Whiplash Associated Disorders (WAD)
Instability & Case Studies

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RADIOSLOGICAL Exam
RADIOLOGICAL Exam

- Weight bearing: Pro – posture assessment; Con – movement artifact / quality (esp. BMI >35)
- Recumbent: Pro – quality best; Con – no biomechanical assessment
- Stress Views (C & L Spine primarily)
  - Sagittal Plane: Flexion/Extension
  - Frontal Plane: Lateral Flexion (Apical/Alar Ligs)
- Special tests: MRI, CT, Bone Scan, fMRI, PET Scan, DTI
The Canadian Cervical-Spine Rule

To be used on alert (Glasgow Coma Scale score=15) and stable trauma patients where cervical spine (C-spine) injury is a concern.

Is there a high-risk factor necessitating radiography?
- Age ≥ 65 years or a significant mechanism of injury or paresthesias in the extremities

No

Yes

Is there any low-risk factor permitting safe assessment of range of motion?
- Was it a simple rear-end collision (excluding rollover, collision with bus, large truck, or vehicle traveling at high speeds, or being pushed into oncoming traffic)?
- Was the patient found seated in the Emergency Department or ambulatory after the incident?
- Was there delayed onset of neck pain or absence of any midline cervical-spine tenderness.

Unable

Yes

Able to rotate neck actively?
- 45 degrees right and left

No Radiography

The NEXUS Low Risk Criteria

C-spine imaging is recommended for patients with trauma unless they meet all of the following criteria:

Absence of posterior midline cervical-spine tenderness
- Patients with midline posterior bony cervical-spine tenderness present with reports of pain on palpation of the posterior midline neck from the nuchal ridge to the prominence of the first thoracic vertebra, or if the patient expresses pain with direct palpation of any cervical spinous process.

No evidence of intoxication
- Patients should be considered intoxicated if they have a recent history provided by the patient or an observer of intoxicating ingestion or evidence of intoxication on physical exam such as an odor of alcohol, slurred speech, ataxia, or any behavior indicative of intoxication. Patients may also be considered to be intoxicated if laboratory tests are positive for alcohol or drugs that affect the level of alertness.

A normal level of alertness and consciousness (baseline mental status)
- Patients with an altered level of alertness may include any of the following: a Glasgow Coma Scale score of 14 or less; disorientation to person, place, time, or events; inability to recall three objects at five minutes; a delayed or inappropriate response to external stimuli; or alternative findings consistent with altered mental status.

Absence of focal neurological deficit
- Patients with a focal neurological deficit is any focal neurological finding on motor or sensory examination.

Absence of any distracting injuries
- Patients with a distracting injury is any condition that, in the examiner’s judgment could be producing enough pain so as to distract the patient from another, particularly cervical, injury. Such injuries may include a long-bone fracture; a visceral injury; a significant laceration, degloving injury, or crush injury; large burns; or any other injury causing acute functional impairment.

SGY: In Handouts

*Adapted with permission from Stiell et al. [72]
American College of Radiology  
ACR Appropriateness Criteria®  

Clinical Condition: Low Back Pain

Variant 1: Acute, subacute, or chronic uncomplicated low back pain or radiculopathy. No red flags. No prior management.

<table>
<thead>
<tr>
<th>Radiologic Procedure</th>
<th>Rating</th>
<th>Comments</th>
<th>RRL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI lumbar spine without contrast</td>
<td>2</td>
<td></td>
<td>O</td>
</tr>
<tr>
<td>X-ray lumbar spine</td>
<td>2</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>X-ray myelography and post myelography CT lumbar spine</td>
<td>2</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Tc-99m bone scan with SPECT spine</td>
<td>2</td>
<td>If there is concern for spondylolysis in a young patient, SPECT/CT remains the gold standard.</td>
<td>3</td>
</tr>
<tr>
<td>CT lumbar spine without contrast</td>
<td>2</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>CT lumbar spine with contrast</td>
<td>2</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>MRI lumbar spine with contrast</td>
<td>2</td>
<td></td>
<td>O</td>
</tr>
<tr>
<td>CT lumbar spine without and with contrast</td>
<td>1</td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

*Relative Radiation Level
American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: Suspected Spine Trauma

Variant 1:
Cervical spine imaging not indicated by NEXUS or CCR clinical criteria. Patient meets low-risk criteria.

<table>
<thead>
<tr>
<th>Radiologic Procedure</th>
<th>Rating</th>
<th>Comments</th>
<th>RRL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray cervical spine</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>CT cervical spine without contrast</td>
<td>1</td>
<td>With sagittal and coronal reformat.</td>
<td>3</td>
</tr>
<tr>
<td>CT cervical spine with contrast</td>
<td>1</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>CT cervical spine without and with contrast</td>
<td>1</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Myelography and post myelography CT cervical spine</td>
<td>1</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>CTA head and neck with contrast</td>
<td>1</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>MRI cervical spine without contrast</td>
<td>1</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>MRI cervical spine without and with contrast</td>
<td>1</td>
<td></td>
<td>0</td>
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<tr>
<td>MRA neck without and with contrast</td>
<td>1</td>
<td></td>
<td>0</td>
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<tr>
<td>MRA neck without contrast</td>
<td>1</td>
<td></td>
<td>0</td>
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<tr>
<td>Arteriography cervicocerebral</td>
<td>1</td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

*Relative Radiation Level

Variant 2:
Suspected acute cervical spine trauma. Imaging indicated by clinical criteria (NEXUS or CCR). Not otherwise specified.

<table>
<thead>
<tr>
<th>Radiologic Procedure</th>
<th>Rating</th>
<th>Comments</th>
<th>RRL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT cervical spine without contrast</td>
<td>9</td>
<td>With sagittal and coronal reformat.</td>
<td>4</td>
</tr>
<tr>
<td>X-ray cervical spine</td>
<td>6</td>
<td>Lateral view only. Useful if CT</td>
<td>3</td>
</tr>
<tr>
<td>X-ray/medical radiography/Industrial radiography</td>
<td>Medical:</td>
<td></td>
<td></td>
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<tr>
<td>-------------------------------------------------</td>
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<td></td>
<td></td>
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<tr>
<td>2D</td>
<td>Pneumoencephalography · Dental radiography · Sialography · Myelography · CXR (Bronchography) · AXR · KUB · DXA/DXR · Upper gastrointestinal series/Small-bowel follow-through/Lower gastrointestinal series · Cholangiography/Cholecystography · Mammography · Pyelogram · Cystography · Arthrogram · Hysterosalpingography · Skeletal survey · Angiography (Angiocardiography · Aortography) · Venography · Lymphogram</td>
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<td></td>
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<tr>
<td>3D/XCT</td>
<td>CT pulmonary angiogram · Computed tomography of the heart · Computed tomography of the abdomen and pelvis (Virtual colonoscopy) · CT angiography · Computed tomography of the head · Quantitative computed tomography · Spiral computed tomography · High resolution CT · Whole body imaging (Full-body CT scan) · Electron beam tomography</td>
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<td>Industrial:</td>
<td>Radiographic testing</td>
<td></td>
<td></td>
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<tr>
<td>Other</td>
<td>Industrial computed tomography</td>
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<tr>
<td>MRI</td>
<td>Magnetic resonance imaging of the brain · MR neurography · Cardiac MRI/Cardiac MRI perfusion · MR angiography · MR cholangiopancreatography · Breast MRI · Functional MRI · Diffusion MRI</td>
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<tr>
<td>Ultrasound</td>
<td>Echocardiography · Doppler echocardiography (TTE · TEE) · Intravascular · Gynecologic · Obstetric · Echoencephalography · Transcranial Doppler · Abdominal ultrasonography · Transrectal · Breast ultrasound · Transscrotal ultrasound · Carotid ultrasonography · Contrast-enhanced · 3D ultrasound · Endoscopic ultrasound · Emergency ultrasound (FAST · Pre-hospital ultrasound) · Duplex</td>
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<td></td>
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<tr>
<td>Radionuclide</td>
<td>2D / scintigraphy</td>
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<td></td>
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<tr>
<td>2D/3D</td>
<td>Cholescitngiography · Scintimammography · Ventilation/perfusion scan · Radionuclide ventriculography · Radionuclide angiography · Radioisotope renography · Sestamibi parathyroid scintigraphy · Radioactive iodine uptake test · Bone scintigraphy · Immunoscintrigraphy</td>
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<td></td>
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<tr>
<td>Full body</td>
<td>Octreotide scan · Gallium 67 scan · Indium-111 WBC scan</td>
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<td></td>
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<tr>
<td>3D/ECT</td>
<td>SPECT (gamma ray: Myocardial perfusion imaging)</td>
<td></td>
<td></td>
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<tr>
<td>PET (positron):</td>
<td>Brain PET · Cardiac PET · PET mammography · PET-CT</td>
<td></td>
<td></td>
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<tr>
<td>Optical laser</td>
<td>Optical tomography (Optical coherence tomography) · Confocal microscopy · Endomicroscopy</td>
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<td></td>
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<tr>
<td>Thermography</td>
<td>Breast thermography</td>
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</table>
Whiplash Injury and Occult Vertebral Fracture: A Case Series of SPECT Imaging of Patients with Persisting Pain Following a Motor Vehicle Crash

Michael Freeman, Ph.D., D.C., M.P.H, Dan Sapir, M.D., Alex Boutselis, M.D., John Gorup, M.D., Glen Tuckman, M.D., Arthur Croft, D.C., M.P.H., M.S., Chris Centeno, M.D., Arnie Phillips, M.D.
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Abstract

Introduction

The pathology of chronic whiplash injury continues to be a controversial subject in the literature, with some authors claiming that long term pain following whiplash is a factitious disorder. These claims are made despite a growing body of research demonstrating the cervicothoracic spine as a primary source of pain in approximately half of all chronic whiplash cases.

Other research suggests that the intervertebral disc may be a source of continuing pain, associated with spondylolisthesis and other disc injuries. The Iatrogenic mechanism of whiplash resulting from a rear impact collision includes both segmental hyperextension in the lower cervical spine during the initial rearward movement of the head as well as flexion following the rebound of the head off the head restraint, suggesting forceful loading of both posterior and anterior elements of the cervical spine. Recent cadaver testing of simulated whiplash has resulted in findings of injuries including fracture of both the vertebral body and elements of the neural arch, leading to the suggestion that bony injury can occur with both the extension and flexion phases of whiplash trauma.

While plain x-ray with lateral flexion and extension views is the generally recognized standard for evaluating bony injury and instability following whiplash, it is not particularly sensitive for the presence of incomplete facet dislocation such as enthesitic fractures and subchondral fractures of the facet. In the current investigation, we undertook bone scan and SPECT evaluation of consecutive patients who were referred for significant refractory pain following whiplash trauma based on the hypothesis that there may be a subpopulation of these patients who have continued symptoms resulting from unobserved occult fractures.

Results

Of the 15 referrals, one could not obtain insurance coverage for the study and thus did not undergo the diagnostic imaging. Of the remaining 14 subjects who were studied, ten had positive findings on bone scan and/or SPECT (71%). Nine of the ten positive studies closely correlated with the patient-reported symptoms. The most frequent finding was vertebral endplate fracture, found in six cervical (60%) and three thoracic (30%) vertebrae.

There were occult fractures identified in the lateral mass-stemming region of two cervical (20%) and two thoracic (20%) vertebrae. A spinous process fracture was identified in the thoracic spine of one (10%) subject.

There were ten females and four males in the study, with an average age of 33.3 (SD 9.0). The bone scan and SPECT imaging was performed an average of 18.9 months post-crash (SD 13.5, range 2-47). Pain levels were uniformly high, with average VAS scores of 7.8 (SD 1.1).

Seven of the crashes were rear impact (50%), four were side impacts (29%), and three were frontal impacts (21%). Nine of the occupants were drivers (64%) and ten were wearing seatbelts (71%). It did not appear that any of the fractures were a result of direct contact with the vehicle interior.

None of the subjects had fractures that were detectable on plain film, even after reviewing the SPECT images and reading the radiographs. Ten of the subjects had MRI testing prior to the bone scan/SPECT protocol, and of these, six had signs of disc bulging in the cervical spine, four had disc bulges in the thoracic spine, and one had a frank thoracic herniation. One subject had undergone prior cervical discectomy and fusion, but had uptakes solely in an area other than the fused facet.

Our results, even though of a limited sample of patients, suggest a possible pathological mechanism at work in chronic whiplash that has not been previously described. While other authors have reported vertebral fractures resulting from whiplash trauma, none of these studies suggest that occult fractures were a potential source of chronic pain. Lack of specificity of bone scan and SPECT imaging for fracture may be a factor in our series, however, the high correlation of symptoms to findings suggests a traumatic rather than degenerative etiology. Greater subject numbers are needed in order to perform meaningful subgroup analyses relating to gender, age, and injury and crash details as risk factors for occult spinal fracture following whiplash. Our findings may point to more effective methods of dealing with chronic spine pain resulting from motor vehicle crashes.
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MRI: Alar & Transverse Ligaments

STUDY:

  - Vetti, Nils MD *,+; Krakenes, Jostein MD, PhD *,+; Damsgaard, Eivind MD, ++; Rorvik, Jarle MD, PhD *,+; Gilhus, Nils Erik MD, PhD [S],[P]; Espeland, Ansgar MD, PhD *,+ Miscellaneous Article
AB Study Design.
- Cross-sectional.

Objective.
- To describe alar- and transverse-ligament magnetic resonance imaging (MRI) high-signal changes in acute whiplash-associated disorders (WAD) grades 1 and 2 in relation to the severity and mechanics of trauma, and to compare them with controls.

Summary of Background Data.
- The alar and transverse ligaments are important stabilizers at the craniovertebral junction. Acute injury of these ligaments should be detected as high-signal changes on high-resolution MRI.
Methods.

- In the study, 114 consecutive acute WAD I-II patients and 157 non-injured controls underwent upper-neck high-resolution MRI, using proton-weighted sequences and Short Tau Inversion Recovery (STIR).
- Two blinded radiologists independently graded high-signal changes 0 to 3 on proton images and assessed ligament high-signal intensity on STIR.
- Image quality was evaluated as good, reduced, or poor (not interpretable).
- Multiple logistic regression was used for both within- and between-groups analyses.
Results.

- All proton and STIR images were interpretable.
- Interobserver agreement for grades 2 to 3 versus grades 0 to 1 changes was moderate to good ($\kappa = 0.71$ alar; and 0.54 transverse).
- MRI showed grades 2 to 3 alar ligament changes in 40 (35.1%) and grades 2 to 3 transverse ligament changes in 27 (23.7%) of the patients.
- Such changes were related to contemporary head injury ($P = 0.041$ alar), neck pain ($P = 0.042$ transverse), and sex ($P = 0.033$ transverse) but did not differ between patients and controls ($P = 0.433$ alar; and 0.254 transverse).
- STIR ligament signal intensity, higher than bone marrow, was found in only three patients and one control.
Conclusion.

- This first study on high-resolution MRI of craniovertebral ligaments in acute WAD 1-2 indicates that such trauma does not induce high-signal changes.
- Follow-up studies are needed to find out whether pre-traumatic high-signal changes imply reduced ligament strength and can predict chronic WAD.
A case-control study of cerebellar tonsillar ectopia (Chiari) and head/neck trauma (whiplash)

Freeman, MD, Rosa S, Harshfield D, Smith F, Bennett R, Centeno CJ, Kornel Ezriel, Nystrom A, Heffez D, Kohles SS

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JACO Editorial Reviewer: James Demetrious, DC, FACO

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Authors’ Abstract

Primary objective: Chiari malformation is defined as herniation of the cerebellar tonsils through the foramen magnum, also known as cerebellar tonsillar ectopia (CTE). CTE may become symptomatic following whiplash trauma. The purpose of the present study was to assess the frequency of CTE in traumatic vs non-traumatic populations.

Study design: Case-control. Methods and procedures: Cervical MRI scans for 1200 neck pain patients were reviewed; 600 trauma (cases) and 600 non-trauma (controls). Half of the groups were scanned in a recumbent position and half were scanned in an upright position. Two radiologists interpreted the scans for the level of the cerebellar tonsils.

Main outcomes and results: A total of 1195 of 1200 scans were read. CTE was found in 5.7% and 5.3% in the recumbent and upright non-trauma groups vs 9.8% and 23.3% in the recumbent and upright trauma groups (p<0.0001).

Conclusions: The results described in the present investigation are first to demonstrate a neuroradiographic difference between neck pain patients with and without a recent history of whiplash trauma. The results of prior research on psychosocial causes of chronic pain following whiplash are likely confounded because of a failure to account for a possible neuropathologic basis for the symptoms.

Keywords: Whiplash trauma, Chiari, cerebellar tonsillar ectopia, upright MRI

SGY: Note the dif. betw recumb vs. upright in trauma group only!
- In considering the prevalence of dural tears, I suspect that such injuries are more common than currently realized. In evaluating the upper cervical ligamentous structures, researchers such as Krakenes [2], Benedetti [3] have demonstrated the MRI manifestations of these injuries in acute and chronic cases. Krakenes [2] and Hallgren [4] have described the adherence of the posterior atlanto-occipital membrane (PAO) to the dura posteriorly. Krakenes has provided an objective gradation scale to assess tectorial membrane and PAO tears. [2]

- I have discussed in my lectures over the past several years that it seems entirely plausible that the force sufficient to tear the PAO or tectorial membrane could tear the underlying and adherent dura and produce post-WAD headache and resultant CNS dysfunction. The following images are from Krakenes [2]:

A. Normal anatomy. The tectorial membrane (arrows) is fused with the dura mater and extends from the C2 body to the clivus. The posterior atlanto-occipital membrane (arrowheads), also fused with the dura mater, extends from the posterior arch of the atlas to the occipital bone.

B, A 40-year-old woman sustaining frontal collision 4 years previously. Upper part of the tectorial membrane (arrows) is absent; only the dura is shown. From: Krakenes: Spine, Volume 31(24). November 15, 2006.2820-2826.
C. A 46-year-old woman sustaining rear-end collision 11 years previously. The flap combined with thinning of the atlanto-occipital membrane/dura complex was classified as Grade 3 (arrowheads).

Clearly, the force necessary to disrupt the tectorial membrane or the PAO could plausibly produce dural tears and resultant headache/CNS symptoms/signs that are commonly described by patients and in the literature. [5,6] In Images B and C above, the patients above sustained sustained injuries 4 and 11 years previous to imaging. With regard to those patients, if dural tears occurred, CSF pressure temporarily may have dropped as described by Freeman and a temporary post-traumatic Chiari could have developed, plausibly producing headache and CNS symptoms/signs.

Would subsequent dural healing allow re-pressurization and, "float" the brain to its normal position above the basion-opisthion line (B-OL)? Would dural healing lend to normalization of CSF pressure, CSF flow dynamics and resolution of headache and CNS symptoms/signs in some patients? For those patients who suffer cervico-cranial ligamentous disruption, it is entirely possible that persistent, chronic headaches, symptoms/signs are at least in part due to the sequelae of ligamentous injury. It is possible that initial post-injury headache/CNS symptoms/signs are attributable to a new CSF flow dynamic alteration from the norm.

Further, if the CSF/Chiari scenario described by Freeman et al. [1] is plausible and ligamentous injury is a factor in this mechanism, when patients' dura mend, how does residual ligamentous deficits affect future CSF flow dynamics? Is there a contribution by the rectus capitis posterior minor/major (RCPMi/Maj) and its myodural bridge? As the myodural bridge seems to restrain infolding of the PAO/dura in extension, how does ligamentous disruption affect CSF flow dynamics? Hallgren [4] discusses many scenarios such as denervation, CSF flow dynamics, painful dural tension, atrophic changes of RCPMi/Ma and resultant loss of spindle cells causing deafferentation, etc.
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• Peck et al. reported that the RCPMi has 36 spindles/gram and RCPMa has 30.5 spindles/gram of muscle. [7] Elliott et al. have clearly demonstrated the presence of paraspinal muscular atrophy via MRI [8]. It is likely that chronic pain is attributable in part to atrophy, lost spindles and resultant pain gait mechanism dysafferentation.

• It would be interesting to perform CSF flow studies using the Dynamic Fonar Multi-Position MRI technology utilized in the Freeman study to assess CSF flow dynamics in flexion and extension postures in the upright posture. For a more complete evaluation, we could obtain EMG evaluation combined with high resolution MR images of the cervico-cranial junction, ligamentous structures and the RCPMi/Ma to assess atrophic changes in the acute/chronic and control groups to establish normative values and varied test groups.
• Perhaps with normative controls and post-WAD values we can then objectively measure the effect of spinal manipulative therapy on affected cases via dynamic MRI and EDX. As a chiropractor who provides HVLA spinal manipulation, I am most concerned with the possibility and extent of residual ligamentous deficit. If acute and latent cervico-cranial ligamentous disruption is present, we need to better define any lack of integrity prior to delivering spinal manipulation.

• What other related mechanisms should we consider? The RCPMi/myodural bridge has been shown to have ligamentous fibers that coalesce with the peri-vascular tissues adjacent to the vertebral arteries. [9] Does disruption of cervico-cranial ligamentous structures affect vertebral artery flow dynamics? Bakris et al. [10] has described cervico-cranial mechanisms that may be attributable to the genesis of hypertension. How does the above considerations factor into their observations?

• Does post-traumatic cervico-cranial derangement, CSF flow, ligamentous disruption, etc. lend to local, central and distal neurologic somatic and autonomic dysfunction as described by chiropractors over the past 115 years? Does this evidence and explanations provide the key elements that describe a plausible syndrome that could be termed the chiropractic subluxation?
References

Chiropractic & Osteopathy

Case report

Post-traumatic upper cervical subluxation visualized by MRI: a case report
James Demetriou""""1,2

Address: 1Private practice, Wilmington, NC, USA and 2Post-graduate faculty, New York Chiropractic College, Seneca Falls, NY, USA
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Abstract

Background: This paper describes MRI findings of upper cervical subluxation due to alar ligament disruption following a vehicular collision. Incidental findings included the presence of a myodural bridge and a spinal cord syrinx. Chiropractic management of the patient is discussed.

Case presentation: A 21-year old female presented with complaints of acute, debilitating upper neck pain with unremitting sub-occipital headache and dizziness following a vehicular collision. Initial emergency department and neurologic investigations included x-ray and CT evaluation of the head and neck. Due to persistent pain, the patient sought chiropractic care. MRI of the upper cervical spine revealed previously unrecognized clinical entities.

Conclusion: This case highlights the identification of upper cervical ligamentous injury that produced vertebral subluxation following a traumatic incident. MRI evaluation provided visualization of previously undetected injury. The patient experienced improvement through chiropractic care.

Background
For many years, chiropractors have utilized x-ray to assess spinal alignment, perform biomechanic assessments and Magnetic resonance imaging provides a nearly unparalleled assessment of the spine. It provides a view of anatomic and physiologic processes while providing a unique
Abstract

**Background:** This paper describes MRI findings of upper cervical subluxation due to alar ligament disruption following a vehicular collision. Incidental findings included the presence of a myodural bridge and a spinal cord syrinx. Chiropractic management of the patient is discussed.

**Case presentation:** A 21-year old female presented with complaints of acute, debilitating upper neck pain with unremitting sub-occipital headache and dizziness following a vehicular collision. Initial emergency department and neurologic investigations included x-ray and CT evaluation of the head and neck. Due to persistent pain, the patient sought chiropractic care. MRI of the upper cervical spine revealed previously unrecognized clinical entities.

**Conclusion:** This case highlights the identification of upper cervical ligamentous injury that produced vertebral subluxation following a traumatic incident. MRI evaluation provided visualization of previously undetected injury. The patient experienced improvement through chiropractic care.
What do you see?
Figure 1
T2 Weighted Image: Syrinx extending from C2-C7 (Large White Arrow).
What do you see?
Figure 2
Axial T2 Weighted Image reveals hyperintense signal corresponding to Alar Ligament sprain disruption (White Arrow).
Note the LT lateral translation of C1 in reference to C2 and the increased signal intensity (T2 weighted image)
What do you see?
An incidental finding included a visualized myodural bridge intervening between the rectus capitis posterior minor (RCPMi) and the spinal cord dura. (Figure 4)

Figure 4
Sagital T2 Weighted Image – Myodural Connection (Black Arrow). Rectus Capitus Posterior Minor (White Arrow).
normal appearing RCPMi was visualized on axial views with good margins, composition and cross-sectional area (Figure 5).

**Figure 5**
Axial 3D MRI – Rectus Capitus Posterior Minor (Arrow).
The Occiput and C1-2 Relationship

LADI within ± 2 mm
Joint "spaces"
1-2 mm
2-3 mm
No overhang

[Images of anatomical structures and radiographs]
MR Imaging Findings in Spinal Ligamentous Injury

Philip F. Benedetti¹, Linda M. Fahr², Lawrence R. Kuhns³ and L. Anne Hayman², ⁴, ⁵

Author Affiliations

Clinical instability of the spine after trauma occurs when the spinal ligaments and bones lose their ability to maintain normal alignment between vertebral segments while they are under a physiologic load. Instability can lead to further injury, pain, or deformity and can require surgical stabilization. MR imaging has been shown to be helpful in the detection of ligamentous injury [1]. The purpose of this study is to familiarize the reader with the MR imaging appearance of these injuries. This article is divided into three sections. The first illustrates injuries to the complex cranio cervical junction. The second reviews the remainder of the spine, and the third addresses the technical factors that optimize the detection of spinal ligamentous injury.

The importance of these MR findings is increasing as clinicians begin to compare outcomes and treatments for specific types of ligamentous injury detected on MR imaging [2,3,4,5,6,7,8]. As this information grows, so does the power of MR imaging to guide treatment and to enable prediction of outcome.

Cranio cervical Injuries

Many ligaments are seen normally at the cranio cervical junction (Fig. 1). However, only three are considered the major stabilizers. These are the tectorial membrane (Fig. 2), the transverse ligament, and the alar ligaments (Fig. 3). The normal tectorial membrane and transverse ligament are routinely seen on MR imaging, whereas the normal alar ligaments can be more difficult to visualize because of their small size and variable anatomy.

SEE Handouts!
Normal anatomy in 43-year-old woman

—Normal anatomy in 43-year-old woman. Sagittal T2-weighted MR image (TR/TE, 4500/117) obtained on 0.3-T MR scanner shows:

1. Normal apical ligament
2. Anterior occipitoatlantal membrane
3. Anterior atlantoaxial membrane
4. Anterior longitudinal ligament
5. Tectorial membrane
6. Dural reflection
7. Posterior occipitoatlantal membrane
8. Posterior atlantoaxial membrane
9. Nuchal ligament
10. Flaval ligaments
11. Area of interspinous ligaments
12. Supraspinous ligament

http://www.ajronline.org/content/175/3/661.long
Normal anatomy in 21-year-old man.

Sagittal T1-weighted MR image (TR/TE, 510/25) obtained on 0.3-T scanner shows:

1. Normal apical ligament
2. Anterior atlantoaxial membrane

http://www.ajronline.org/content/175/3/661.long

Benedetti P F et al. AJR 2000;175:661-665
Normal anatomy in a 38-year-old man. Axial gradient echo or fast low-angle shot MR image (TR/TE, 420/18; flip angle, 30°) obtained on 1.0-T MR scanner shows

1. Dens
2. Presumed anterior atlantodental ligaments
3. Alar ligaments
4. Transverse ligament
5. Lateral masses of C1
WHAT DO YOU SEE?
Left alar ligament tear in 19-year-old woman with severe neck pain after fall on her head while snowboarding.

Fixed deviation of dens to right was seen on radiograph (not shown). C1-2 rotatory subluxation was suspected. Axial T2-weighted MR image (TR/TE, 4000/90) obtained on 1.0-T MR scanner shows isolated tear of left alar ligament (1) and deviation of dens (2) toward right with respect to lateral masses of C2 (3). Transverse ligament (4) is intact. Sagittal images (not shown) depict normal alignment of occipital condyles with C2, thus no rotatory subluxation is present. CT performed before MR imaging was negative for fracture and fixed rotatory subluxation. These results allowed confident symptomatic treatment that led to full recovery.
WHAT DO YOU SEE?
Fig. 5A. —Occipitoatlantal dislocation in 11-year-old boy who was neurologically intact after motor vehicle crash. Sagittal gradient-echo MR image (TR/TE, 510/35; flip angle, 20°) obtained on 0.3-T MR scanner shows intact (1) and torn (2) portions of anterior occipitoatlantal membrane, anterior arch of C1 (3), intact anterior atlantoaxial membrane (4), prevertebral edema or hemorrhage (5), torn tectorial membrane (6), torn posterior occipitoatlantal membrane (7), torn posterior atlantoaxial membrane (8), intact dural reflection (9), and intact nuchal ligament (10). Before MR imaging, full extent of injury and degree of instability were not appreciated either clinically or from results of radiographs or CT scans. Patient underwent surgical fusion shortly thereafter.
WHAT DO YOU SEE?
Fig. 5B. — Occipitoatlantal dislocation in 11-year-old boy who was neurologically intact after motor vehicle crash. Axial gradient-echo MR image (510/35; flip angle, 20°) obtained on 0.3-T MR scanner shows torn right alar ligament (1), displacement of dens (2) to left with respect to lateral masses of C2 (3), and intact transverse ligament (4).
SAGITTAL PLANE STRESS XR

• Flexion / Extension Lateral Cervical
Ligaments, Capsules, Discs and Muscles

Figure 9.1. The components of the cervical three-column spine. The ligamentous complexes resist distractive forces. The bony structures counteract compression.


MECHANISM OF INJURY

- Motor vehicle accidents (primarily in young patients), falls (primarily in older patients), diving accidents, and blunt trauma account for the majority of cervical spine injuries.
- Forced flexion or extension resulting from unrestrained deceleration forces, with or without distraction or axial compression, is the mechanism for most cervical spine injuries.
Sagittal C-Spine Instability

Panjabi & White: Clinical Checklist of Instability (discussed in):

Cervical Spine Injuries in Sports
Author: Andrew A Sama, MD; Chief Editor: Mary Ann E Keenan, MD

http://emedicine.medscape.com/article/1264627-overview#showall
Cervical Spine Injuries in Sports

One of the most challenging roles of the team physician involves the intervention and decision-making processes regarding cervical spine (C-spine) injuries in contact sports. The team physician must be well versed in the prevention, evaluation, stabilization, and treatment of C-spine injuries. A high index of suspicion and an understanding of cervical alignment and architecture, as well as comprehension of the mechanics exerted during a sporting event, are imperative in diagnosing cervical injuries. More than half of catastrophic injuries in sports are cervical spine injuries. C-spine injuries have been reported in most contact sports, including football, hockey, rugby, and wrestling, as well as in several noncontact sports, such as skiing, track and field, diving, surfing, power lifting, and equestrian events. C-spine injuries are estimated to occur in 10-15% of all football players, most commonly in linemen and defensive players. Serious injuries with neurologic sequelae remain infrequent, and most of these injuries are self-limited. Injuries occur in all levels of play, from the high school to the professional level. Well more than half of catastrophic injuries in sports are cervical spine injuries. C-spine injuries have been reported in most contact sports, including football, hockey, rugby, and wrestling, as well as in several noncontact sports, such as skiing, track and field, diving, surfing, power lifting, and equestrian events. C-spine injuries are estimated to occur in 10-15% of all football players, most commonly in linemen and defensive players. Serious injuries with neurologic sequelae remain infrequent, and most of these injuries are self-limited. Injuries occur in all levels of play, from the high school to the professional level. More than half of catastrophic injuries in sports are cervical spine injuries. C-spine injuries have been reported in most contact sports, including football, hockey, rugby, and wrestling, as well as in several noncontact sports, such as skiing, track and field, diving, surfing, power lifting, and equestrian events. C-spine injuries are estimated to occur in 10-15% of all football players, most commonly in linemen and defensive players. Serious injuries with neurologic sequelae remain infrequent, and most of these injuries are self-limited. Injuries occur in all levels of play, from the high school to the professional level.
Anterior elements destroyed or unable to function  
Posterior elements destroyed or unable to function  
Positive stretch test  
Radiographic criteria*  
A. Flexion/extension x-rays  
   1. Sagittal plane translation > 3.5 mm or 20% (2 pts)  
   2. Sagittal plane rotation > 20° (2 pts)  
   OR  
B. Resting x-rays  
   1. Sagittal plane displacement > 3.5 mm or 20% (2 pts)  
   2. Relative sagittal plane angulation > 11° (2 pts)  
Abnormal disc narrowing  
Developmentally narrow spinal canal  
   1. Sagittal diameter < 13 mm  
   OR  
   2. Pavlov’s ratio < 0.8†  
Spinal cord damage  
Nerve root damage  
Dangerous loading anticipated  

A TOTAL of 5 or more = UNSTABLE

SGY: Note the inconsistency with the AMA Guides (11° in flexion vs. here 20° in flexion; 11° in neutral)

http://emedicine.medscape.com/article/1264627-overview#showall
To compensate for these variances in radiographic techniques, Torg and Pavlov described the Torg/Pavlov ratio.\[28\] This ratio is a measurement of the width of a given vertebral body on the lateral C-spine radiograph divided by the corresponding space allowed for the cord at the same level (see the image below). A value of less than 0.8 was considered to be cervical stenosis and a serious risk factor for neurologic injury in contact sports.

Herzog illustrated that the Torg/Pavlov ratio may have resulted in false-positive indications.\[29\] Herzog reviewed the CT scans of football players with abnormal Torg/Pavlov ratios and found that 70% of players with abnormally small Torg/Pavlov ratios had normal-sized cervical spinal canals.\[29\] These findings are explained by the fact that football players have abnormally large vertebral bodies. This fact makes the denominator in the Torg/Pavlov ratio larger, and the ratio value is artificially decreased, resulting in a false positive. Additionally, Herzog found no correlation between a Torg/Pavlov ratio of 0.8 and any transient neuropraxia or permanent neurologic deficits. Castro et al, in the American Journal of Sports Medicine, illustrated that cord diameter also varies, and it is the relative difference between the canal size and the cord diameter that creates the clinical condition of stenosis.

SGY: Note the high “false-positive” rate & the recommended cord diameter / canal size option
This is a schematic representation of White and Panjabi's description of abnormal angulation. The finding of abnormal angulation greater than 11° between supra-adjacent and subadjacent cervical motion segments on a static lateral cervical spine (C-spine) radiograph is considered unstable. The basic mathematical formula to analyze this is as follows: The angle of the motion segment in question minus the angle of the supra-adjacent segment or the subadjacent motion segment. The difference is less than 11° in the normally stable C-spine. In this image, the formula is illustrated by the following examples: For the supra-adjacent level: 30° - (-8°) = 38°. 38 > 11. For the subadjacent level 30° - (-4°) = 34°. 34 > 11.
C-Instability/AOMSI:

1) > 20% translation anterior OR posterior on FL or Ext XR
2) > 11° on FL only XR
3) Fusion/disc arthroplasty

Cervical spine AOMSI is defined using flexion/extension X rays (Figures 17-5 and 17-6 describe similar technique for lumbar spine). A diagnosis of AOMSI in the cervical spine by translation measurements requires greater than 20% anterior or greater than 20% posterior relative translation of one vertebra on another, on flexion or extension radiographs, respectively; or angular motion of more than 11° greater than each adjacent level on the flexion radiograph. Alternatively, there may be complete or near-complete loss of motion of a motion segment due to developmental fusion; successful or unsuccessful attempts at surgical arthrodesis, including dynamic stabilization; or preserved motion with disk arthroplasty.
Method 1

Lines are drawn along the superior border of the vertebral body of the lower vertebrae and the superior border of the body of the upper vertebrae and the lines extended until they join. The angles are measured and subtracted. Note that lordosis (extension) is represented by a negative angle and kyphosis (flexion) by a positive angle. Loss of motion segment integrity is defined as motion greater than 15° at L1–2, L2–3, and L3–4 and greater than 20° at L4 to L5. Loss of integrity of the lumbosacral joint is defined as angular motion between L5 and S1 that is greater than 25°. The flexion angle is +8° and the extension angle is −18°. In the illustration, the flexion angle is +8°. Therefore (+8) − (−18) = 26° and would qualify for loss of structural integrity at any lumbar level.

**NOTE**: L-spine is different! FL – EXT (vs. FL only XR in C-spine)
**Lumbar spine AOMSI** is defined using flexion/extension X rays (Figures 17-5 and 17-6). A diagnosis of AOMSI in the lumbar spine (L1-L5) by translation measurements requires greater than 8% anterior or greater than 9% posterior relative translation of one vertebra on another, on flexion or extension radiographs respectively. In the lumbosacral spine (L5-S1), it requires greater than 6% anterior or greater than 9% posterior relative translation at L5-S1 of L5 on S1 on flexion or extension radiographs, respectively. A diagnosis of AOMSI in the lumbosacral spine by angular motion measurements requires greater than 15° at L1-2, L2-3, and L3-4; greater than 20° at L4-5, or greater than 25° at L5-S1 (compared with adjacent level angular motion).

Alternatively, there may be complete or near-complete loss of motion of a motion segment due to developmental fusion or to successful or unsuccessful attempts at surgical arthrodesis; including dynamic stabilization; or preserved motion with disk arthroplasty.

Some relevant information on selected clinical tests is provided in the following subsections.
Loss of Motion Segment Integrity

A motion segment of the spine is defined as two adjacent vertebrae, an intercalated disk, and the vertebral facet joints. Loss of motion segment or structural integrity is defined as abnormal back-and-forth motion (translation) or abnormal angular motion of a motion segment with respect to an adjacent motion segment.

The loss of integrity is defined as an anteroposterior motion or slipping of one vertebra over another greater than 3.5 mm for a cervical vertebra or greater than 5 mm for a vertebra in the thoracic or lumbar spine (Fig. 62, at right), or a difference in the angular motion of two adjacent motion segments greater than 11° in response to spine flexion and extension (Fig. 63, at right). Motion of the spine segments is evaluated with flexion and extension roentgenograms. Loss of integrity of the lumbosacral joint is defined as an angular motion between L-5 and S1 that is 15° greater than the motion at the L-4, L-5 level.

Abnormal motion or translation is depicted in Fig. 62 (below). In that figure, if line A + line B > 5 mm, there is more than 5 mm of translation, which meets the criterion of loss of segmental integrity. The criterion for the cervical spine is that the translation is greater than 3.5 mm.

Figure 62. Loss of Motion Segment Integrity: Translation

Figure 63. Loss of Motion Segment Integrity: Angular Motion

*Source: ref 64.

*Source: ref 64.

Abnormal motion or translation is depicted in Fig. 62 (below). In that figure, if line A + line B > 5 mm, there is more than 5 mm of translation, which meets the criterion of loss of segmental integrity. The criterion for the cervical spine is that the translation is greater than 3.5 mm.

Loss of Motion Segment Integrity

DEFINITION:
A+B >3.5mm
translation in
FL + EXT
C-Spine Instability
OR, >11° on FL XR
ONLY!
CASE STUDIES
CASE 1: Name: LA; DOB: 8/14/1986, Age: 27; Sex: Female; X-ray #: 10356; Complaint: Mid-back, low back and neck pain of a chronic history; XR taken 2-19-2014

C5: 14°
C6: 1°
Net: 13°
13° > 11°
(neutral XR)
CASE 1: Name: L A; DOB: 8/14/1986, Age: 27; Sex: Female; X-ray #: 10356; Complaint: Mid-back, low back and neck pain of a chronic history; XR taken 2-19-2014

LOOK FOR:
1) SP widening
2) Angular rotation
3) Facet coverage
4) Translation
BB, DOB: 6/17/1987, Age: 26; Sex: Female; X-ray #: 10345; Complaint: Chronic low back and mid back pain arising from a 3/17/10 motor vehicle collision.
CASE 2: BB, DOB: 6/17/1987, Age: 26; Sex: Female; X-ray #: 10345; Complaint: Chronic low back and mid back pain arising from a 3/17/10 motor vehicle collision.
### Unstable Definition
- > 11° rotation
- >20% translation

<table>
<thead>
<tr>
<th>Spinal Levels</th>
<th>Final Angle Measured</th>
<th>Translation (&gt;20%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2/3</td>
<td>9°</td>
<td>NA</td>
</tr>
<tr>
<td>C3/4</td>
<td>12°</td>
<td>11% / 2mm = WNL</td>
</tr>
<tr>
<td>C4/5</td>
<td>3°</td>
<td>NA</td>
</tr>
<tr>
<td>C5/6</td>
<td>8°</td>
<td>NA</td>
</tr>
<tr>
<td>C6/7</td>
<td>10°</td>
<td>NA</td>
</tr>
</tbody>
</table>

CASE 2: BB, DOB: 6/17/1987, Age: 26; Sex: Female; X-ray #: 10345; Complaint: Chronic low back and mid back pain arising from a 3/17/10 motor vehicle collision.
FRONTAL PLANE STRESS XR

- RT & LT Lateral Flexion APOM
The Alar Ligaments

1. Alar Ligaments
2. Apical Ligament

Lateral Atlas-Dens Interval (see article next slide: LMI/LADI >4mm = abnormal!)
Construct Validity of Clinical Tests for Alar Ligament Integrity: An Evaluation Using Magnetic Resonance Imaging

Abstract

The alar ligaments are integral to limiting occipito-atlanto-axial rotation and lateral flexion and enhancing craniovertebral stability. Clinical testing of these ligaments is advocated prior to the application of some cervical spine manual therapy procedures. Given the absence of validation of these tests and the potential consequences if manipulation is applied to an unstable upper cervical spine segment, exploration of these tests is necessary. The purpose of this study was to examine the direct effect of the side-bending and rotation stress tests on alar ligaments using magnetic resonance imaging (MRI). This was a within-participant experimental study. Sixteen participants underwent MRI in neutral and end-range stress test positions using proton density-weighted sequences in a 3-Tesla system.

Measurements followed a standardized protocol relative to the position of the axis. Distances were measured from dens tip to the inferior margin of the foramen magnum and from midsubstance of the dental attachment of the ligament to its occipital insertion. Between-side differences were calculated for each measurement to account for inherent asymmetries in morphology. Differences were compared between the test and neutral positions using a Wilcoxon signed rank test. Side-bending stress tests produced a median between-side difference in ligament length of +1.15 mm. Rotation stress tests produced a median between-side difference in ligament length of +2.08 mm. Both results indicate increased measurement of the contralateral alar ligament. Limitations Assessment could be made only in the neutral position due to imaging limitations. Clinical texts state that tests should be performed in 3 positions: neutral, flexion, and extension. Both side-bending and rotation stress testing result in a measurable increase in length of the contralateral alar ligament. This finding is consistent with mechanisms that have been described to support their use in clinical practice.

Alar Ligament MRI Study

ABSTRACT SUMMARY:

- Alar Lig: Side-bending & Rotation Stress (n=16)
  - Lat. Fl: 1.15 mm (mean from neutral distance)
  - Rotation: 2.08 mm (mean from neutral distance)

- Clinical texts state stress XR should be N, FL, Ext

- This study supports LF & Rotation stress XR
Alar Ligament MRI Study (see Handout)

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Construct Validity of Clinical Tests for Alar Ligament Integrity

Figure 2.
(A) Measurement from the tip of the odontoid process to the inferior margin of the foramen magnum indicated by the arrow. (B) Direct estimation of alar ligament length. A line corresponding to the axis of the ligament (indicated by the arrow) is generated and measured between origin midpoint and insertion into the occiput.

Alar Ligament MRI Study (see Handout)

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Figure 3.
The alar ligaments (circled) following imposition of the side-bending stress test.
**Summary of Findings Following the Examination of Alar Ligament Stress Testing.**

Table 2. Summary of Findings Following the Examination of Alar Ligament Stress Testing

<table>
<thead>
<tr>
<th>Position</th>
<th>Median</th>
<th>IQR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>0.02</td>
<td>−0.05 to 0.23</td>
</tr>
<tr>
<td>Side bending</td>
<td>0.85</td>
<td>0.10 to 2.52</td>
</tr>
<tr>
<td>Rotation</td>
<td>1.44</td>
<td>0.76 to 1.90</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th></th>
<th>Left-Right Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance Tip of Odontoid Process to Foramen Magnum (mm)</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>IQR</td>
</tr>
<tr>
<td>Neutral</td>
<td>−0.05</td>
</tr>
<tr>
<td>Side bending</td>
<td>1.15</td>
</tr>
<tr>
<td>Rotation</td>
<td>2.08</td>
</tr>
</tbody>
</table>

<p>| Direct Measurement of Alar Ligament Length (mm) |                      |</p>
<table>
<thead>
<tr>
<th>Median</th>
<th>IQR</th>
<th>P Value for Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>−0.05</td>
<td>−0.17 to 0.36</td>
<td></td>
</tr>
<tr>
<td>1.15</td>
<td>0.58 to 1.67</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>2.08</td>
<td>1.09 to 2.60</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

\[IQR = \text{interquartile range.}\]

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Intraclass Correlation Coefficients (ICCs) for the Left-Right Difference in Alar Ligament Length Measurements.

**Table 3.**
Intraclass Correlation Coefficients (ICCs) for the Left-Right Difference in Alar Ligament Length Measurements

<table>
<thead>
<tr>
<th>Position</th>
<th>Left-Right Difference Assessed</th>
<th>ICC</th>
<th>95% CI*a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>Odontoid process to foramen magnum</td>
<td>.85</td>
<td>.63 to .95</td>
</tr>
<tr>
<td></td>
<td>Direct measurement of ligament length</td>
<td>.81</td>
<td>.54 to .93</td>
</tr>
<tr>
<td>Side bending</td>
<td>Odontoid process to foramen magnum</td>
<td>.63</td>
<td>.24 to .86</td>
</tr>
<tr>
<td></td>
<td>Direct measurement of ligament length</td>
<td>.83</td>
<td>.58 to .94</td>
</tr>
<tr>
<td>Rotation</td>
<td>Odontoid process to foramen magnum</td>
<td>.68</td>
<td>.29 to .88</td>
</tr>
<tr>
<td></td>
<td>Direct measurement of ligament length</td>
<td>.62</td>
<td>.22 to .85</td>
</tr>
</tbody>
</table>

*a CI=confidence interval.*

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CASE 3: CE
DOB: 12-10-91; DOI: 8-15-09 MVC
Frontal Plane C1/2 Left Lateral Flexion Stress X-ray

**5mm LT and 3mm RT Lateral ADI (& notice the C1 lateral mass translation)**
CASE 3: CE DOB: 12-10-91; DOI: 8-15-09 MVC

Frontal Plane C1/2 Right
Lateral Flexion Stress X-ray

**4mm LT and RT Lateral ADI**
LADI within ± 2 mm

Joint "spaces"
1-2 mm
2-3 mm

No overhang
Frontal Plane C1/2 Left Lateral Flexion Stress X-ray

** 3mm of C1 overhang over C2
Defining and Detecting Missed Ligamentous Injuries of the Occipitocervical Complex

Chaput, Christopher D. MD; Walgama, Jonathan BS; Torres, Erick BS; Dominguez, David MD; Hanson, Jeramie BS; Song, Juhee PhD; Rahm, Mark MD

Abstract

Study Design. Retrospective radiographic and clinical review of patients in a comprehensive trauma database.

Objective. The primary aim of this study was to detect occipitocervical complex (OCC) injuries initially missed at a level 1 trauma center.

Summary of Background Data. Recent case series demonstrate that OCC injuries are potentially survivable. Delay in diagnosis can lead to increased morbidity and mortality.
Methods. Normative maximum values that included 97.5% of the population were defined, with a sample of 251 consecutive normal computed tomographic (CT) scans for the Basion-Dens Interval (BDI), atlantooccipital interval, and lateral mass interval (LMI) of C1–C2. Subsequently, 844 cervical CT scans from consecutive polytrauma patients were reviewed for the evidence of OCC injury. Measurements greater than the normative maximum values were considered suspicious for injury. A BDI greater than 12 mm or a BDI greater than 10 mm with a confirmatory magnetic resonance imaging was considered a definite evidence of an OCC injury, as was an LMI 4 mm or greater with confirmatory magnetic resonance imaging. The electronic medical record was reviewed to determine whether an injury was detected on any final neuroradiology report or during follow-up.

Results. Five patients had evidence of atlantooccipital dissociation (AOD), and two had atlantoaxial dissociation (AAD). Of these, three cases of AOD and two cases of AAD were missed on the final report by the neuroradiologist. The undiagnosed patients were subsequently diagnosed by orthopedic surgeons consulted for axial spine or other musculoskeletal trauma. No patients who were diagnosed with AAD or AOD in the electronic medical record were missed by using the criteria of BDI greater than 10 mm and LMI 4 mm or greater to define OCC injuries.

Conclusion. OCC injuries can be missed even with standardized multidetector CT with multiplanar reconstructions. High-quality normative data used to determine a reliable picture archiving and communication system-based measurement of the OCC anatomy can detect ligamentous injuries initially missed in polytrauma patients.
How many OCC injuries have we missed???

Spine:
20 April 2011 - Volume 36 - Issue 9 - p 709–714
doi: 10.1097/BRS.0b013e3181de4ec1
Cervical Spine

Defining and Detecting Missed Ligamentous Injuries of the Occipitocervical Complex
Chaput, Christopher D. MD; Walgama, Jonathan BS; Torres, Erick BS; Dominguez, David MD; Hanson, Jeramie BS; Song, Juhee PhD; Rahm, Mark MD

Conclusion. OCC injuries can be missed even with standardized multidetector CT with multiplanar reconstructions. High-quality normative data used to determine a reliable picture archiving and communication system-based measurement of the OCC anatomy can detect ligamentous injuries initially missed in polytrauma patients.
Ortho tests for the Alar Ligament? (see Handouts)

Osmotherly G, Rivett D, Rowe LJ. Toward understanding normal craniocervical rotation occurring during the rotation stress test for the alar ligaments. Phys Ther 2013;93:986-992
Osmotherly G, Rivett D, Rowe LJ. Toward understanding normal craniocervical rotation occurring during the rotation stress test for the alar ligaments. Phys Ther 2013;93:986-992
Ortho tests for the Alar Ligament? (see Handouts)

**Design.** A within-subject experimental study was conducted.

**Methods.** Sixteen participants underwent magnetic resonance imaging in neutral and end-range rotation stress test positions. Measurements followed a standardized protocol relative to the position of the axis. A line connecting the transverse foramina of the axis created a reference plane. The position of the occiput in the head-neutral position was calculated as the angle formed between a line joining the foramina lacerum and the reference plane. Measurements were repeated at the end-range test position. Total rotation of the occiput was calculated as the difference in angles measured in neutral and test positions. Measurement was performed on 4 occasions, and reliability of measurements was assessed using the standard error of measurement (SEM) and the intraclass correlation coefficient (ICC).

Osmotherly G, Rivett D, Rowe LJ. Toward understanding normal craniocervical rotation occurring during the rotation stress test for the alar ligaments. Phys Ther 2013;93:986-992
**Results.** Measurement of rotation of the occiput relative to a stabilized axis ranged between 1.7 and 21.5 degrees ($\bar{X}=10.6$, SD=5.1, SEM=1.14, ICC=.96, 95% confidence interval= .90-.98).

**Limitations.** Sustaining the test position for imaging increased the potential for loss of end-range position and image quality. Testing could be performed only in the neutral position, not in 3 planes as commonly described.

**Conclusions.** The range of craniocervical rotation during rotation stress testing of intact alar ligaments should typically be 21 degrees or less. Rotation may be quantified using the method protocol outlined.
Ortho tests for the Alar Ligament? (see **Handouts**)

**Figure 1.**
Stabilization of the axis (view from superior aspect). The therapist’s thumb and index finger provide broad contact around the neural arch of the axis. The hand is “cupped,” and the thumb is adducted.

**Fig. above from:** Osmotherly PG, Rivett D, Rowe LJ. Toward understanding normal craniocervical rotation occurring during the rotation stress test for the alar ligaments. Phys Ther 2013;93:986-992

**Figure 1.**
Patient position in standard neck coil for side-bending testing during imaging.

**Fig. above from:** Osmotherly PG, Rivett DA, Rowe LJ. Construct validity of clinical tests for alar ligament integrity: An evaluation using magnetic resonance imaging. Phys Ther 2012;92:718-725.
Many more Ortho tests for the Alar Lig:
See: “examination_of_the_cervical_spine” PDF in Handouts (WAD 4)

This has MANY motion palpation methods to assess occipito-atlantal-axis ligament integrity (see pp135-! An EXCELLENT RESOURSE (not enough time to cover in today’s webinar.

SEE HANDOUTS!
Case 4: Michael L. 37yo M

WAD Injury
INITIAL EXAMINATION 2-25-13

Michael 2-25-13 SOAP

2-25-13

SUBJECTIVE:
COMPLAINT #1: Neck
MECHANISM OF INJURY: Martial Arts instructor; numerous MVC's (about 12x - worse injury = concussion, roll overs, all recovered within 3 days). He states he was diagnosed with borderline Narcolepsy since about age 18 or 19 yrs old (when he started driving). He takes the Rx: Provigual which reportedly keeps him from falling asleep behind the wheel. He used to drink a lot of caffeine but no longer has to with the prescription. 
Riding = falls asleep within 5-10 min., can't watch a whole movie.
ONSET: 2-3 weeks ago.
PAIN PROVOCATION: Turning head.
PALLIATIVE MEASURES: Stretches neck.
QUALITY: Michael describes the pain as achy and tight.
RADIATION / LOCATION: Michael denies radiation.
SEVERITY (0-10 scale): Michael was asked to rate his pain on a 0-10 pain scale in which 0 equals no pain and 10 equals unbearable pain. He currently rates his pain as a 2, on average a 2, best a 1 and at worst a 3.
TIMING: Michael feels the pain more in the morning.
PAST HISTORY: Has not had any x-rays, or has not seen anyone for this problem.
OUTCOMES ASSESSMENTS:
A **cervical Bournemouth questionnaire** was completed by the patient. **Michael scored 20%**.
A patient specific functional and pain scales (PSFS) questionnaire was filled out by **Michael** which requests the patient to list up to 3 activities that he is unable to perform or is having difficulty with as a result of their chief complaint. **He listed the following activities: nothing.** Each activity is rated on a 0-10 scale with 10 being unable and 0 being able to perform. **Michael scored 0% on this questionnaire.**
A **severity Index/Yellow Flags Questionnaire** was completed by Mr ____________ This questionnaire evaluates pain, psycho-social, function and fear avoidance issues. **He scored 13 points**. This places the patient at **low risk for chronic disability (< 55 points).**

RED FLAGS:
No Red Flags for infection, Ex, Cx or Cauda Equina

ROUTINE/ACTIVITY PERFORMANCE RATING:
Not filled out

PREVIOUS INJURIES:
Auto: 2 MVA - concussions (12+MVCs, most without injury)
Work Related: None reported
Personal: Shot in hand with a BB gun. Had surgery to have BBs removed

GENERAL STATE OF HEALTH:
OBJECTIVE:

VITAL SIGNS:
Sex: Male
Age: 37
Temperature: 98.2 degrees Fahrenheit.
Respiratory Rate: 12 breaths per minute and was observed to be normal.
Pulse: 64 bpm, rhythm was regular and amplitude was normal.
Blood Pressure: 138/80mmHg sitting on the right.
Height: 66 inches.
Weight: 204 LBS.

OBSERVATION: Postural examination reveals elevation of the right iliac crest, right shoulder and right occiput. Moderate hesitation is noted when transitioning from sitting to standing. Moderate pain behavior was noted in today’s examination.

PALPATION: Joint fixation/dysfunction with moderate tenderness is noted at the spinal levels of C2-4; T6 - 8, T12/L1, L4/5, and bilateral sacroiliac joints. Muscle tightness and moderate tenderness with trigger points are noted in the upper trapezius, levator scapulae, and anterior scalene musculature, bilaterally greater on the right with firm palpation. Pain/tightness is noted in the erector spinae, sacrospinalis, and quadratus lumborum musculature bilaterally equal.

ORTHOPEDIC TESTS: Cervical distraction reduces neck pain. Maximum cervical rotatory compression increases moderate pain on the right side of the neck when performed on the right at 40% of expected range. Kemp’s Test elicits low back pain at approximately 50% of the expected range without lower extremity radiation of pain when performed on the right side only. SLR is limited by hamstring tension > LBP at 50° without evidence of nerve root entrapment. Hip extension/Yeomans test elicits more lumbosacral than sacroiliac pain at 30% left, 40% right of the expected range of motion with moderate pain elicited without radiation. Patrick Fabere test is negative for hip or low back pain.
for hip or low back pain.

RANGE OF MOTION: (actively perform/visually measured):

Cervical ROM: flexion 40/50° tight>pain; extension 45/63° reproducing mid and right upper cervical pain rated 3/4; left lateral flexion 35/45°; right lateral flexion 30/45°; left rotation 70/85°; right rotation 60/85°. No radiation of symptoms into the upper extremities was noted during the cervical range of motion exam.

Lumbar ROM: flexion 55/65° which reportedly "feels good"; extension 15/30° increases low back pain graded 3/4 right L4-5 and lumbosacral; left lateral flexion 20/25°; right lateral flexion 15/25° pinching on the right L4-5. No radiation of symptoms were noted into the lower extremities during the lumbar range of motion exam.

NEUROLOGICAL TESTS: Neurological examination of the C5 through T2 and L2-S2 nerve roots utilizing deep tendon reflex, muscle strength, and sensory perception testing failed to reveal any signs of motor paresis or sensory dysesthesia. More specifically, upper and lower extremity deep tendon reflexes are 2/5 and symmetrical, myotomes are symmetrically normal at 5/5 muscle grades, and sensation is symmetrically intact to pinwheel examination in the upper and lower extremities. Babinsky signs were absent with normal downward plantar responses. Cerebellar and cerebral functions are intact. Cranial nerves II through XII are symmetrically intact and normal.

X-RAY: Please refer to the x-ray report regarding radiographic findings. In summary, left leg length deficiency with compensatory sacral left inferior inclination measuring 5° compensatory levo rotoscoliosis measuring 5° between T12 and S1. The sacral base angle is accentuated at 50° with a forward shift of the weight-bearing line. Advanced one level C5-6 degenerative disc disease with flexion angular rotation which is acute measuring 18° compared to adjacent angles is present with...
ASSESSMENT:
Cervical sprain/strain and myofascial pain superimposed on pre-existing degenerative disc disease with a rather acute kyphosis at C5-6. Spinal joint dysfunction is noted in the cervical, thoracic, lumbar and sacroiliac spinal regions. Lumbar sprain/strain of the posterior facet joints is noted.
Diagnosis:

Complicating factors include: A past history of more than 4 prior episodes; symptoms exceeding one week prior to presenting; severe pain intensity; a new injury superimposed on pre-existing structural pathology; and symptoms exceeding one month in spite of treatment.

Short-term goals: Decrease pain, increase range of motion, and decrease muscle spasm, 50% over the next 30 days. Please refer to the outcome assessment tools for a patient specific set of goals.
Long-term goals: Functional restoration, initiate a home/active care, a guided rehabilitation/strengthening program.

PLAN:
TREATMENT PLAN: The frequency of the care will be initiated at 3 times per week for 2 – 4 weeks, dependent on the patient’s response to management.
CARE PLAN: Care will consist of spinal manipulation of the fixated joints noted in the objective portion of the office note. Neuromuscular reeducation will include contract hold with a slow, coordinated, eccentric isotonic active release approach applied to the tight/short muscles described in the objective portion of the office note. Myofascial release will include eccentric stretch with longitudinal and transverse friction massage with Biofreeze applied to the tight/short muscles and trigger point zones. Physical therapy modalities will be utilized as indicated. Exercise training will take place when the patient’s condition is at a safe point in healing to initiate active care.

I have informed this patient regarding risks, benefits and treatment alternatives to the above stated plan. The patient has had the opportunity to discuss the options and has agreed to the above plan.
CARE PLAN: Care will consist of spinal manipulation of the fixated joints noted in the objective portion of the office note. Neuromuscular reeducation will include contract hold with a slow, coordinated, eccentric isotonic active release approach applied to the tight/short muscles described in the objective portion of the office note. Myofascial release will include eccentric stretch with longitudinal and transverse friction massage with Biofreeze applied to the tight/short muscles and trigger point zones. Physical therapy modalities will be utilized as indicated. Exercise training will take place when the patient's condition is at a safe point in healing to initiate active care.

I have informed this patient regarding risks, benefits and treatment alternatives to the above stated treatment plan. The patient has had the opportunity to have questions asked and answered and gives consent to treatment.

Treatment performed today included:
1. SPINAL MANIPULATION: C2/3/5, T6-8 anterior, L4/5, and bilateral SI joints using high velocity/low amplitude diversified manipulation with associated joint cavitation obtained with good patient tolerance reported.
2. NEUROMUSCULAR REHABILITATION: Slow, coordinated eccentric and concentric isotonic resistance was applied to the hamstrings, iliopsoas, piriformis, thoracolumbar paraspinal musculature and upper trapezius musculature.
3. MFR / Myofascial release: Longitudinal and transverse friction massage with the use of Biofreeze was applied to the paraspinal cervical, upper trapezius, levator scapula, and anterior scalene musculature. In addition, thoracolumbar paraspinal musculature longitudinal friction massage.
4. PT: Electrical physical therapy: Ice/IFC 80-120 cps/15 minutes was utilized in the cervicothoracic region.
5. HOME THERAPIES: Cervical and lumbar range of motion and fiber stretching exercises will be given when clinically indicated; the use of ice at 15 minute rotations as needed; no restrictions will be placed on his athletic desires since he feels best when active.

Time spent face-to-face with patient 46 minutes. Dr. Steven G. Yeomans, DC, FACO
TREATMENT HISTORY: 2/27; 3/1, 4, 6 / 2013 (4x)

3/6/2013

Subjective:

**COMPLAINT # 1: Neck**
Tired from working with a coded patient today (CHN).
Location: neck
Quality: Stiffness more than pain is reported
Progress: much better
Pain scale: 0/10 average 0/10, best 0/10, worst 0/10.
Frequency: 0%
Timing: all day
Provocative: nothing
Palliative: Chiropractic treatments, exercises, stretching and a hot bath
Response after last therapy: felt better

**COMPLAINT # 2: Low back**
Location: low back
Quality: pain free currently
Progress: much better
Pain scale: 0/10, average 0/10, best 0/10, worst 0/10.
Frequency: 0%
Timing: all day
Provocative: nothing - even doing chest compressions today
Palliative: nothing specific
Response after last therapy: felt better

(LAST VISIT)
Objective:

OBSERVATION: Postural examination reveals elevation of the right iliac crest, right shoulder and right occiput. Less hesitation is noted when transitioning from sitting to standing. Less pain behavior was noted in today’s examination. Good treatment response was observed.

PALPATION: Joint fixation/dysfunction with mild/less tenderness is noted at the spinal levels of C2-4; T6 - 8, T12/L1, L4/5, and bilateral sacroiliac joints. Muscle tightness and moderate tenderness with trigger points are noted in the upper trapezius, levator scapulae, and anterior scalene musculature, bilaterally greater on the right with firm palpation. Pain/tightness is noted in the erector spinae, sacrospinalis, and quadratus lumborum musculature bilaterally equal.

ORTHOPEDIC TESTS: Cervical distraction reduces neck pain. Maximum cervical rotatory compression reproduces mild pain on the right side of the neck when performed on the right at 70% (improving) of expected range. Kemp’s Test elicits low back pain at approximately 75% (improved) of the expected range without lower extremity radiation of pain when performed on the right side only. SLR is limited by hamstring tension > LBP at 50° without evidence of nerve root entrapment. Hip extension/Yeomans test elicits more lumbosacral than sacroiliac pain at 40% left, 50% right of the expected range of motion with moderate pain elicited without radiation. Patrick Fabere test is negative for hip or low back pain.

RANGE OF MOTION: Not retested today. Patient is lumbar and cervical flexion bias.

NEUROLOGICAL TESTS: There are no focal motor or sensory neurological losses in the upper or lower extremities.

X-ray: Please refer to the x-ray report regarding radiographic findings. In summary, left leg length deficiency with compensatory sacral left inferior inclination measuring 5° compensatory levo
torescoliosis measuring 5° between T12 and S1. The sacral base angle is accentuated at 50° with a
Assessment:
Improvements are noted with less inflammatory signs. The patient is improving with better activity tolerance/ADLs.
Diagnosis:

Plan:
TREATMENT PLAN: The frequency of the care will be continued at 3 times per week for 2 -- 4 weeks, dependent on the patient's response to management.

Treatment performed today included:
1. SPINAL MANIPULATION: **C2/3/5** (C2 LP = RTC pain 3-4-13), T6-8 anterior, L4/5, **and bilateral SI joints** using high velocity/low amplitude diversified manipulation with associated joint cavitation obtained with good patient tolerance reported.
2. NEUROMUSCULAR REHABILITATION: Slow, coordinated eccentric and concentric isotonic resistance was applied to the hamstrings, iliopeas, piriformis, thoracolumbar paraspinal musculature and upper trapezius musculature.
3. MFR / Myofascial release: Longitudinal and transverse friction massage with the use of Biofreeze was applied to the paraspinal cervical, upper trapezius, levator scapula, and anterior scalene musculature. In addition, thoracolumbar paraspinal musculature longitudinal friction massage
4. PT: PEMF 3-4-13; 3-1-13: IF/US COMBO; 2-25-13: Electrical physical therapy: Ice/IFC 80-120 cps/15 minutes was utilized in the cervicothoracic region.
5. HOME THERAPIES: Cervical and lumbar range of motion and fiber stretching exercises will be given when clinically indicated; the use of ice at 15 minute rotations as needed no restrictions will be placed on his athletic desires since he feels best when active.

2-27-13: Considering new foot orthotics (abnormal foot scans today) - his old orthotics are rigid and the rear foot post is unstable. He indicated that he had significant medial calcaneal pain which required cortisone injections for which the foot orthotics helped significantly. He recently obtained new shoes 4 months ago and has not used them since and has suffered negatively. He has worn orthotics for over 5 years. Consideration for flexible functional orthotics versus rigid orthotics was discussed and he will discussed this with his spouse.

Time spent face-to-face with patient 22 minutes. Dr. Steven G. Yeomans, DC, FACO
Case 4:
2-25-2013
ML 37yoM
Case 4:
2-25-2013
ML 37yoM
Case 4:
2-25-2013
ML 37yoM
Case 4:
2-25-2013
ML 37yoM
Impressions:

1. There is a rather acute kyphosis noted between C3 and 5 with advanced degenerative C5-6 changes. This produces an S-shaped sagittal cervical curve - kyphotic between C2 and 5 and the lordotic between C5 and 7.
2. Extension reveals hypomobility with a linear C2-5 pattern and accentuated lordosis between C5 and 7.
3. Vacuum phenomenon is noted in extension at C5-6 with failure to approximate the C5-6 interspinous space with corresponding excessive widening in flexion supporting abnormal spinal biomechanics.
4. Flexion reveals excessive angular rotation at C4-5 measuring 18° compared to -4° at the motor unit below and 8° at the motor unit above.
5. Right spinal listing with a 3° right lateral flexion malposition of C6 is noted and uncinate arthrosis reveals some blunting of the right C5 and left C6 uncinate process.
6. Grade 1 levolaterality of C1 with grade 1-2/4 dextrorotation of C2 is noted.
7. There are no signs of fracture or dislocation and bone density appears normal.

X-rays read and dictated by Steven G. Yeomans, DC, FACO
Case 4:
2-25-2013
ML 37yoM
2-25-2013 ML 37yoM

SUMMARY

- Significant past Hx: 12 MVC’s (all “quick” recoveries – within 3 days); martial artist
- NOT severe: Pain: 1-3/10; C-BQ: 20%; YFQ: 13% (<45 = low risk of prolonged recovery)
- Complicating factors: Significant
- XR Findings: Significant
- Treatment Outcome: RESOLVED (only 4 visits in <2 weeks)
- UNUSUAL CASE!!!
Is MRI a sensitive tool for assessing clinical changes? Answer: NO
SIDE BAR:
NEW STUDY re: NDI!
SIDE BAR: NEW NDI STUDY!

- NDI Score of 15-21% = recovered in WAD
- SGY correlate w/: Use Patient’s Global Impression of Change to validate! (“Very Much Improved”): (See Documentation Handouts / Next Slide)
PGIC

- Use at re-exams & discharge
- Compare to scores of other OATs
- Score of 1 or 2 = 50% & 30% improvement, respectively

Patient’s Global Impression of Change (PGIC)

Since the start of my care at this clinic, my overall status is:

1. □ Very Much Improved
2. □ Much Improved
3. □ Minimally Improved
4. □ No Change
5. □ Minimally Worse
6. □ Much Worse
7. □ Very Much Worse

NDI Score of 15-21% = recovered in WAD; SGY rec: Use PGIC to validate! (“Very Much Improved”): See Documentation Handouts or “GOOGLE” for the 7-item PGIC
Questions and Answers