

Cervical Spine: Postmortem Assessment of Accident Injuries Comparison of Radiographic, MR Imaging, Anatomic, and Pathologic Findings

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Axel Stähler, MD, Jurik Eck, MD, Randolph Penning, MD, Stefan P. Milz, MD, Reiner Bartl, MD, Donald Resnick, MD and Maximilian Reiser, MD

FROM ABSTRACT

PURPOSE:

To assess the ability of postmortem radiography and magnetic resonance (MR) imaging to depict occult cervical spine injuries as compared with anatomic and pathologic findings.

MATERIALS AND METHODS:

The cervical spines of 10 adult accident victims underwent radiography and MR imaging, with T1-weighted, fast spin-echo T2-weighted, and four gradient-echo pulse sequences.

The frozen specimens were cut into 3-mm-thick slices (sagittal plane) and photographed, and microfocus radiographs were obtained.

Imaging findings were compared with the anatomic and pathologic findings.

RESULTS:

Eight of the 10 specimens had 28 posttraumatic lesions: three fractures (two missed at the initial MR imaging reading), 10 facet joint capsule lesions with bleeding, five soft-tissue and ligament lesions, eight disk lesions, and two spinal cord lesions.

Radiography depicted one lesion (4%).

Two partial ruptures of the anterior annulus fibrosus were depicted at only MR imaging.

Initially, 11 of 28 lesions were detected on MR images; retrospectively, 17 of 28 lesions were correlated with anatomic findings.

CONCLUSION:

Soft-tissue and intervertebral disk and ligament injuries account for 89% (25 of 28) of posttraumatic cervical spine lesions detected on postmortem images.

Occult lesions, including apophyseal joint injuries, were found in clinically noninjured cervical spines.

MR imaging was limited in the depiction of discrete lesions when T1-weighted non-fat-saturated, fast spin-echo T2-weighted, and gradient-echo pulse sequences were used.

THESE AUTHORS ALSO NOTE:

"In acceleration or deceleration injuries, the cervical spine, with its wide range of motion and its relative lack of supporting structures, is a particularly susceptible site for injury."

Injuries of the cervical spine include lesions of the bone, ligaments, and soft tissue and these injuries are often occult.

The purpose of this study was to assess the ability of postmortem radiography and MR imaging, in comparison with anatomic and pathologic findings, to depict occult cervical spine injuries.

The cervical spine was removed from the cadavers of 10 consecutive accident victims (nine men, one woman; age range 19-67 years; mean age, 39.5 years) with craniocerebral injuries.

The clinical examination of the cadavers revealed that none had obvious cervical spine injuries.

AP, lateral, and oblique x-rays were exposed on each specimen.

MR images were obtained with a 1.5-T MR imager.

After imaging, the specimens were cut into 3-mm-thick slices along the sagittal plane, and evaluated.

The criteria for evaluation of the x-rays were cortical disruption for fractures, widening of the intervertebral disk space, and intervertebral joint or spinous process distance for diskoligamentous injuries.

The MR imaging evaluation included:

- 1) Anterior and posterior longitudinal ligaments were evaluated for continuity and increased signal intensity on T1-weighted, T2-weighted, and gradient-recalled echo MR images.
- 2) The intervertebral disks were reviewed for increased signal intensity on T2-weighted MR images and signal intensity changes on gradient-recalled echo MR images, as indicators for bleeding.
- 3) The bone structures were evaluated for cortical disruption as an indication of fracture and for signal intensity increase on T2-weighted MR images in the bone marrow as an indirect sign of bone lesions.

4) The intervertebral joints and surrounding soft tissues on T2-weighted MR images were also examined for fluid accumulations.

The anatomical slices were magnified and studied, with special focus on hemorrhage in the prevertebral muscles; rupture or bleeding of the anterior or posterior longitudinal ligaments; rupture or bleeding of the anterior or posterior annulus fibrosus or nucleus pulposus; bleeding into the uncovertebral and facet joints; and bleeding into the posterior muscles, ligamenta flava, ligamenta interspinosa, and ligamentum supraspinale. The spinal canal and spinal cord were also evaluated for bleeding.

RESULTS

The pathologic, radiographic, and MR imaging findings, including fractures and soft-tissue injuries.

28 posttraumatic lesions were found in eight of the 10 cervical spines.

Three (11%) of the 28 lesions were fractures.

Two of the three fractures were not seen on the radiographs of the whole specimen but were detected on the contact radiographs.

"Radiography depicted only one of the 28 lesions."

"Two of the three fractures were initially missed on the MR images."

"Two partial ruptures of the anterior annulus fibrosus near the anterior upper end plates of C4 and C5 were not identified in specimen 3; they were recognized only after correlation with the MR imaging findings."

"Only 11 of the 28 lesions were detected on the MR images during the initial blinded reading session."

"Seventeen of the 28 lesions were detected on MR images after direct correlation with the lesions confirmed at pathologic examination."

"MR images were negative for 11 of the 28 lesions found at pathologic examination, even when the exact location of the bleeding was known." **[WOW!]**

"Diskoligamentous disruption after a hyperextension injury was present in one specimen. Avulsion of the anterior longitudinal ligament and disk disruption were complete, while the posterior longitudinal ligament was only stretched."

"MR images tended to depict lesions of the disk, annulus fibrosus, and anterior longitudinal ligament better than lesions of the apophyseal joints and soft tissue."

"Lesions of the facet joints were detected only indirectly on the basis of depiction of fluid in the joint."

"Direct depiction of the ruptured apophyseal joint capsule was almost impossible."

DISCUSSION

"The cervical spine is susceptible to injuries during hyperextension or hyperflexion."

"Only 20% of cervical spine injuries are represented by a fracture; even in fatal cases, 80% of traumatic lesions are injuries of the soft tissues." **[IMPORTANT]**

A study of 22 traffic accident victims found 245 bone, diskoligamentous, and soft-tissue lesions of the cervical spine that were not detected on radiographs. **[WOW!]**
[Jónsson H, Bring G, Rauschnig W, Sahlstedt B. Hidden cervical spine injuries in traffic accident victims with skull fractures. J Spinal Disord 1991; 4:251-263]

Another study reported the cases of seven patients with hidden flexion injuries of the cervical spine that were not detected on radiographs.

[Webb JK, Broughton RBK, McSweeney T, Park WM. Hidden flexion injury of the cervical spine. J Bone Joint Surg Br 1976; 58:322-327].

"Findings in our comparison study confirmed these results."

"Twenty-five (89%) of 28 lesions detected during the study were injuries to soft-tissue structures, including the longitudinal ligaments, the disks, and the apophyseal joint capsules."

"Only three of the 28 lesions were fractures; two were missed on the radiographs."

Others note that fractures contributed to 20.0% - 22.7% of the injuries overall.

"Hyperextension injuries of the cervical spine are common and are associated with a risk of spinal cord compromise of variable degree even in the presence of normal radiographs." **[IMPORTANT]**

"Degenerated segments with fissuring of the disk expose the longitudinal ligament to increased loading forces and increased risk of hyperextension injury." **[IMPORTANT]**

"The spectrum of cervical hyperextension injuries ranges from muscle sprains to serious lesions, such as diskoligamentous disruption"

"In hyperextension injuries, both the anterior and posterior longitudinal ligaments are stretched or disrupted, the anterior longitudinal ligament more severely, which causes hemorrhage beneath the prevertebral fascia and occasional avulsion fragments from the anterior margin of the vertebra."

“Diagnosis of hyperextension injuries may be difficult because they often show only subtle radiographic abnormalities, even in severe or unstable lesions.”

“In young persons, a special form of lesion in the intervertebral segment can occur, with characteristic separation of the intervertebral disk from the vertebral end plate.”

“The annulus fibrosus itself can remain intact in a hyperextension injury, and a partial or complete avulsion of the fibro-osseous junction, including the hyaline cartilage end plate, can occur at the ossified ring apophysis.” **[rim lesion]**

“Incomplete lesions of the annulus fibrosus may also occur in whiplash injuries.”

“Incomplete avulsion of the anterior annulus fibrosus is responsible for the vacuum phenomenon.”

“This annulus cleft vacuum phenomenon after hyperextension injury of the cervical spine is located in the anterior portion of the annulus fibrosus and not in the center of the nucleus pulposus.”

In this study, the authors noted the anterior vacuum phenomenon on lateral MR images of the cervical spine in extension. Importantly, in this specimen, the anterior longitudinal ligament remained intact, and stability was preserved.

- 1) [Reymond RD, Wheeler RS, Parovic M, Block B. The lucent cleft, a new radiologic sign of cervical disc injury or disease. Clin Radiol 1972; 23:188-192].
- 2) [Resnick D, Niwayama G, Guerra J, Vint V, Usselman J. Spinal vacuum phenomenon: anatomical study and review. Radiology 1981; 139:341-348].
- 3) [Bohrer SP. The annulus vacuum sign. Skeletal Radiol 1986; 15:233-235].
- 4) [Bohrer SP. Acute traumatic vacuum sign (letter). AJNR Am J Neuroradiol 1986].

“Hyperflexion injuries of the cervical spine can cause partial or complete disruption of the posterior cervical complex, which comprises the posterior articulations stabilized by the joint capsule, interspinous and supraspinous ligaments, and ligamenta flava.”

“No clear border exists between maximal physiologic flexion and partial subluxation on lateral radiographs obtained in flexion and extension.”

“It is also difficult to decide whether the lesion is complete and unstable or only a partial tear without instability.”

An anterior subluxation can represent an unstable cervical spine injury.

"MR imaging has proved to be more accurate than conventional radiography in the depiction of a wide spectrum of neck injuries, because it is capable of direct depiction of disruption of the joint capsule of the apophyseal joints, the ligamenta flava, and the inter- and supraspinous ligaments."

In this study, "the most frequently injured sites were the apophyseal joints, and the most frequently missed lesions were in the posterior elements." **[IMPORTANT]**

"In conclusion, this correlation study of postmortem MR imaging, conventional radiographic, microfocus radiographic, and pathologic findings of cervical spines in accident victims confirmed the high frequency of associated cervical spine injuries after severe head injuries."

"In our study, nearly 89% (25 of 28) of the posttraumatic lesions were soft-tissue lesions; only three of the 28 lesions were fractures, and only one was visible on the radiographs."

"An incomplete hyperextension injury with incomplete rupture of the anterior annulus fibrosus was depicted at MR imaging."

"We presumed that this type of injury was responsible for a vacuum phenomenon (annulus cleft), which can be seen occasionally on lateral images of the cervical spine in extension obtained after acceleration injuries of the cervical spine."

"Findings in our study showed the limitations of MR imaging for depicting posttraumatic lesions of the lower cervical spine with gradient-recalled echo, T1-weighted, and non-fat-saturated fast spin-echo T2-weighted sequences."

"Various occult lesions, including many apophyseal joint injuries, which can also occur in survivors of vehicle accidents, were found on postmortem MR images obtained in clinically noninjured cervical spines." **[IMPORTANT]**

KEY POINTS FROM DAN MURPHY

- 1) Overall, 20% of cervical spine injuries are fractures, and 80% are injuries to the soft tissues.
- 2) In this study, 25 of 28 (89%) lesions found were injuries to soft-tissue, including the longitudinal ligaments, the disks, and the apophyseal joint capsules.
- 3) Only 3 of the 28 lesions were fractures, and two were missed on the x-rays. These 2 missed fractures were also initially missed on the MR images, but noted after the readers knew the fractures existed.
- 4) Overall, x-rays were pathetic, finding only one of the 28 lesions in this study.
- 5) MR imaging was superior to x-rays, but still initially found only 11 of the 28 lesions. After knowing the lesions were present, MR reading found an additional 6 lesions, but still not being able to find 11 of the 28 lesions found at pathologic examination, even when the exact location of the bleeding was known.
- 6) Hyperextension injuries of the cervical spine are common and increase the risk of spinal cord compromise, and the x-rays are usually normal.
- 7) Pre-accident degenerated spinal segments increase loading forces and increased the risk of hyperextension injury.
- 8) Hyperextension injuries can separate the annulus of the disc from the cartilaginous end-plate, especially in young victims.
- 9) The hyperextension injury annulus cleft vacuum phenomenon of the cervical spine is caused by an incomplete avulsion of the anterior annulus fibrosus.
- 10) A post-traumatic anterior subluxation represents an unstable cervical spine injury.
- 11) MR imaging is more accurate than conventional radiography in the depiction of a wide spectrum of neck injuries, but it still missed about 60% of the pathologic findings.
- 12) In this study, the most frequently injured site was the facet joints.
- 13) Various occult lesions, including many apophyseal joint injuries, occur in survivors of vehicle accidents.