IT'S A WIDE WIDE WORLD

Literature Reviews

Gary B. Clark, MD, MPA

CERVICAL SPINE WHIPLASH INJURIES AND PROLOTHERAPY

Case Study: *On 9 December 1945, General George S. Patton and his chief of staff were being driven in a sedan near Mannheim, Germany, with Patton sitting on the right side of the back seat. A US Army 2½-ton truck, traveling in the opposite direction, veered across the median and hit Patton's car at the right front fender. Each vehicle was traveling at 20-30 miles-per-hour. Of the four involved, Patton was the only person injured. Immediately complaining of neck pain, struggling for breath, and paralyzed from the neck down, he was rushed to the US Army hospital in Heidelberg.*

INTRODUCTION

Cervical spine injury following abrupt acceleration-deceleration accidents were first labeled by Crowe in 1928 as "whiplash injury."[1] Such neck injuries can be experienced from very early life, as witnessed in the "shaken baby syndrome,"[2] on into adulthood. Whiplash has been most often described subsequent to motor vehicle accidents in which the victim is rear-ended. However, similar neck injury symptoms and signs have been attributed to a variety of other causes, including head-banging, head-first falls, diving, snowboarding and skiing, bicycling, roller coaster riding, pugilistic or criminal assault-and-battery, minor railway accidents, aircraft launching and ejection accidents, commercial airplane runway accidents, high-velocity therapeutic manipulation—and even low speed, carnival-style, bumper-car accidents. The exact circumstances of the accident can be complex, involving very complicated force vectors.

HISTORY AND RELATED SYMPTOMS

From the very beginning of life, the cervical spine (C-spine) is fraught with significant risks of injury. This includes varying degrees of ligament and musculotendon strain or sprain, along with vertebral dislocation or fracture and even spinal cord trauma (e.g., contusion, hemorrhage) with associated neurological effects. C-spine whiplash injuries can be compounded by brain stem injury due to direct trauma or edema and stroke due to arterial damage and intracranial injuries of varying severity, including coup-countercoup contusion, translational parenchymal tearing, and hemorrhage. These central nervous system injuries can lead to a wide spectrum of neurological and psychological symptoms commensurate with a closed head injury. Cervical sprain injury can also be associated with signs and symptoms of Barré-Lieou Syndrome due to injury of the cervical sympathetic chain.

Table 1. The 1995 Quebec Task Force guidelines provide a convenient scheme for grading the severity of a whiplash disorder.

Grade	Symptoms	Signs
Grade 0	No neck pain, stiffness, or any other physical symptoms	No physical signs on examination
Grade 1	Only complaints of neck pain, tenderness, or pain	No physical signs on examination
Grade 2	Complaints of neck pain, tenderness, or pain	Physical examination evidence of musculoskeletal point tenderness and/or decreased range of motion
Grade 3	Complaints of neck pain, tenderness, or pain plus history of insomnia	All the above plus physical examination evidence of decreased range of motion or neurological signs, e.g., decreased deep tendon reflexes, weakness, or sensory deficit.
Grade 4	All the above	All the above plus radiological evidence of vertebral subluxation, fracture, or spinal cord injury.

CLINICAL DIAGNOSIS

The complete understanding of the patient's whiplash accident often has to be reconstructed forwards and backwards from a carefully gleaned clinical history and an expert, thorough, functional musculoskeletal and neurological physical examination. A good understanding of the biomechanics of whiplash injury is a "must-have."

The 1995 Quebec Task Force guidelines provide a convenient scheme for grading the severity of a whiplash disorder.[3] (*See Table 1.*)

BIOMECHANICAL PATHOPHYSIOLOGY

Since the John Stapp sled experiments in the 1940s-50s, it has been conventional wisdom that a rear impact causes the victim's head and neck to abruptly move out of their normally lordotic neutral posture in two phases.

- First, in the *Retraction Phase*, the head is forced to move into hyperextension as the victim's seat pushes the person's torso forward, causing the unrestrained head and neck to move backwards into extreme hyperextension.
- Secondly, after a very brief inertial delay, there is a *Rebound Phase* during which the head and neck recover and recoil into an extremely hyperflexed position.

Our main intention is to familiarize the reader—both Physician and Patient—with the basic concepts and language of cervical spine whiplash injury. We would also like to stimulate reading and increase the general level of understanding of Prolotherapy of this anatomic area. Please access the website of the National Library of Medicine (www.pubmed.gov) to review the following, and other articles.

S-SHAPED CERVICAL SPINE DEFORMATION DURING WHIPLASH

Biomechanics of Whiplash injury.
Panjabi MM, et al. Orthopade, 1998 Dec;27(12): 813-9.

ABSTRACT SUMMARY

Panjabi, Cholewicki, et al., (1998) employed human cadaveric specimens subjected to 2.5 to 10.5 g-force accelerations. These tests were monitored by functional radiography, high-speed cinephotography, transducer stretch monitoring, flexibility tests, post-trauma and CT and MRI scans, and the specimens were ultimately sectioned for histological microscopic study.

In this study, the investigators observed that, in their Phase I, the normally lordotic C-spine was deformed into an S-shaped curve resulting in:

a. Upper cervical hyperflexion at C0-C2 with elongation of the vertebral artery
b. Lower cervical hyperextension with the most severe capsular ligament stretching occurring at C6-C7.

This first, S-shaped phase was associated with soft tissue injuries.

In their Phase II, all segments of the C-spine became fully extended, with the head reaching its maximum posterior excursion. No soft tissue injuries were noted in this phase.

JOP COMMENTARY

The cited paper represents a series of Yale University studies that strongly suggest that, after direct rear-to-front (posterior-to-anterior) impact to the cervical spine, the cervical vertebrae at C6-7 are initially forced into a nonphysiological hyperextension while, in the same initial phase, the upper cervical vertebrae (C0-C1-C2) essentially are forced into hyperflexion, resulting in the formation of an abnormal S-shape curvature of the cervical spine. Their Phases I and II represented the classical Retraction Phase. They did not report on a classic Rebound Phase.

The extent of traumatic damage depended on the degree of the accelerative g-force acting on the C-spine. At lower g-force acceleration, the inferior C-spine, particularly at C6-C7, was most vulnerable—causing stress on inter-vertebral zygapophyseal facet joint ligament structures. At higher g-forces, the upper C-spine (C0-C1) was more vulnerable—stressing those vertebral musculoskeletal structures as well as the vertebral artery. However, during either extreme of acceleration, the lower C-spine still remained structurally more at risk—with the risk of lower C-spine (C6-7) injury being four times as great at higher acceleration.

Based on these observations, the classic Rebound Phase did not appear associated with significant ligament injury. However, more will be said, later, in regard to specific musculotendinous injuries occurring in the classic Rebound Phase.

CERVICAL VERTEBRAL ZYGAPOPHYSEAL FACET JOINT INJURY AFTER REAR-END WHIPLASH

The prevalence of chronic cervical zygapophyseal joint pain after whiplash. Barnsley, et al. *Spine*. 1995 Jan 1;20(1):20-25.

Neck ligament strength is decreased following whiplash trauma. Yashura T, et al. *BMC Musculoskelet Disor*. 2006;7:103.

ABSTRACT SUMMARIES

Barnsley, et al., (1995) employed diagnostic local anesthetic blocks of cervical zygapophyseal facet joints of whiplash patients to determine the nature of refractory cervical joint pain after whiplash. This double-blind, controlled study revealed that the cervical facet joints were the most common source of chronic neck pain amongst 54% of 50 whiplash patients.

Yashura, et al., (2006) conducted a controlled study of anterior and posterior longitudinal, capsular, and interspinous and supraspinous cervical ligaments from cadaver donors who had sustained various severities of documented rear impacts. Intervertebral zygapophyseal facet capsular ligaments demonstrated significantly lower failure force and less energy absorption capacity, overall. The injuries were most predominant at the C5-C6 level. The ligamentum flavum and the interspinous and supraspinous ligaments played only secondary roles in post-whiplash intervertebral instability.

JOP COMMENTARY

The controlled Australian studies of Barnsley, et al., demonstrate evidence that corroborates the biomechanics of whiplash observed by Panjabi, et al.. These studies suggest not only direct correlation of the chronic clinical symptoms suffered by whiplash victims with the observed biomechanical S-shaped distortion—but also direct correlation of zygapophyseal facet joint injury. (*See Figure 1.*)

The controlled studies of Yashura T, et al., represent a collaboration of investigative efforts amongst Marianna University (Japan), Yale, Dartmouth, and Rush University (Chicago). They surmised that direct, rear-to-front acceleration accidents produce cervical spine whiplash injuries that are characterized by intervertebral zygapophyseal facet joint instability and facet capsular ligament sprain laxity. (*See Figure 2.*) These injuries are

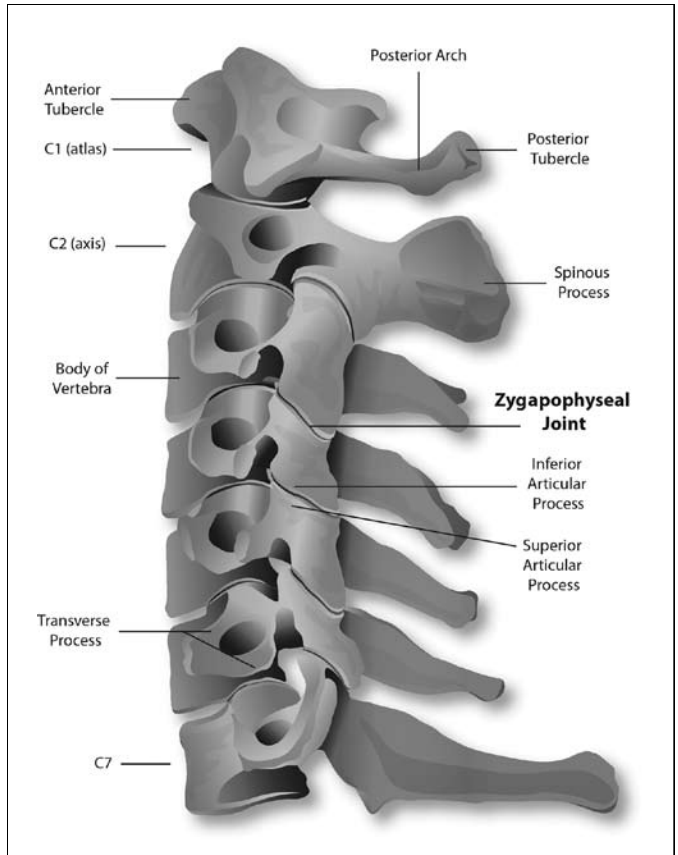

Figure 1. Lateral view of the cervical spine anatomy highlighting a zygapophaseal facet joint.

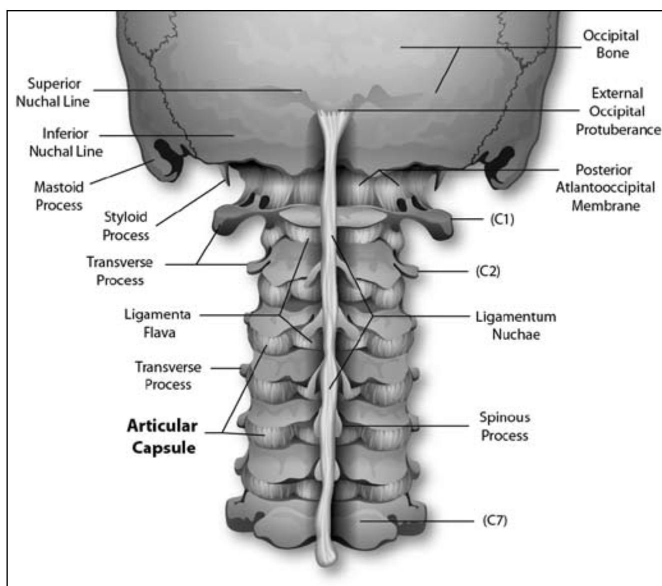

Figure 2. Posterior view of cervical spine and occipital highlighting articular capsules.

amenable to Prolotherapy treatment as long as they are in the Grade 0 to low-Grade 3 of severity using the Quebec Scale. This study supports what Prolotherapists have demonstrated empirically in the course of their clinical assessments and treatments over the past 70-80 years.

CERVICAL SPINE MUSCLE INJURY AFTER REAR-END WHIPLASH

Musculotendon and fascicle strains in anterior and posterior neck muscles during whiplash injury.
Vasavada An, et al. *Spine*. 2007 Apr1;32(7):756-65.

ABSTRACT SUMMARY

Vasavada, et al., (2007) integrated experimental human rear-end automobile impact data with a biomechanical neck musculoskeletal model based on clinical electromyographic studies. They calculated anterior and posterior neck musculotendon and fascicular strains that would be experienced subsequent to the forces of direct rear-end whiplash injuries. They observed that the anterior Sternocleidomastoid muscle was selectively strained during the classic Retraction Phase. On the other hand, in the classic Rebound Phase, the posterior muscles (Splenius capitis, Semispinalis capitis, and upper Trapezius) were selectively strained. These extensor muscles demonstrated more extensive strain injuries consistent with clinical reports of preponderant extensor muscle pain after whiplash.

JOP COMMENTARY

Vasavada, et al., from Washington State University, helped to better correlate the dynamics of the classic whiplash Retraction-Rebound phasing. Whereas Panjabi and Bogduk, et al., reported no particular importance of the classical Rebound Phase to zygapophyseal facet capsular ligament injury. Vasavada, et al., demonstrated that the classic Retraction Phase is related to anterior muscle injury—whereas the Rebound Phase is associated with more extensive posterior muscle injury.

When excessive intervertebral ligament strain is associated with excessive paravertebral musculotendon strain, one should consider Prolotherapy of both ligament and musculotendon sprain injuries.

CERVICAL SPINE INJURY AFTER REAR-END WHIPLASH IMPACTS WITH NECK-HEAD ROTATION

Effect of neck rotation in whiplash-type rear impacts.
Kumar, et al. *Spine*. 2005;30(15)1742-9.

ABSTRACT SUMMARY

Kumar, et al., (2005) from Edmonton, Canada, performed bilateral electromyographic monitoring of human volunteers subjected to incremental acceleration forces. With the volunteer's head rotated out of neutral at the time of simulated rear impact, there was a 88 to 94% greater risk of sprain injury to the contralateral Sternocleidomastoid muscle.

JOP COMMENTARY

The Kumar, et al., report represents three separate papers published in 2005 by this Canadian team. The effect of head rotation on the contralateral anterior Sternocleidomastoid muscles was quite prominent—at least triple compared to any effect on the posterior Trapezius and Splenius capitis muscles.

UPPER CERVICAL INTERVERTEBRAL INJURY AFTER FRONTAL WHIPLASH WITH NECK-HEAD ROTATION

Head position and impact direction in whiplash injuries: associations with MRI-verified lesions of ligaments and membranes in the upper cervical spine.
Kaale BR, et al. *J Neurotrauma*. 2005 Nov;22(11):1194-302.

ABSTRACT SUMMARY

Kaale, et al., (2005) performed a controlled MRI study of upper cervical spine injuries in whiplash patients. They focused on the alar and transverse ligaments and tectorial and posterior atlanto-occipital membrane at the C1-C2 levels. Whiplash victims who had been sitting with their head and neck rotated to one side demonstrated a predominance of high-grade injuries of the alar and transverse ligaments. Those who were involved in front-to-rear collisions were more likely to have transverse ligament and posterior atlanto-occipital membrane injuries. In any case, alar ligament injury was found to be the most common upper C-spine injury. In all whiplash victims affected by upper C-spine injury, their injuries were predominantly high-grade.

JOP COMMENTARY

These Norwegian studies again corroborate the biomechanical model presaged by the 1998 work of Panjabi, et al., which suggested that the upper cervical spine segments are more likely to be involved in higher g-force rear-end whiplash accidents. Kaale, et al., even go further to suggest that upper cervical spine injuries are further unique in that they are more likely to be seen in accelerative trauma in which the patient's head was either rotated or when the force was coming from the front instead of the rear.

PROLOTHERAPY TREATMENT OF CERVICAL WHIPLASH INJURIES

Retrospective case series on patients with chronic spinal pain with dextrose prolotherapy.
Hopper RA, et al. *J Altern Complement Med*. 2004 Aug;10(4):670-4.

Fluoroscopically guided cervical prolotherapy for instability with blinded pre and post radiographic reading.
Centeno CJ, et al. *Pain Physician*. 2005 Jan;8910:67-72.

Intraligamentous injection of sclerosing solutions (Prolotherapy) for spinal pain: a critical review of the literature.
Dagenais S, et al. *Spine J*. 2005 May-Jun;5(3):310-28.

Side effects and adverse events related to intraligamentous injection of sclerosing agents (Prolotherapy) for the back and neck: a survey of practitioners.
Dagenais S, et al. *Arch Phy Med and Rehab*. 2006 Jul;87(7):909-913.

Case series on chronic whiplash related neck pain treated with intraarticular zygapophyseal joint regeneration injection therapy. Hooper, et al. *Pain Physician*. 2007 Mar;10(2):313-318.

ABSTRACT SUMMARIES

Hooper and Ding (2004) reported on a non-controlled, retrospective case series study of 77 patients receiving Prolotherapy to various spinal sections including the C-spine. They reported their C-spine treatments as having lower pain reduction outcomes than thoracic and lumbar treatments.

Centeno, et al., (2005) conducted a blinded, prospective case series study—the first report of fluoroscopy-guided cervical Prolotherapy. They treated 6 patients exhibiting varying degrees of C-spine instability between C3 and C7. Flexion instability was most marked at the C4-C5 level, whereas extension instability was most marked at C2-C3 level. There were no details regarding collision variables. Their treatment, using 12.5% dextrose Prolotherapy decreased instability in flexion more often than in extension, which correlated with their treating only posterior ligaments.

Dagenais, et al., (2005) conducted a Cochrane computerized review of the literature reporting on Prolotherapy of all segments of the spine. It pointed to a great variation of injection and supportive treatments protocols, there being a lack of standardization in the overall practice of Prolotherapy as reported in the literature. It recommended better focus of future research and improved standardization of the practice. Still, the authors reported that the literature, overall, indicates that Prolotherapy "may be effective at reducing spinal pain."

Dagenais, et al., (2006) conducted a survey of 171 Prolotherapy practitioners and reported on the benign and adverse events related to Prolotherapy for the back and neck. They found that the collateral events cited were not unlike those associated with any other spinal injection procedures.

Hooper, et al., (2007) reported an uncontrolled study of Prolotherapy of 18 whiplash patients receiving intraarticular cervical zygapophyseal facet joint injection with 20% dextrose. Their mean neck disability index was reduced by 55% in 12 months from 24.71 to 10.94. Their best clinical outcomes were those combining Prolotherapy with rehabilitative physical therapy.

JOP COMMENTARY

The above-cited articles on Prolotherapy of the C-spine are representative of most investigative reports on Prolotherapy. Generally, such reports consist of case studies, either retrospective or prospective. However, the reports that do exist provide substantial "strength of evidence" that Prolotherapy is effective. Better delineation of the efficacy of C-spine Prolotherapy by more rigorous controlled experimental study is needed.

One major "pearl" gleaned from Hooper, et al. (2007) is the value of ancillary rehabilitative care, such as Rolfing, Pilates, or Physical Therapy following Prolotherapy. Also, one major correction of a common misconception is that Prolotherapy is not a "sclerosing" (i.e., scarring) therapy—as is inappropriately proposed by Dagenais, et al.. Prolotherapy is a "regenerative" technique that is substantiated by the current literature.

The topic of cervical spine injury was exhaustively addressed by Ruth Jackson, MD, in the 1940s and 50s based largely upon her clinical radiological and surgical observations.[4] Much of what has been revealed by experimental research has corroborated her work. We hope that the above review widens the reader's understanding of whiplash injury and Prolotherapy of associated ligament and tendon injuries.

Case Study (continued): *Why was General Patten the only person out of four injured? To piece that mystery together one might ask, "What was Patten doing at the time of impact that the other two individuals in the sedan were not doing?" Was Patton looking away from the oncoming truck while the other three individuals were looking straight at the suddenly looming problem and bracing appropriately? Was he gazing out the window to his right—perhaps lost in reverie over some ancient battle—if so, he would have not seen the oncoming truck. He would not have had time to effectively brace. And his neck and head would have been rotated to the right.*

All speculation aside, Patton experienced an abrupt frontal acceleration due to a 2½-ton truck hitting his 1-ton sedan at the front right quarter. It was a violent frontal impact with a clockwise centrifugal element. With those forces alone, he could have easily have sustained a severe Quebec Grade 3 to 4 whiplash injury of the mid to upper C-spine with potential vertebral skeletal fracture, along with vertebral artery, cervical cord, and medullary brainstem collateral damage.

Another way to ask the question is, "What forces impacting on Patton were different compared to what the other two individuals in the sedan experienced?" Hit by a 2½-ton truck at the sedan's right front quarter, delivering a robust, clockwise centrifugal force, the other two in the sedan were thrust outward against the right interior insides of the vehicle. Seat belts were not standard equipment in the 1940s. After an initial hyperflexion phase, Patton was forcibly launched tangentially across a spacious rear seating compartment, his forehead impacting against the driver's front seat framework. In so doing, he experienced a crushing, frontal blow with severe cervical hyperextension.

Confirmed by X-ray, his cervical injuries included a fractured C3 vertebra and posterior dislocation of C4 on C5, all associated with quadriplegia and one unfunctional hemidiaphragm. Whatever neck ligament and muscle soft tissue damage existed suddenly became moot.

Despite the determined and expert efforts of Colonel R. Glen Spurling, USA, MC, and a sterling neurosurgical team, Patton died, likely of pulmonary embolism, on 21 December. He was placed to rest outside of Luxembourg aside many of his fellow soldiers. All the rest is clinical history. But, biomechanically, we can still wonder and learn.[5] ■

BIBLIOGRAPHY

1. Crowe H. A new diagnostic sign in neck injuries. *Cal Med* 1964;100:12-13.
2. Bandak F. Shaken baby syndrome: A biomechanics analysis of injury mechanisms. *Forensic Science International*, 2005 Jun;151(1):71-79
3. Guideline on the management of claims involving whiplash-associated disorders (html). 11-24-2005. http://www.fsco.gov.on.ca/English/pubs/guidelines/gudeline7-1.asp.
4. Jackson R. *The Cervical Syndrome*. Springfield, IL: Charles C. Thomas Pub. 4th ed, 1978.
   Thanks to Thomas Ravin, MD.
5. Rovit RL, et al. Patton: death of a soldier. *Journal of Neurosurg*. 2008 Feb;108(2):402-8.
   Thanks to Sandy Schatsky, MD.