

CORRELATIVE PATHOLOGY AND BIOMECHANICS OF CRANIOSPINAL INJURIES:
A POST-MORTEM STUDY OF FIFTY FATAL CASES AND A CLINICAL REVIEW
OF 300 TREATED CASES

With the apparent increased incidence of vehicular accidents, craniospinal injuries are becoming a more common occurrence.

Method

At the Baltimore City Medical Examiner's Office and the Johns Hopkins Hospital, a pathological study was carried out on fifty fatal craniospinal injuries. Complete autopsy was performed following vertebral arteriograms and roentgenograms with the cadaver in horizontal and suspended positions using head halter traction. The entire cervical spine, including the base of the skull, was removed en bloc from a posterior approach. Careful gross examination was carried out, followed by a midsagittal cut through the cervical spine made with a Stryker saw. The cut surfaces were inspected for disc and bony disruptions. Finally the brains and spinal cords with meninges were removed and fixed in formalin with appropriate histological preparations.

Pathological Findings

Injuries were not confined to the head or neck. Limb fractures were found in 21, chest injuries in 19, abdominal injuries in 13, with ruptured organs.

Craniospinal injuries occurred in combinations. Lesions of the brain were associated with cord pathology in 61% of the cases, and in 25% lesions of the skull and cervical spine were found together. Injuries of the cervical cord were associated with overt brain damage in 23 cases, and vertebral or ligamentous lesions in the same number. On the other hand, lethal lesions of the brain and cord occurred without bone damage to the skull or cervical spine. Table 1 summarizes the pathological findings.

As one might expect, the level of the injury was high in this fatal series, most commonly at C2.

Soft tissue injuries were the result of both extrinsic and intrinsic mechanical forces. Intrinsic forces were demonstrated by osseous or ligamentous damage, while external forces were revealed by scalp laceration, with or without skull fracture or brain damage. The musculature of the neck was frequently hemorrhagic, without frank tears, except at the level of bony injury. Retropharyngeal hematomas as large as 600 cc. were found in six persons. These hemorrhages were the result of tearing the small radicular vessels in the foramina.

Ligamentous injuries occurred in combinations rather than individually, attesting to the fact that multiple forces were involved rather than pure hyperextension or flexion injury seen

more commonly in the clinical series. Because the anterior and posterior longitudinal ligaments were usually torn together, (11 cases), this suggests that sequential flexion and extension forces are involved. In six cases, all of the ligaments between adjacent vertebrae were avulsed, and in one case the alar ligaments were torn from the occipital condyles, allowing dislocation of the atlas superiorly off of the odontoid process. The latter case illustrates longitudinal as well as flexion-extension vectors of force. The majority of ligamentous injuries occurred between the occiput and C2, which one would expect in these more severe injuries. Unexpectedly, the transverse ligament was torn in only one case.

Disc disruption was found in 38% of the cases and unrelated to the level of bony or spinal cord pathology. Pure disc protrusion was uncommon.

Fractures of the skull, especially basilar, were common (27), and were associated with craniospinal junction injuries, indicating that external forces were transmitted to the most mobile spinal level. Vertebral body fractures were less common (4) than in the clinical series, however, fracture dislocations between the occiput and C2 levels were frequent (11).

Pathological findings in the brain included intracerebral hemorrhages (25), contusions (20), and lacerations (11), and one subdural hemorrhage. The frontal region was involved most commonly with lacerations and contusions of the brain, and associated with signs of externally applied force to the same region.

The major pathological findings in the cervical cord and brainstem included contusions and lacerations in two-thirds of the fifty cases, associated with petechial hemorrhages (22) within the cord substance at the level of osseous or ligamentous injury. There were lacerations at the craniospinal junction in six cases, totally transecting the cord, indicating the severity of force concentrated at the occipito-cervical joint. Small epidural hemorrhages occurred in three cases.

Vascular lesions of the cervical area were uncommon with only one case each of thrombosis and tear of the vertebral artery. The small radicular arteries passing into the intervertebral foramina were frequently torn, causing local intramuscular hemorrhage.

Discussion

The most common pathological findings in this series were tears and disruptions of the intervertebral discs which could not be demonstrated in all cases radiologically. It is likely that disc disruptions occur commonly in the clinical situation associated with neck pain and no abnormal x-ray findings.

There was a greater percentage of upper cervical lesions attributable to the severity of these fatal injuries.

The high association of head and neck injuries emphasizes the concentration of forces at the craniospinal junction.

CLINICAL REVIEW OF 300 TREATED CASES

Following the above study of fifty fatal craniospinal injuries, a retrospective clinical review of 300 cervical spine injuries was carried out to determine factors surrounding the injury, methods of treatment and results. Seventy of the 300 patients died, and autopsy results were gathered on 42 cases that died acutely within three months of injury.

Approximately one-third of the injuries were automotive, one-third falls, and the remaining one-third were sports or missile wounds.

Mechanisms of injury were determined by the patient's history, and the nature of the head and neck trauma sustained, i.e. sites of lacerations and cervical fractures.

Seventy-one per cent (213) of the 300 patients struck their moving heads on a relatively stationary object, sustaining a deceleration force. Twenty-four or 8% were struck by missiles, and 63 (21%) did not strike their heads.

The known site of force applied in 198 out of 300 was frontal in 62, vertex in 55, occipital in 33 and parietal in 10. Multiple sites were involved in 20 cases. The anterior neck was struck in five and posterior in 13 patients.

Diving injuries occurred in 45 patients with vertex-flexion type forces applied. Twenty-eight of the 45 had vertebral body crush fractures and 17 had anterior facet subluxations without vertebral body fractures.

Vertex or axial compression force and frontal or extension force was associated with the highest number of bony fractures (181). Occipital or pure flexion force was associated with the next highest number of fractures (61). However, 63 patients did not injure their heads, indicating sufficient momentum at the craniospinal level to cause fractures in flexion or extension.

Pathological Findings

Disc disruptions or protrusions were diagnosed at operation in 26 cases, and in 80% of the 29 anterior operations. A flexion force of sufficient magnitude to crush a vertebral body was nearly always associated with a crushed disc.

Ligamentous injuries are difficult to ascertain in a clinical

situation unless there is overt distraction of bony structures by x-ray or direct visualization at operation. Thirty-two patients without fractures had anterior subluxations between C-2 and C-7 indicating ligamentous injuries posteriorly while atlanto-axial subluxations without fractures occurred in nine patients. In only one case out of 300 was the transverse ligament of the atlas torn with dislocation.

Seventy of the 300 patients died, and 42 autopsies were performed on the acute deaths that occurred within three months of injury.

The major causes of death in the 42 autopsied cases were spinal cord injury (19), sepsis (9), pulmonary emboli (5), and GI hemorrhage (5). Two died of brain injury and two of multiple injuries.

Arterial injury was rare with only one vertebral artery thrombosis found on pathological examination. The radicular arteries were grossly damaged and implicated in four cases of cord necrosis with facet dislocation secondary to flexion injuries.

Unfortunately, cervical soft tissue injuries were seldom documented at routine autopsy as they were in the author's study of fatal injuries. However, all of the central nervous system specimens were examined in detail, most by Dr. Richard Lindenberg, the neuropathologist at the Baltimore City Morgue. Grossly, the brain pathology in 42 cases consisted of twelve with swelling, seven with contusions or lacerations, six with subarachnoid hemorrhage, two with subdural hemorrhage, and three with intracerebral hemorrhage.

The spinal cord pathology analysis in the 42 autopsies is summarized in Table 2.

Epidural hemorrhage was only massive and compressing the cord in four cases -- all with Marie-Strumpell arthritis. Patients with Marie-Strumpell disease have massive scarring within the confines of the bony canal which tears epidural veins and the fractures through medullary bone of the ossified disc space causes more hemorrhage.

Necrotic softening was found in over one-half of the cases, indicating vascular damage. Contusions with or without lacerations were found in greater than one-half of the autopsies indicating a mechanical force applied to the cord at the time of injury.

In summary, there was a positive correlation of cervical cord pathology and cervical spine pathology in 94% of the autopsies. Brain pathology was associated with spinal cord

pathology in 38%. Of the total 300 cases, 60% had simultaneous head and neck injuries of some type.

Discussion

It appears that the gross vasculature and microvasculature play a major role in cervical cord injuries, in association with cord contusions of the original injury. Therefore both the osseous displacement compressing the cord and the forces applied at the time of injury are important. Early reduction of dislocations, and anterior decompression of vertebral body fragments or discs may prevent ischemia of the cord by restoring the radicular and microvascular blood supply.

Finally, there is a very high association between head and neck injuries; therefore, one should not be considered without relation to the other.

TABLE 1
SUMMARY OF PATHOLOGICAL FINDINGS

<u>Pathological Findings</u>	<u>No. of Cases</u>
Fractured skull only	24
Neck lesion only	36
Brain lesion only	38
Brain lesion plus spinal cord lesion	23
Brain lesion plus fractured skull	21
Brain lesion plus osseous ligamentous spinal lesion	18
Brain lesion plus cranial and vertebral lesions	13
Spinal cord lesion only	35
Spinal cord lesion plus brain lesion	23
Spinal cord lesion plus osseous and ligamentous spinal lesion	23
Spinal cord lesion plus fractured skull	11
Spinal cord lesion plus cranial and vertebral lesions	13
Pathological findings in both brain and cord without lesions of skull and neck*	10

*Including disc disruptions and severe ligamentous injuries

TABLE 2
 SUMMARY OF
 SPINAL CORD PATHOLOGY
 (42 cases)

<u>Lesion</u>	<u>No. of Cases</u>
Contusions and/or lacerations	25
Complete transection	8
Swelling	10
Epidural hemorrhage (only massive in 4 Marie-Strumpell's)	8
Subdural hemorrhage	0
Necrotic softening or infarction (4 cases with radicular artery damage) (1 case with vertebral artery thrombosis)	24
Parenchymal hemorrhage	14
central gray matter - 6	
white matter - 3	
diffusely - 5	