this particular case, the cyclist experienced Type I GCS where both the superficial and deep branches of the ulnar nerve were compromised. The injury was likely more severe to the superficial ulnar branch since its function remained impaired.

A prospective study by Patterson et al in 2003, investigated the incidence of ulnar neuropathy in cyclists.[10] The authors investigated twenty-five cyclists (ages 20-60 years old) randomly chosen for the study, who underwent a 600km bicycle tour over the course of four days.[10] Using a questionnaire and physical examination, ulnar and median nerve function were assessed day 0 (the day before the ride began) and then re-evaluated on day 4 (within hours of completion of the ride).[10] Seventy percent of the participants experienced some form of neurological symptoms by the end of the ride.[10] Motor weakness was experienced by 36%, sensory loss was apparent in 10%, and 25% experienced both motor and sensory deficit.[10] Further results showed there was no difference between experienced riders compared to inexperienced riders regarding symptoms, and mountain bikers (9/25) had more sensory loss when compared to individuals who were using road bikes (16/25).[10] Results from this study highlight an area of research to be further explored. This particular study lacked strength due to its small sample size, multiple co-founding factors, and use of examination procedures with unknown sensitivity and specificity. The results, therefore, are difficult to generalize to the entire population of cyclists.

The actual incidence of GCS in the population is unknown due to difficulty in reporting the injury and a lack

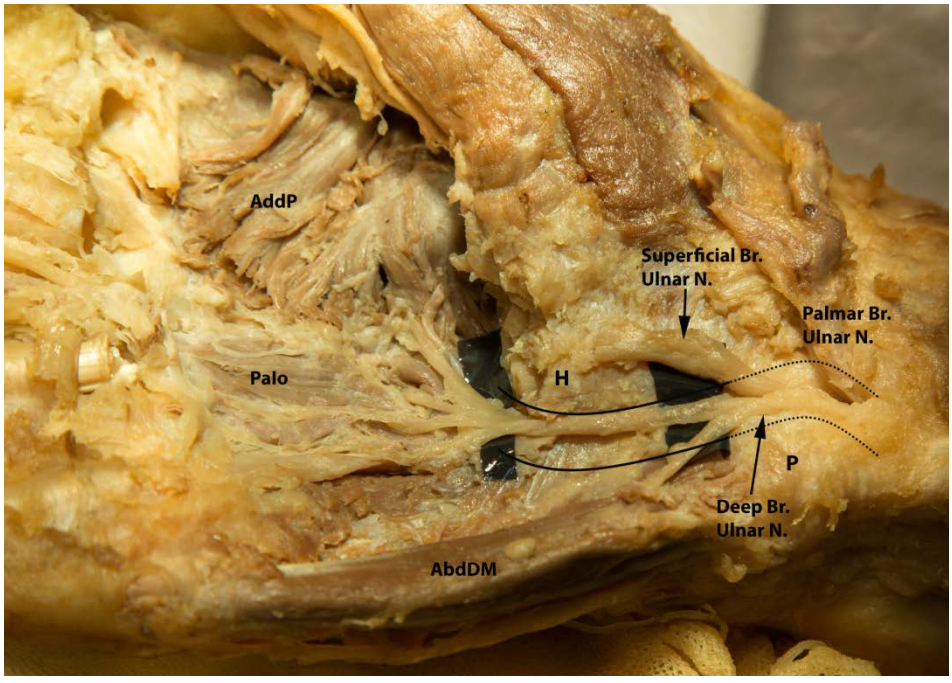


Figure 1.
Dissection of the right palm indicating Guyon's canal. The path outlined by the dotted and continuous lines indicates Guyon's canal. The dotted lines indicates the proximal zone (part 1) and the continuous lines indicates the deep ulnar compartment (part 2). AddP – adductor pollicis (transverse head), PaIo – palmar interossei, AbdDM – Abductor digiti minimi, H – hook of hamate, P – pisiform. (Superficial branch of palmar N. reflected laterally).

of a standardized definition.[1,10,11] Symptoms experienced are usually not severe enough to seek care, compared to injuries such as a fracture experienced from a traumatic fall.[12] Most of what we currently know about GCS exists from previous case reports that attempt to highlight the usual sign and symptoms, physical evaluation, diagnostic testing, and management of this condition. These case reports are important first steps in evidence-based medicine to introduce new concepts or ideas to guide case management and to present new ideas for future investigations.[1,10,11]

Although ulnar nerve compression injuries are fairly rare, there is a growing popularity in participation of large-scale long-distance bike rides, thus this condition may increase in prevalence. This article presents a case of GCS following in a young female cycling across Canada who continues to experience neurological deficits in the ulnar nerve distribution seven years after initial injury.

Case report

In the summer of 2007, a 23-year-old female cyclist experienced discomfort in the fifth digit of her left hand. This began approximately eight days (~325km) into a cycling trip across Canada. She described abnormal sensation in the fifth digit, with mild difficulty extending it completely. She was unable to clearly articulate her exact symptoms at that time. Over the course of the next six days, her symptoms progressed and became more distinct. After 408 km, the feeling of mild numbness progressed from the distal fifth digit (palmar surface) to include the entire fourth and fifth digits, and the entire hypothenar eminence. She also experienced extreme difficulty moving her fourth and fifth digits; she was unable to abduct or adduct her digits, extend the fifth digit, or adduct her thumb. Along with these neurological findings she had the ensuing physical deformities: complete atrophy of the left hypothenar eminence and adductor pollicis

muscle, as well as the presentation of claw hand, which is a classic representation of an injury to the ulnar nerve. Furthermore, she was unable to perform any fine motor skills with her left hand, which resulted in severe difficulties in performing activities of daily living. Throughout the summer symptoms continually progressed such that she lost the ability to perform many gross or fine motor skills with her hand, and was unable to shift gears on her bike. She reported fear of permanent dysfunction in her left hand if she was unable to regain motor function.

Management of this patient's case was variable and lacking for the most part due to the nature of the trip. There was no consistent monitoring or follow-up that took place. The patient received occasional treatment that consisted of chiropractic manipulation of the cervical spine, and generalized soft tissue therapy of the upper limb musculature. No specific treatment was provided to help manage the distinct peripheral nerve injury that was occurring. Afraid of losing function of her hand and that it would remain in the "claw" appearance, the patient self-prescribed and performed passive abduction, adduction and extension of her fingers and adduction of the left thumb 100 times daily. Her bike fitting was re-assessed (without change). After approximately 4000 km of cycling, she was advised to wear foam-cushioned gloves.

Once full disability from GCS occurred, her symptoms no longer progressed; however, there was also no improvement over the next 55 days. Within a month of completing the ride, the patient's motor function returned, however she was still experiencing symptoms of residual sensory loss. The patient did not receive any form of chiropractic treatment after completing her ride, but continued to do passive range of motion exercises.

Unfortunately, seven years after the initial injury this individual continues to self-report residual symptoms of decreased sensation in the pad of the fourth digit, the entire palmar aspect of the fifth digit and hypothenar eminence. There is also mild decrease in size of the hypothenar eminence. The individual was not interested in addressing these issues with any diagnostic imaging or treatment.

Regrettably, this patient's case was not well managed or documented. The patient's evaluation and care were provided by various therapists and chiropractors encountered on her cycling journey across Canada. No specific treatment was provided, no diagnostic testing or laboratory procedures were performed, and no outcomes were documented using valid and reliable tools. This case accurately reflects the nature of an independent athletic event where consistent health care monitoring or provision was not available.

Discussion

Peripheral nerves can be injured in a variety of ways. In this particular case, the ulnar nerve sustained prolonged external compression and traction in the confines of the anatomical region of Guyon's canal by the handlebars. To better understand what occurred, it is important to look at three types of nerve injuries identified by Seddon in 1943.[13] The first type of nerve injury, neuropraxia occurs where there is transient mechanical trauma or ischemia to the nerve resulting in a signal conduction block.[13,14] Recovery of the nerve within days or weeks is possible because there is no disruption of the nerve or its supporting sheath.[13,14] This is one of the more common types of peripheral nerve injury that presents to a chiropractic practice. The second type of nerve injury, axonotomesis occurs when there is disruption of the nerve but the supporting Schwann cell sheath remains intact.[13,14] This can occur when there is prolonged compression or traction of the nerve often leading to Wallerian degeneration of the nerve and signs of denervation distal to the lesion.[13,14] If intervention to remove the insult to the nerve, such as long standing compression, is not removed at a reasonable time it can lead to end organ damage, or permanent loss of function.[13,14] This is likely the type of injury the young cyclist in this case experienced. Regeneration of nerve and recovery of function is possible given that the offending cause of injury is removed or avoided which can be accomplished by stopping cycling. The third type of injury is referred to as neurotemesis.[13,14] This involves serious injury or transection of the nerve and it's supporting sheath.[13,14] Partial recovery is generally achieved with surgical intervention. Chances for spontaneous recovery of nerve function diminish with continuous deformation or insult to the nerve.[13,14] Typically after a nerve undergoes Wallerian degeneration, the regrowth rate is typically 1-3mm/day.[13,14] This is important in order to educate our patients that recovery from a nerve injury typically a long gradual process.[13,14]

The clinical presentation of GCS is fairly straightforward. A clear history and physical examination will most often lead to the correct diagnosis without need for

imaging or special tests.[15] Patients generally present to a health care practitioner complaining of sensory and/or motor loss in the ulnar nerve distribution of the hand beyond the anatomic region of Guyon's canal. These symptoms typically transpire after a long distance bike ride, a ride with a long downhill component or event after mountain biking where prolonged compression of the ulnar aspect of the hand and wrist is compressed and extended on the bike's handlebars. Occasionally, these neurologic symptoms may be accompanied by atrophy of the hypothenar eminence and adductor pollicis, claw hand presentation, and pain or tenderness, however these are not always present. At this point it is extremely important to ask the patient how long they have been experiencing symptoms as duration of insult to the nerve provides critical information for prognosis.[3,11,15]

A typical physical examination includes a screen of the cervical spine and upper limb, and a detailed upper limb neurological exam. Sensory loss (paraesthesia, numbness or tingling) over the hypothenar eminence and palmar aspect of the fifth digit and ulnar half of the fourth digit may be mapped out. If the deep ulnar nerve branch has been affected, motor testing will reveal the inability to abduct or adduct fingers, and/or inability to adduct the thumb, and a positive Froment's test may be present.[3,11,15] The following tests might also be positive in patients with GCS: upper limb tension test of the ulnar nerve, Tinel's test, or Phalen's test where tension, tapping and compression is focused on straining the ulnar nerve at the anatomic site of Guyon's canal. If required, or the clinician suspects an anatomical issue resulting in ulnar nerve compression, further diagnostic testing can be done including plain film radiographs, ultrasound, MRI, electromyogram, or nerve conduction velocity study (with acute injury).[3,11,15] However, the sensitivity and specificity of many of these tests for ulnar neuropathy at the wrist are unknown because existing studies are limited to a small number of patients with known neuropathy.[15] Furthermore, electrodiagnostic testing may be used to monitor extent of the injury, progression or improvement, however abnormal results are variable and normal results do not always rule out pathology.[15]

The classical clinical presentation of GCS is generally understood well by healthcare practitioners, however it is important to consider both external and internal factors, possibly associated with the development of this condition. This is especially important when an individual's symptoms persist over a long period of time. Important differential diagnoses include: cervical radiculopathy, thoracic outlet syndrome, cubital tunnel syndrome (which is more common than Guyon's Canal Syndrome), and fracture (traumatic) of the hook of the hamate.[3,11,15]

Treatment and recommendations

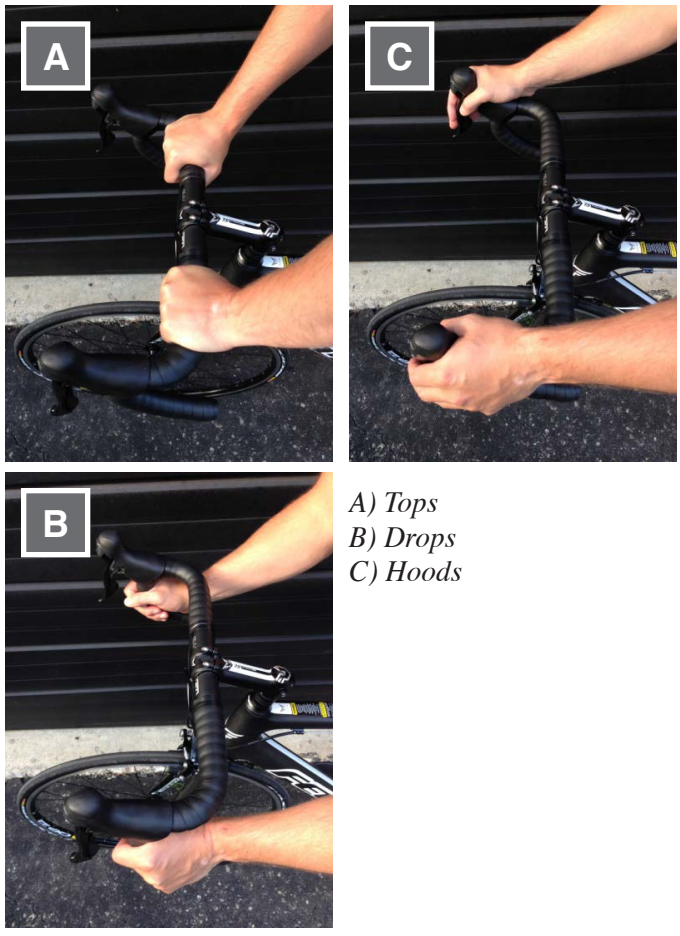
There is a gap in the literature regarding evidence-based information for the management of ulnar nerve compression injuries in cyclists. There are currently no systematic reviews or randomized controlled trials assessing the effectiveness of interventions to help inform or direct our treatment principles. In the absence of evidence-based information, expert opinion from a Delphi Consensus Strategy is often looked upon for guidance. To assist professionals in the management of patients with this condition, Hoogvliet et al, performed a Delphi Consensus strategy to provide recommendations for multidisciplinary treatment of GCS as part of the European HANDGUIDE study in 2013.[2] A total of 35 hand experts selected by their national membership associations were assembled as the panel, consisting of 18 surgeons, 13 therapists, and five physical medicine and rehabilitation physicians. A steering committee was formed to initiate and guide the Delphi process through rounds in order to reach consensus on the description, symptomatology, diagnosis and intervention for GCS.[2] Their role was to design sequential questionnaires for the expert panel, analyze their responses and then formulate feedback for the next Delphi round. A minimum of 70% agreement was required for consensus to be achieved among the experts. Questions in the 2nd and 3rd rounds were formulated by the steering committee based on the results from the previous rounds.[2] After three rounds consensus was achieved on the description of the syndrome, symptomatology and physical examination, diagnosis and classification coinciding with descriptions of GCS previously alluded to in this article.

The most commonly recommended intervention in the HANDGUIDE was instructions to avoid local pressure and/or limit mechanical overload including repetitive or static movements such as wrist extension or compression of the wrist.[2] This should not be used as the sole treatment, but always in combination with another form of treatment such as splinting the wrist in a neutral position in a fingers-free splint for one to 12 weeks at night, or when tol-

erated throughout the day.[2] These first two interventions were more common for mild-moderate symptoms of less than three months duration.[2] In patients who have more severe or chronic presentation, surgery is an option to explore anatomical causes of ulnar nerve compression in the canal.[2] Lastly, non-steroidal anti-inflammatory drugs (NSAIDs) use or corticosteroid injections can be considered. However, 94% of the panel agreed that NSAID were not useful for the treatment of GCS.[2] The HAND-GUIDE concluded that the main factors for choosing a particular therapeutic intervention included severity of symptoms, duration of symptoms and previous treatments received.[2] They also prepared a handout as a guideline for practitioners to follow to help guide their identification and treatment of this condition. The steering committee proposed to include the following note in the guideline based on suggestions by several experts: **"**Depending on the patient**'**s situation and personal preferences, additional therapeutic modalities, such as ultrasound or nerve gliding exercises, can be added to the treatment"; however, no consensus was achieved to add this note to the guideline.[2] The inclusion of this note would have strengthened the idea that this guideline should not be considered as a rigid set of rules.

There is a lack of evidence-based recommendations regarding therapeutic interventions for the prevention and treatment of GCS. Slane et al in 2011 investigated the influence of glove and hand position on pressure over the ulnar nerve during cycling in an attempt to provide some concrete recommendations.[16] The study assessed a sample of thirty-six experienced cyclists from a local cycling group consisting of equal numbers of males (40.2 y, 180 cm, 82 kg) and females (37 y, 170 cm, 80 kg). These individuals were placed on a stationary bike adjusted to their individual specifications and underwent a typical one- to two-hour tempo ride.[16] Hand pressures over the handlebars were measured using a high-resolution pressure mat (peizo-capacitive pressure mat). These pressures were recorded in each participant over a series of trials where hand position (tops, drops, hoods) see Figure 2, glove type (foam, gel) and glove thickness (3mm, 5mm) were randomized in order to produce pressure profiles in different combinations. Pressure data was summarized over a standardized anatomical region of interest that overlies the ulnar nerve at Guyon's Canal.[16] Wrist posture was simultaneously monitored with a motion capture system. Results of the study demonstrated that pressure and loading patterns experienced by cyclists was significant enough to induce ulnar nerve damage.[16] The highest pressure over the region of interest was observed in the drops hand position.[16] This was also the posture that produced the greatest wrist extension.[16] Riding in the tops hand position produce the greatest ulnar deviation.[16] In these cycling postures, sustained compression of the ulnar nerve ensues.[16] Severe conduction block within the nerves can occur within hours, and when the duration of insult to the nerve persist it can lead to the classic Wallerian degeneration which can take upwards of months to recover.[13,16]

Figure 2.
Hand positions when cycling



A) Tops
B) Drops
C) Hoods

Recommendations yielded from the study to reduce peak pressures included wearing padded cycling gloves, which reduce peak pressure by 10-29%, and the greatest

reduction in peak pressure was achieved while wearing a glove made of thin compliant padding (3mm, foam).[16] Damage to the nerve can be minimized by additional countermeasures such as frequently changing hand position and ensuring proper bike-set up by a professional. The clinical relevance of the results of this study is unknown and recommendations are difficult to generalize. This study was done in a controlled steady-state laboratory environment, measuring pressure profiles on the dominant hand only and fitted with brand new gloves. Only the normal forces were considered, while pressure profiles of shear forces on the hand during an actual ride on varied terrain when steering is involved are likely different. Future studies should consider dynamic variations in hand pressure and wrist posture when cycling. Another major limitation of this study was that the authors commented on statistical significant finding, however did not provide any statistical information to justify these conclusions.

Prolonged pressure of the wrists on the handlebars during cycling could negatively affect nerve physiology and can lead to temporary or permanent neurological dysfunction as demonstrated in this case. Chiropractors should be aware of the clinical presentation of the condition and be able to advise their patients on prevention, self-care, and provide proper management strategies. Prevention strategies that can be utilized are essential to help reduce the negative effects of prolonged compression and traction on the ulnar nerve at Guyon's Canal. These include wearing cycling gloves (thin compliant padding of 3mm foam), padding the handlebars, changing hand and body position frequently as well as taking breaks to avoid prolonged compression, and having your bike fitted properly by a specialist.[3,10,11,17] However, even in the face of preventative strategies, the forces on the ulnar nerve are still high enough to sustain damage. Therefore, it is important to recognize when the ulnar nerve has been compromised and diagnose the condition early so that necessary adjustments can be made given the circumstances.[2,17] First and foremost the athlete should be advised to stop the activity and be made aware of the risks for permanent dysfunction if they continue. Instructions should be given to the athlete on how to avoid insult to the injury, and perhaps the athletes wrist and hand can be immobilized in a splint to help decrease the amount of mechanical load on the irritated nerve.[2,17] The support for different management techniques of ulnar nerve compression in cyclist's has yet to be investigated.

Even though direct evidence does not exist for the use of certain management strategies for GCS, chiropractors should utilize evidence regarding treatment of peripheral nerve injuries. This could include the use of low-level laser therapy that has been shown to accelerate the rate of recovery of injured peripheral nerves through modulating several neurotrophic factors and through its anti-inflammatory effect.[18] The use of therapeutic ultrasound has also been shown to modulate certain cellular and molecular responses involved in the healing process and improve the rate of recovery of peripheral nerve injuries.[19] Ebenbichler et al[20] demonstrated in clinical trials ultrasound can improve symptoms as well as median nerve conduction velocities in patients with a neuropraxic grade of injury, further supporting the clinical use of ultrasound to accelerate and improve functional recovery after a peripheral nerve injury.[19,20] Proper settings for the use of these modalities in treating a patient with GCS have yet to be determined and further research is required to prove their efficacy in the management of GSC.

Clinicians should always keep in mind weighing risk versus harm against patient preferences and goals and explore all options, as our goal is to improve on natural history. Future research should focus on the role of conservative management for the treatment of GCS.

Conclusion

Ulnar nerve compression injuries are common in the sport of cycling. We report a case of a 23-year old recreational cyclist who experienced severe ulnar nerve injury while cycling across Canada. This case highlights the necessity of all primary health care practitioners responsible for diagnosing and treating these athletes to be aware of the potential ramifications and long-term disability that can occur with prolonged insult to injury. A delayed diagnosis and inappropriate management may lead to prolonged neurological sequelae.

Chiropractors are well suited to offer a continuum of supportive care for their athletes and as in most sports it is important to consider the integrated team working with the athlete in order to benefit their performance. This case was not well managed or documented, hence is worth highlighting, as neurological symptoms remain unresolved. More attention should have been paid to the

proper management of this patient in order to help prevent the severity of the injury. Perhaps by fitting with gloves at an earlier stage, as well as advice to stop immediately once hard neurological signs of ulnar nerve dysfunction presented may have prevented the progression and chronicity of the complaint. Nevertheless, despite the injury and dysfunction, the individual was able to complete the trip across Canada with only minor unresolved neurological deficits. This case accurately reflects the nature of an independent athletic event where consistent health care monitoring or provision was not available.

References

1. Eckman PB, Peristein T, Altrocchi PH. Ulnar neuropathy in bicycle riders. Arch Neurol. 1975;32:130-131.
2. Hoogvliet P, Coert JH, Fridén J, Huisstede BM. How to treat Guyon's canal syndrome? Results from the European HANDGUIDE study: a multidisciplinary treatment guideline. Br J Sports Med. 2013;47(17):1063–70.
3. Izzi J, Dennison D, Noerdlinger M, Dasilva M, Akelman E. Nerve injuries of the elbow, wrist, and hand in athletes. Clin Sports Med. 2001;20(1):203–17.
4. Kollmer J, Bäumer P, Milford D, Dombert T, Staub F, Bendszus M, Pham M. T2-Signal of the ulnar nerve branches at the wrist in Guyon's canal syndrome. PloS ONE. 2012;7(10):1-8.
5. Leversedge FJ, Goldfarb CA, Boyer MI. The distal ulnar tunnel. J Wrist Surg. 2012;1:185-186.
6. Moore KL, Dalley AF, Aqur, AMR. Clinically Oriented Anatomy, 6th Edition. Lippincott Williams and Wilkins. (2009).
7. Polatsch DB, Melone CP, Beldner S, Incorvaia A. Ulnar nerve anatomy. Hand Clin. 2007;23(3):283–9.
8. Shea JD, McClain EJ. Ulnar-nerve compression syndromes at and below the wrist. JBone Joint Surg [Am]. 1969;51(6):1095-1103.
9. Akuthota V, Plastaras C, Lindberg K, Tobey J, Press J, Garvan C. The effect of long-distance bicycling on ulnar and median nerves: an electrophysiologic evaluation of cyclist palsy. Am J Sports Med. 2005;33(8):1224–30.
10. Patterson JMM, Jaggars MM, Boyer MI. Ulnar and median nerve palsy in long-distance cyclists. A prospective study. Am J Sports Med. 2003;31(4):585–9.
11. Capitani D, Beer S. Handlebar palsy--a compression syndrome of the deep terminal (motor) branch of the ulnar nerve in biking. J Neurol. 2002;249(10):1441–5.
12. Dettori NJ, Norvell DC. Non-traumatic bicycle injuries: a review of the literature. Sports Med. 2006;36(1):7–18.
13. Seddon HJ. Three types of nerve injury. Brain. 1943;66(4):238-283.
14. Birch, Rolfe. Peripheral Nerve Injuries: A Clinical Guide. Spinger-Verlag, London (2013).
15. Shehab R, Mirabelli MH. Evaluation and diagnosis of wrist pain: a case-based approach. Am Fam Physician. 2013;87(8):568–73.
16. Slane J, Timmerman M, Ploeg H-L, Thelen DG. The influence of glove and hand position on pressure over the ulnar nerve during cycling. Clin Biomech (Bristol, Avon). 2011;26(6):642–8.
17. Aldridge JW, Bruno RJ, Strauch RJ, Rosenwasser MP. Nerve entrapment in athletes. Clin Sports Med. 2001;20(1):95–122.
18. Akgul T, Gulson M, Gulcur. Effects of early and delayed laser application on nerve regeneration. Laser Med Sc. 2014;29:351-357.
19. Mourad PD, Lazar DA, Curra FP, Mohr BC, Andrus KC, Avellino AM, McNutt LD, Crum LA, Kliot M. Ultrasound accelerates functional recovery after peripheral nerve damage. Neurosurgery. 2001;48(5):1136-40.
20. Ebenbichler GR, Resch KL, Nicolakis P, Wiesinger GF, Uhl F, Ghanem AH, Fialka V. Ultrasound treatment for treating the carpal tunnel syndrome: Randomized "sham" controlled trial. BMJ. 1998; 316:731–735.