Radiological Diagnosis of Spinal Injuries and Deformities

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Introduction

All vertebral fractures can be demonstrated by adequate examination and technique. In most cases the radiological examination can be done at the earliest opportunity though caution is to be exercised in the handling of the injured. Injury to the inter-vertebral discs and ligaments cannot be recognised with complete accuracy immediately but observation and later myelography can provide a proper diagnosis.

Spinal canal may be affected by injuries such as trauma to posterior ligaments, apophyseal joints, fracture of the posterior arch, posterior displacement of a fractured vertebral body or a fragment, and posteriorly compressed and herniated disc material. As a result of such injuries the spinal canal may be narrowed or angulated and its contents compressed, damaged or severed.

A transverse compression lesion may require an immediate examination with a contrast medium for exact determination of the level of injury. Generally speaking, myelographic examination is to be avoided in a freshly injured patient. Radiological examination itself entails considerable risk in seriously injured patients and care is necessary when they are transferred from stretcher to the X-ray table. It is better to utilize stationary grids in the initial survey and carry out examination without turning or undue manipulation of the patient. Precise spot filming may be deferred until proper immobilization is attained. Radiological examination in emergencies has to be a limited one, however, it must be done at least in two profiles the antero-posterior and the lateral.

Routine radiological examination of aircrew following ejection from aircraft or crash landings should be done for the entire spine. Even in the absence of symptoms, compression fractures are possible and as such radiological examination is necessary. In the presence of symptoms and signs, oblique view radiographs should also be carried out. Further special view radiographs such as open mouth projection for cervical 1 and 2 vertebrae may be required in suspected injury to this region. Tomography examination in the antero-posterior or lateral planes may be needed and can be invaluable in demonstrating fractures of the body with displacements and fractures of pedicles, laminae, articular facets and spinous processes.

Radiologically the fractures may be grouped as follows:

(*a*) Compression fractures or hyperflexion fractures.
(*b*) Hyperextension fractures.
(*c*) Fracture dislocations.
(*d*) Fracture of appendicular structures including:
transverse processes.
spinous processes.
neural arches.

Compression Fractures

These occur from any injury which forces the body into a jack knife or hyperflexion position. Falls from height frequently lead to compression fractures involving one or more vertebrae. Shearing forces affect the vertebral bodies at the point of maximal

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flexion. Compression of intervertebral disc produces an additional force which acts in an axial direction on the end plates.

Compression fractures are characterised in the lateral projection by :

(*a*) Wedging of the affected vertebrae, maximum anteriorly.

(*b*) Broad based indentation of the upper end plate at the anterior and central portions.

(*c*) Step formation of the anterior contour of the fractured vertebrae resulting from a disruption of continuity as a result of displacement of the anterior fragment.

The wedge formation and step formation are easily recognised. The true extent of the fracture of end plate can be usually assessed in the X-ray films taken after a few months when reactive new bone formation occurs at the edge of the fracture (Fig. 1).

In principle the first examination should clarify whether or not the posterior ligaments (including joint capsules) are intact. Injury of the ligaments determines the immediate treatment as well as the prognosis. Even more important than this is a fracture of the posterior arch in the lumbar region which worsens the prognosis. In the cervical region a fracture of the arch in the presence of vertebral displacement may prevent spinal cord compression.

In fresh fractures condensation of the body structure slightly below the upper end plate is a convincing finding and is the result of impaction of body trabeculae. This disappears in healthy bones in about 3 months. Step formation anteriorly, also disappears.

In the Antero Posterior Projection characteristic findings of vertebral fractures are :

(*a*) Reduction in the height of vertebral body (more pronounced unilaterally in the presence of rotational element at the moment of accident).

(*b*) Loss of detail and indentation of upper end plate.

Fig. 1

Recent compression fracture of Lumbar 1 vertebra wedging, anterior step formation and broad based indentation of superior end plate.

(*c*) Step formation or angulation of the lateral aspect of the vertebral body due to the frequent caudal displacement of the fractured segment.

Hyper-extension Fractures

Hyper-extension fractures are rare and may occur with a posterior fall, landing on the buttocks. The posterior segments of the vertebral bodies as well as the discs are subjected to considerable pressure. In the majority of cases this leads to rupture of the disc with the well recognised dorsal dislocation as well as posterior herniation of this disc. Fractures of posterior inferior pole of the vertebral body may occur.

Injuries of Cervical Spine

A typical cervical vertebra consists of:

(*a*) A body in front and an arch behind. The pedicles arise from the back of the body, supporting the laminae which complete the arch and form the spinal canal.

(*b*) The arch gives rise to several processes:

(*i*) The spinous process,

(*ii*) The transverse process on each side,

(*iii*) The articular processes, one above and one below,

(*iv*) A costal element.

(*c*) The third to sixth cervical vertebrae are typical. The first two vertebrae are especially adapted.

(*d*) The atlas or the 1st cervical has no body; instead there is a short anterior arch and a long posterior arch which connect two lateral masses. The inner surface of the anterior arch articulates with the odontoid process of the axis or the 2nd cervical vertebra.

(*e*) The axis possesses a conical process, the odontoid process which arises from the body. The transverse processes are small. The spinous process is strong and bifid.

(*f*) The head and the atlas rotate together on the axis, the odontoid process acting as a pivot.

Anomalous Development

Some common developmental anomalies or variants which may cause diagnostic problems while examining neck injury cases are:

(*a*) Spina bifida affecting lower cervical spine.

(*b*) Fusion of one or more bodies with formation of a block vertebra.

(*c*) An independent transverse atlantal process separate from lateral masses of the atlas.

(*d*) Small round osseous nuclei projecting several mm anterior to the anterior tubercle of C1 may be mistaken for chip fractures.

(*e*) A notch at the site of fusion of odontoid process and the body of axis vertebra.

(*f*) Fissures at the anterior and posterior arches of atlas.

(*g*) Incomplete closure of the posterior arch of C1.

(*h*) Clefts in the spinous processes.

(*j*) The odontoid process may be deformed, notched or absent.

(*k*) Non-fusion of odontoid process with the body of axis.

(*l*) Basilar invagination leading to compression of medulla and pons. Atlanto-occipital fusion may be present.

(*m*) Unusually long transverse processes of C2.

(*n*) Long transverse processes at C7 with or without cervical ribs.

(*o*) Hemivertebrae.

Whiplash Injuries of the Neck

Whiplash injuries of the neck may occur with sudden acceleration or deceleration when the patient's head is snapped backward forcibly and then jerked forward with equal violence. There is acute flexion and hyperextension of the cervical spine. The prime injury is muscle and ligament stretching. Altered vertebral alignment and limitation of ability to flex, extend and rotate the neck are the usual findings. In assessment of whiplash injuries the radiological examination should include:

(*a*) A supine AP view of the cervical spine.

(*b*) An open mouth view of the odontoid process (Supine).

(*c*) Following standard X-rays:

(*i*) Lateral view with chin relaxed.

(*ii*) Lateral view in maximum flexion.

(*iii*) Lateral view in maximum extension.

(*iv*) 45 degrees right and left posterior oblique view to show intervertebral foramina.

Radiological and clinical signs of significance are:

(*a*) Complete obliteration of normal lordosis and reversal of curvature.

(*b*) Marked limitation in the ability to flex the cervical spine.

(*c*) Limitation of both flexion and extension.

(*d*) Wedging and narrowing of intervertebral discs exclusive of degenerative arthritic changes.

(*e*) Encroachment on intervertebral foramina.

(*f*) Scoliosis as determined from the AP projections.

(*g*) Segmental straightening in association with limitation of flexion.

(*h*) Articular processes may extend somewhat beyond their normal range of motion because of muscle spasm. Joints, however, maintain their parallelism.

Dislocations and Subluxations

Articular processes may slip forward or backwards depending upon whether the patient has sustained a flexion or extension type of injury. In flexion injury crushing fracture of a vertebral body below the dislocated upper segment may occur, though isolated dislocations may also take place. In extension injuries the posterior arch may be fractured.

Radiological examination in neutral lateral position may not demonstrate a dislocation where spontaneous reduction had occurred following momentary dislocation. However, a lateral radiograph in flexion may demonstrate a dislocation. If dislocation is identified, no attempt at motion of the neck should be made.

Subluxations of the cervical spine occur with more severe injuries, with acute trauma directed to a specific level leading to a malalignment of segments just short of actual dislocation. In the lateral projection alteration in the contour occurs at the affected level. There is a sharp bend in a continous line connecting the anterior or posterior aspects. The articular processes do not show overriding or locking.

Important Radiological signs in dislocation/subluxation

(*a*) Sharp level of discontinuity in the normal contour in lateral projection (Fig. 2).

(*b*) Locking of the inferior articular process over the superior articular process of vertebra below.

Fig. 2

There is an abrupt change in the normal curvature of the cervical spine at the level of C 5 and 6 — there is slight compression of C 6 and subluxation is present — (C5 over C6).

(*c*) The posterior segments of the displaced vertebra are tipped anteriorly and cranially because of the altered inclination of articular facets. Dislocation is complete when the inferior articular process of the displaced vertebra becomes anterior to the superior articular process of the subjacent vertebra.

(*d*) When the inferior articular process remains posterior but is displaced partly anteriorly and upwards, partial dislocation is present.

Fractures of Cervical Spine

Fractures of the cervical vertebral body are less common than fracture dislocations or primary

vertebral dislocations. Fractures of the lamina, pedicles, articular facets, and transverse process occur with reasonable frequency. Lamina fractures involving intervertebral foramina may lead to nerve root compression and simulate a ruptured cervical disc. The commonest cause of fracture of the atlas and axis vertebrae is a blow on the head or a fall from a height striking head first. Fracture of the body may exist as a crush injury or as a horizontal fracture. This may occur below the odontoid process. Fig. 3 shows a fracture of the odontoid process of the axis vertebra alongwith an anterior dislocation of atlas vertebra.

Fig. 3

There is a fracture of the odontoid process of the axis vertebra alongwith an anterior dislocation of atlas vertebra.

The posterior arch should receive special attention for detection of a fracture. The base of the odontoid is carefully examined in open mouth AP projection and lateral projection.

To demonstrate fractures of the atlas a basal view of the skull or tomography may be necessary. Hyperflexion injury of the spine may also cause herniation of intervertebral discs in the lower cervical region with compression or damage to spinal cord. Diseased discs are more prone to such displacement. Multiple discs may be displaced and plain films will show reduction of the corresponding disc spaces. Myelography may be necessary for demonstration of the prolapsed disc.

Thoracic Spine

Fractures of the thoracic vertebrae commonly follow injuries causing sudden, severe hyperflexion. These are usually of the compression type with narrowing of the anterior aspect of the involved bodies. The posterior aspect tends to retain its normal height in cases of mild compression.

The most frequent site is the lower thoracic spine, fractures of the neural arches and of transverse and spinous processes are infrequent.

Usually the superior aspects of the vertebrae are affected. Multiple fractures may occur (Figs. 4 and 5). Compaction of cancellous bone results in increased density of the injured vertebrae. When the trauma includes a lateral and rotatory force as wel las hyperflexion the resultant fracture presents, lateral wedging together with injury to the pedicles, laminae and adjacent rib heads.

Soft tissues are affected with para-vertebral haemorrhage and laceration of the ligaments. The intervertebral disc may be torn, so that a lateral and anterior shift of the upper vertebra is produced. Together with this there may be intraspinal haemorrhage, displacement of bony and disc fragments into the spinal canal and oedema, all contributing to spinal cord compression.

Simple minor fractures of a vertebral body usually are of little concern. When comminution of fractured fragments occurs, particularly with injury of the neural arches and pedicles, or when dislocations are superimposed, serious symptoms may be produced. Dislocations of thoracic vertebrae are rare and are usually seen with fractures.

Significant Radiological Signs

(*i*) In lateral projection, the vertical height of the involved segment as compared with the adjacent vertebrae is important and signs of compression of superior surface are looked for.

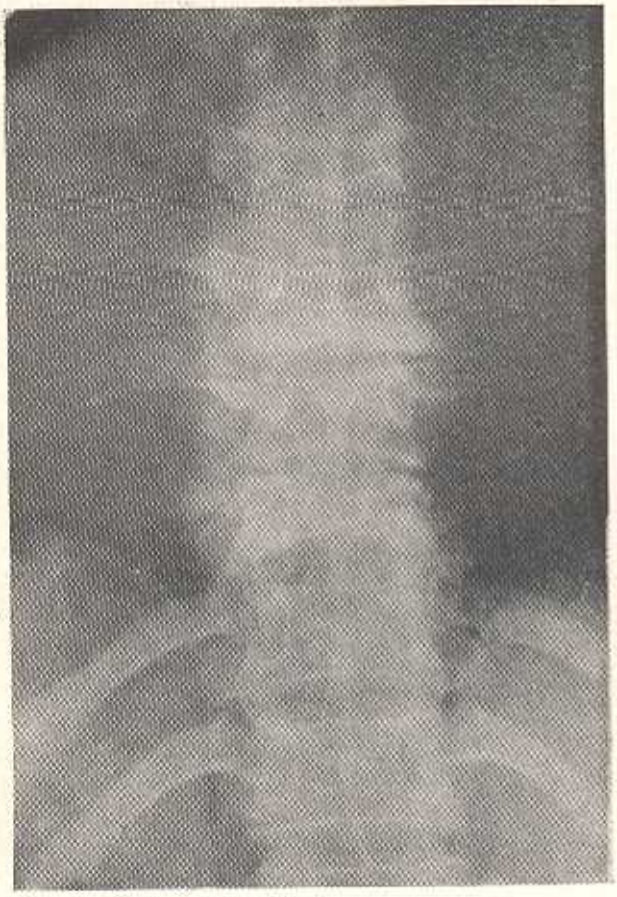

Fig. 4

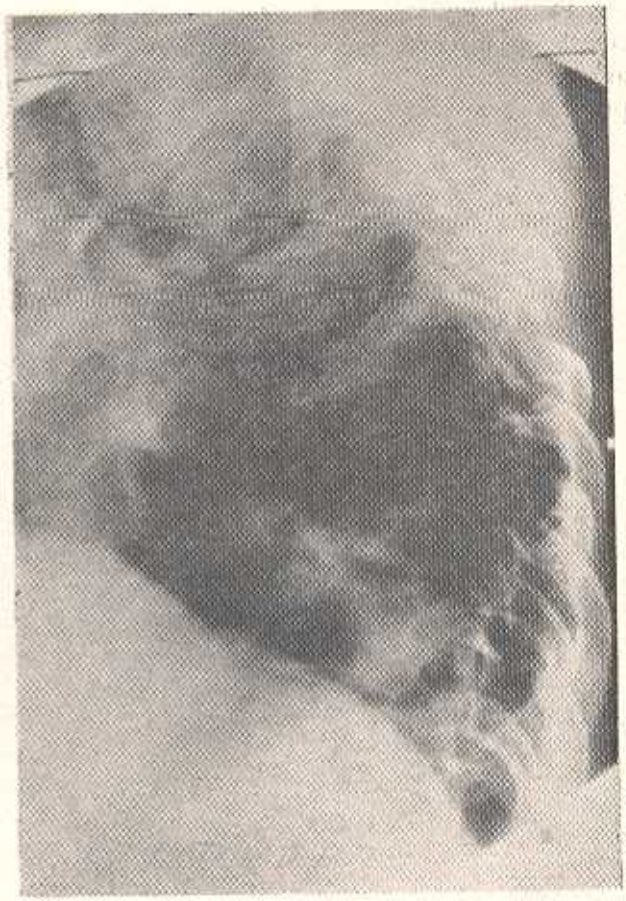

Fig. 5

There are multiple compression fractures involving the lower thoracic spine (D7–9).

(*ii*) Some narrowing of an I V space and increase in width of the affected body may be seen in AP projections. Alteration in height may be detected if the compression is great.

(*iii*) A paravertebral haematoma displacing mediastinal pleura may be noted (AP view).

(*iv*) Kyphosis may occur at the level of injury.

(*v*) Posterior displacement of the posterior portion of the involved vertebra should be noted since cord damage may be present.

(*vi*) Scoliosis and lateral displacement may be seen (AP view).

(*vii*) With a comminuted fracture, alignment of the posterior aspect of the involved body requires to be checked to detect posterior displacement.

(*viii*) Evidence of fracture of the neural arch is sought in lateral projection.

(*ix*) Most dislocations are anterior, so that it is the lower segment which protrudes into the neural canal.

Injuries to Lumbar Spine

Injuries to the lumbar spine are similar to the thoracic and result from similar mechanisms. Fractures of the upper lumbar spine are frequently associated with fractures of 11th and 12th thoracic vertebrae. Though single vertebra may be involved, it is more common to observe compressions of two or three segments. Concomittant injuries to the ligaments, capsular structures, soft tissues and intervertebral discs are frequent (Fig. 6). Symptoms depend on effects of local haemorrhage, lacerations, cauda equina and nerve root distortions. There is higher incidence of paraplegia associated with injuries to the thoracolumbar region than in the lower lumbar regions.

Neural arches are involved with pronounced rotational injuries. Fractures of transverse processes are commoner and occasionally fractures of spinous processes may occur.

Subluxation of the apophyseal joints may also occur and are a cause of persistent pain from tension on ligaments, encroachment on intervertebral foramina and erosion of opposing joint surfaces. Oblique view radiographs or tomography is essential for demonstration of such injuries.

Intervertebral Disc Injury

Repeated trauma or a single vigorous traumatic incident may lead to herniation of the intervertebral disc from damage to the annulus fibrosus. Sudden spinal cord or root compression may occur as a result of the herniation of part of intervertebral disc. In the cervical region it is often from severe flexion injury. In the dorsal region the condition is rare. In the lumbar region disc protrusion is common and far more frequent in the last three spaces than elsewhere (Fig. 6).

Cervical disc protrusion may lead to severe cord injury and a single narrow disc space may be sufficient evidence to confirm the diagnosis. However the absence of narrowing of disc space does not exclude disc herniation in the lumbar spine nor presence of narrowing itself a conclusive proof of the same. With characteristic clinical and neurological picture, the diagnosis can be offered with reasonable certainty and confirmed by myelographic examination which will demonstrate its exact extent and nature. Degenerated discs are more prone to herniation.

When a disc is truly herniated there may be a lateral defect in the column of contrast medium, a complete block or even a root defect.

Fig. 6
Myelogram showing intervertebral disc protrusion at the level of lumbar 4 and 5 vertebrae.

Conclusion

Radiological techniques of diagnosing and assessing spinal injuries have been discussed. X-rays of the spine at the time of entry into IAF are considered essential to eliminate persons with spinal abnormalities who are more prone to injuries during high G conditions associated with ejection seats.