Chapter 1

Overview of vertebral injuries

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In the course of human history, no injuries have evoked greater fear than vertebral fracture and dislocation. They are among the most devastating of insults and result in a gamut of abnormalities ranging from mild pain and discomfort to severe paralysis and even death. Despite improved technology for the diagnosis and treatment of vertebral fracture and dislocation, the physician who is confronted with a spine-injured patient often feels incapable of interpreting the imaging studies that would delineate the full extent of injury.

This book presents the systematic approach to the diagnosis of vertebral trauma that my colleagues and I have used for the interpretation of images (radiographs, computed tomography [CT] scans, and magnetic resonance [MR] images) of patients suspected of having vertebral injury. Furthermore, it amplifies several concepts that I have developed – namely, that vertebral injuries occur in a predictable pattern, that the imaging findings produced by a generic injury are similar, and that findings for injuries caused by the same mechanism are identical no matter where they are encountered within the vertebral column [1].

This chapter defines the descriptive terms pertaining to fractures and dislocations, reviews the terminology used for reporting these abnormalities, and discusses basic mechanisms of injury. Succeeding chapters discuss anatomy, biomechanics, imaging methods available for diagnosing vertebral injuries, and the basic diagnostic principles that make possible a logical and systematic approach to diagnosing vertebral injuries and to determining whether or not vertebral stability has been maintained. The final chapter discusses pseudofractures and normal variants. In addition, we will discuss the current controversies in imaging patients suspected of having vertebral injuries.

Fractures

Most medical dictionaries define a fracture as a disruption, either complete or incomplete, in the continuity of a bone, physis, or cartilaginous joint surface. I prefer a definition that has a more practical significance: *a fracture is a soft tissue injury in which a bone is broken*. This definition is of greatest importance in injuries to the skull and to the vertebral column, where the bony disruption itself may be the least important component of the injury, and damage to the meninges, brain, spinal cord, blood vessels, or peripheral nerves is more serious.

A number of descriptive terms are used in regard to fractures. Most of these are applicable to the peripheral skeleton. A *complete* fracture is one in which both cortices of a bone have been broken; an *incomplete* fracture involves only one cortex. In *closed* (or *simple*) fractures, there is no communication of the fracture site with the exterior of the body; in *open* (or *compound*) fractures, there is communication between the fracture site and the external environment. Most fractures of the vertebral column are closed. Open fractures generally result from missile injuries. Operative intervention converts a closed fracture to an open one.

Fractures can be the result of either direct or indirect injury. In a direct injury, force is applied directly to the bone, and fracture occurs at the site of impact. In the vertebral column, this is most likely to occur in a spinous process (Fig. 1.1) [2]. Most vertebral injuries result from indirect trauma in which force is applied at a distance from the involved vertebra (Fig. 1.2). In the case of a cervical injury, a loading force applied to the head or trunk is transmitted directly to the vertebral column, producing a deformity as a result of exceeding the normal physiologic range of motion (as explained in Chapter 3). Sudden acceleration or deceleration of the head relative to the trunk, or vice versa (as often occurs in motor vehicle crashes and falls), can also produce indirect injury, particularly in the cervical region [1,3–15].

Joint injuries

Joint injuries result from the same types of force that produce fractures. The mildest form of joint injury is a ligamentous *sprain* caused by stretching of the ligament fibers beyond their normal range of elasticity. This produces small tears and hemorrhages. *Rupture* of a ligament may occur with more severe injury. The only difference between a sprain and a rupture is the degree of injury.

Sprain or rupture of a ligament or a combination of ligaments can result in three types of joint instability: occult instability, subluxation, and dislocation. *Occult instability* is recognizable radiographically only when a joint is stressed in flexion or extension (Fig. 1.3). *Subluxation* is a more severe joint injury in which there is a partial loss of contact between

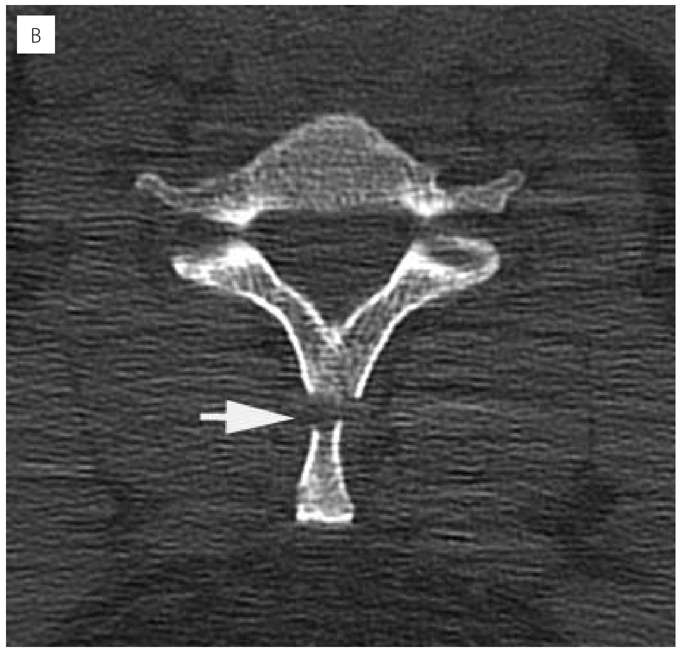

Fig. 1.1 Spinous process ("clay-shoveler") fracture. (A) Sagittal reconstructed CT image shows the fracture in the spinous process of C7 (large arrow). Note the teardrop extension fracture of the body of C2 (small arrow). The small ossific density along the inferior aspect of C3 is another avulsion fracture. (B) Axial image shows the fracture (arrow).

Fig. 1.2 Flexion teardrop fracture of C5. Patient dove into shallow water. Note the retrolisthesis of the body of C5 (arrowhead) and widening of the facet joints (arrows).

Fig. 1.3 Flexion sprain C4–C5. (A) Lateral radiograph shows reversal of lordosis and widening of the interlaminar space between C4 and C5 (*). (B) Frontal radiograph shows widening of the interspinous space (double arrow). (C) T_1-weighted MR sagittal image shows rupture of the posterior longitudinal ligament (arrow).

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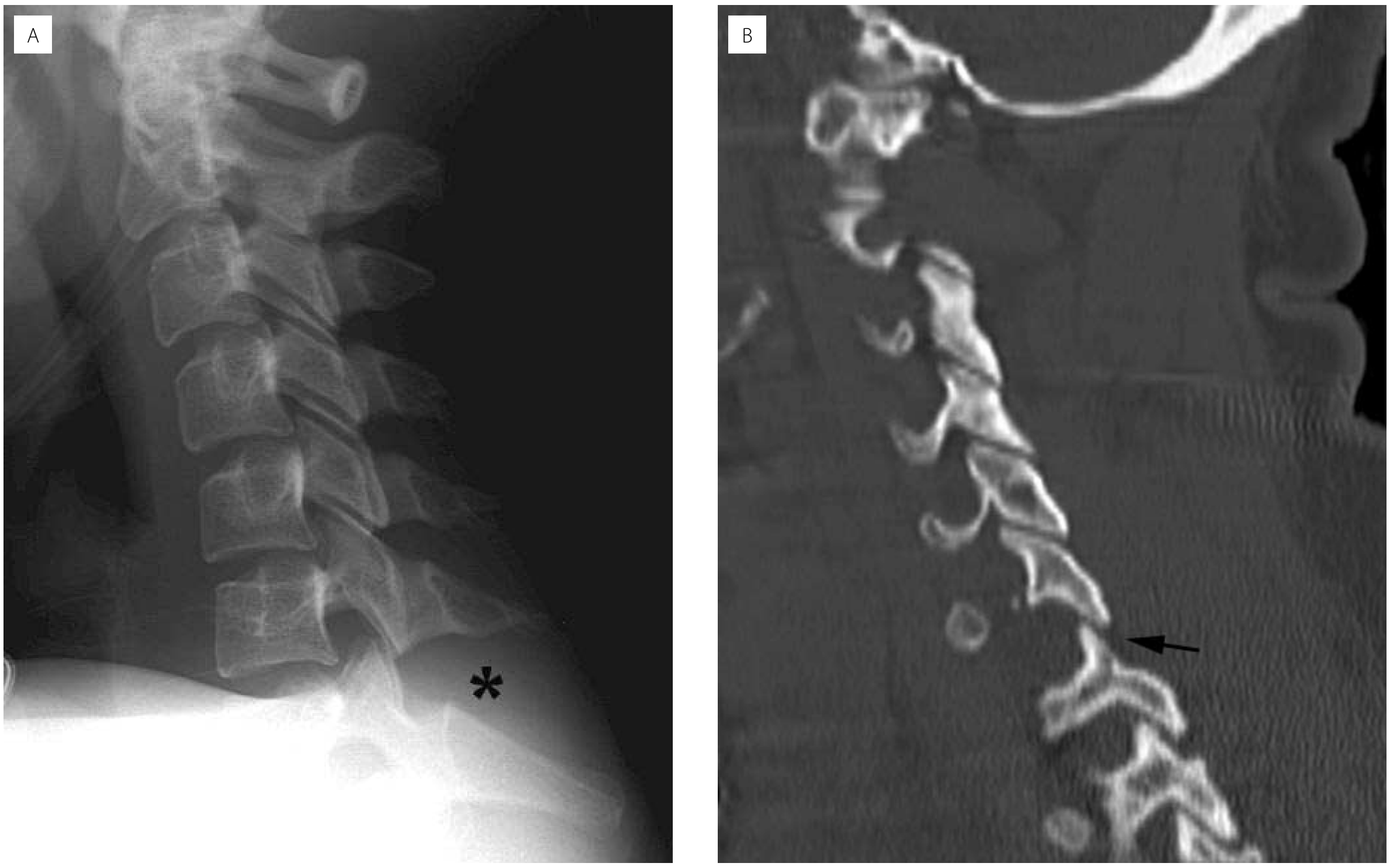


Fig. 1.4 Flexion sprain C6–C7. (A) Lateral radiograph shows widening of the interlaminar space (*) and wide facet joints. (B) Sagittal reconstructed CT image shows the subluxation of the facet joint (arrow).

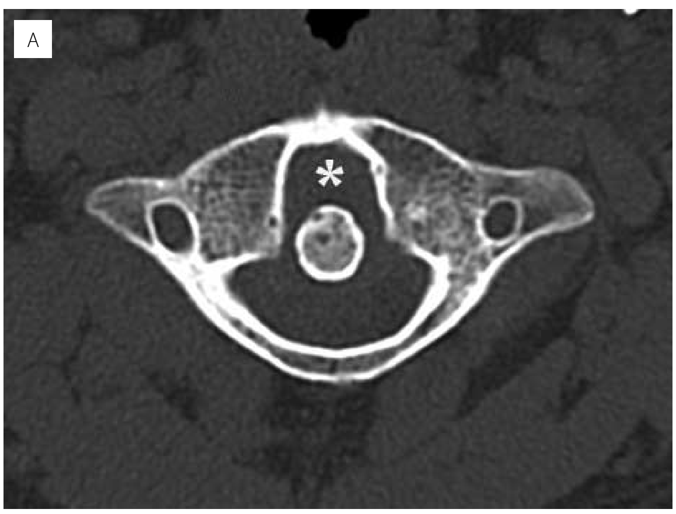


Fig. 1.5 Atlanto-axial dislocation. Axial (A) and sagittal (B) reconstructed CT images show widening of the predental space (*).

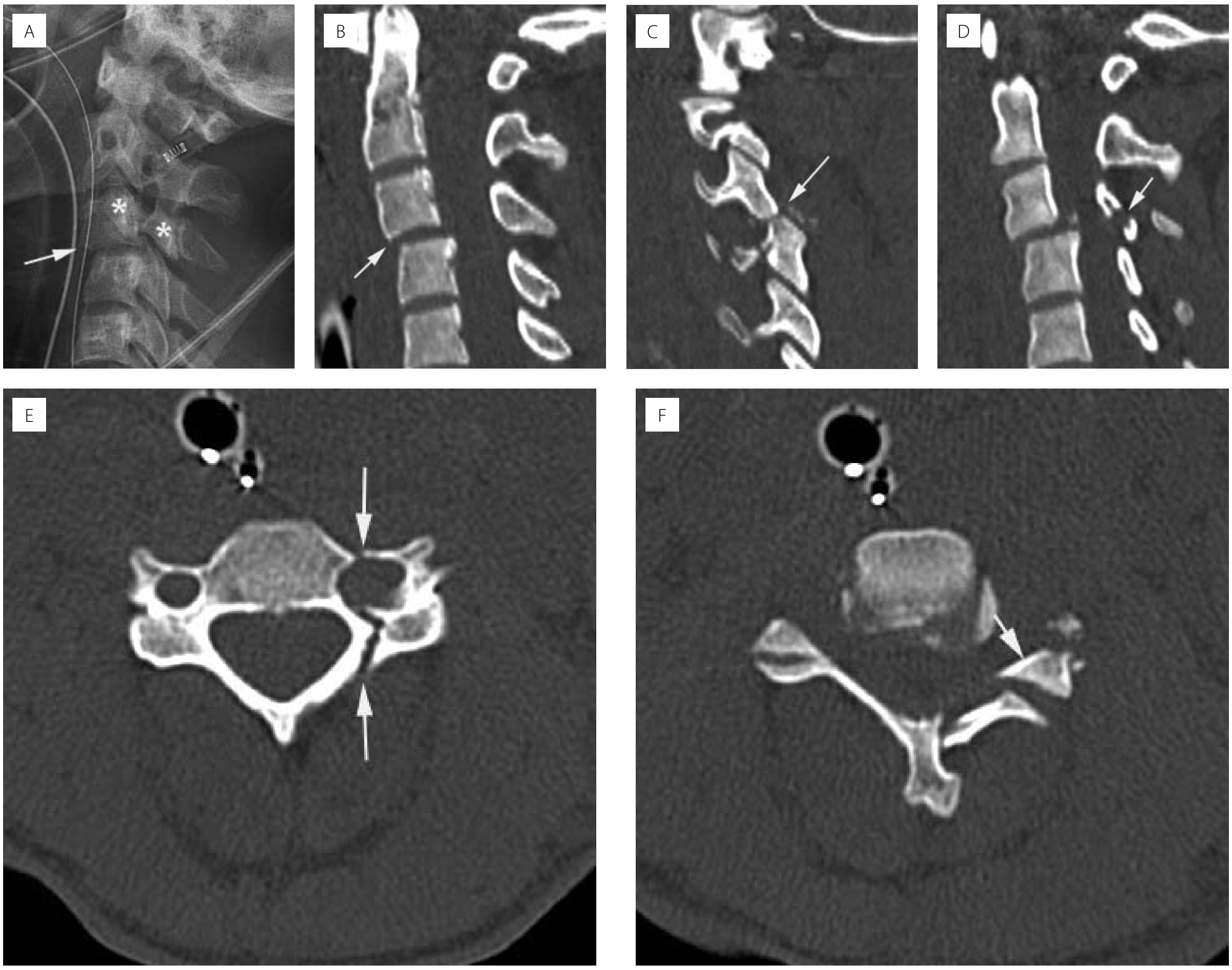


Fig. 1.6 Unilateral facet lock C3–C4. (A,B) Lateral radiograph (A) and sagittal reconstructed CT image (B) show anterolisthesis of C3 on C4 (arrows). Note the pillar duplication producing a "bowtie sign" (* in A). (C) Sagittal reconstructed CT image shows the locked facet (arrow) with multiple fracture fragments. (D) Sagittal CT image further medial shows a lamina fracture (arrow) as well as the anterolisthesis and a fracture off the inferior body of C3. (E) Axial CT image shows pillar and pedicle fractures extending into the transverse foramen on the left (arrows) as well as the body and laminar fractures of C3. (F) Axial CT image shows facet fragmentation as well as an unpaired facet on the left (arrow). Compare with the normal "hamburger bun" appearance of the facet joint on the right.

apposing joint surfaces (Fig. 1.4). *Dislocation* (*luxation*) is the complete loss of contact between the apposing articular surfaces (Fig. 1.5). The term *locking* refers to an abnormal relationship between articular surfaces that results from dislocation (Fig. 1.6).

Descriptive terminology

Fractures and dislocations in the axial skeleton are described, with one important exception, by the same terms as those in the peripheral skeleton. By convention, an injury should be defined at the level or levels at which it has occurred. When an injury occurs at a disc level, it is defined by the vertebra *above* it. Thus, an injury to the C4–C5 disc space is said to have occurred at the C4 disc space.

Descriptive terms such as *avulsion, impaction, distraction, rotation, compression*, and *burst* should all be used. The plane of fracture (*horizontal, transverse, coronal*, or *sagittal*) and displacement of major fragments should also be identified and described. In addition, if a fracture appears to have a pathologic etiology, this should be stated. Figures 1.7 through 1.11 show examples of various fractures and the descriptive terminology used for these injuries.

Subluxations and dislocations are described by relating the *direction taken by the upper vertebra with regard to the one below*. This is in contradistinction to the descriptive terminology used for peripheral fractures, in which the position and angulation of the distal fragments are described in relation to the proximal fragments. Figures 1.12 through 1.14 show variations of joint injuries and their descriptions.

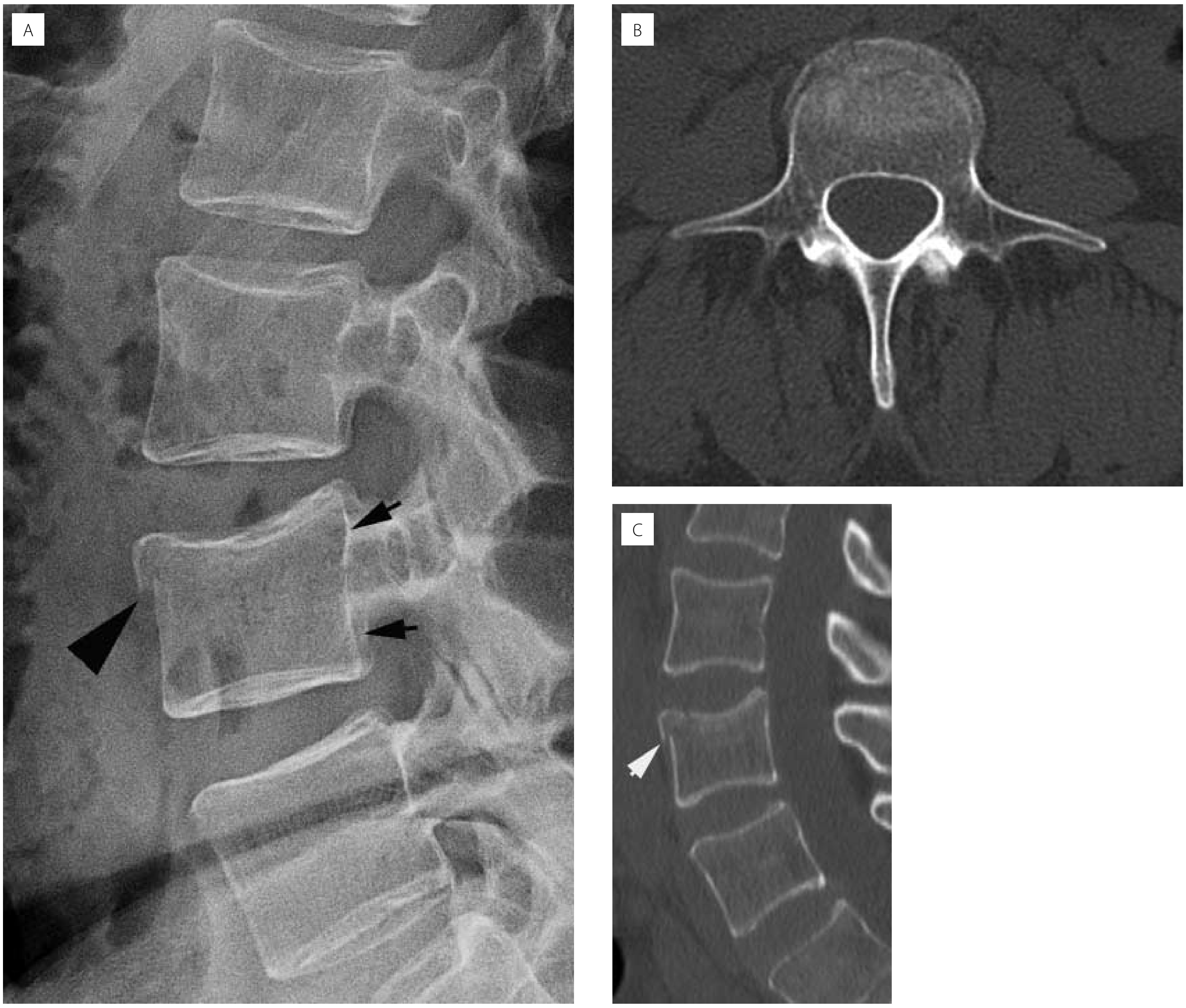


Fig. 1.7 Simple compression fracture of L4. (A) Lateral radiograph shows the compression fracture of the anterior superior margin (arrowhead). The posterior vertebral body line (arrows) is intact. (B) Axial CT image shows fracture of the anterior margin of the vertebra with an intact posterior vertebral body line. (C) Sagittal reconstructed CT image shows the fracture to involve the anterior superior margin of the vertebra only (arrow).

A number of terms are used throughout this book in regard to the mechanisms of injury [1,2,4,7–9,13,14]. Although these terms are defined in further detail in Chapters 3 and 7, they require a brief description at this time.

Flexion injuries result from a *forward bending* motion of the vertebral column at any level. Such injuries are the result of either posterior impact of a force on the vertebral column or anterior impact of the torso on a solid object [7,14,15].

Extension injuries are caused by a *posterior bending* of the vertebral column in response to either an anterior force or sudden deceleration against a solid object posteriorly [1,12,13,15].

Shearing injuries are the result of *horizontal* or *oblique linear forces* being transmitted to the vertebral column from any direction. Limited motion in flexion, extension, and rotation are permitted within the vertebral column. However, horizontal (translational) or oblique linear motion is never normal [1,15].

Rotational injuries result from abnormal *torque* applied to the vertebral column. The normal vertebral column is permitted limited motion in flexion and extension and even less motion in rotation [1,15]. Thoracolumbar rotary injuries usually result in severe neurologic compromise because they are extremely disruptive [1].

All of these mechanisms may occur in combination. In addition, they take into account the effect of axial loading.

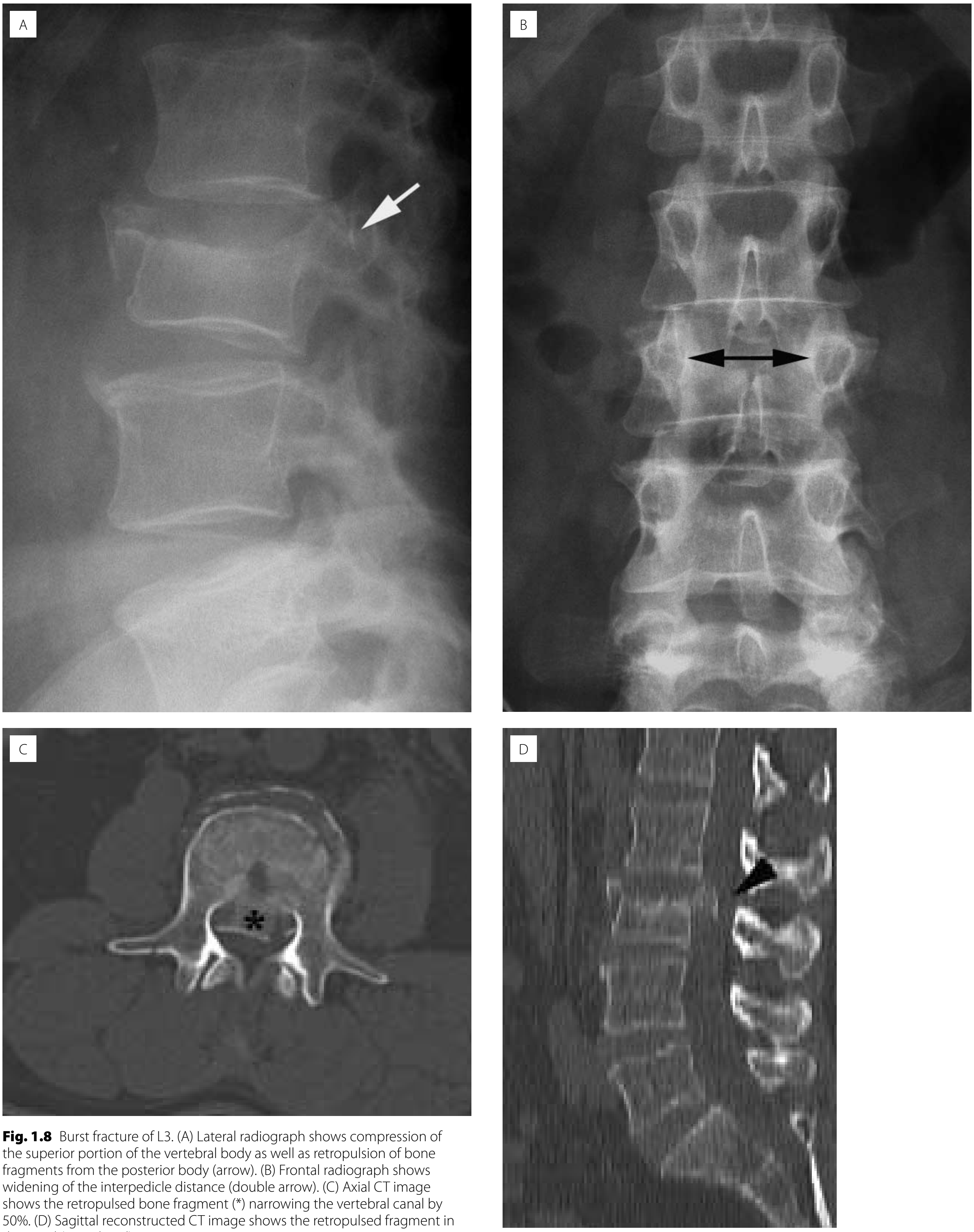
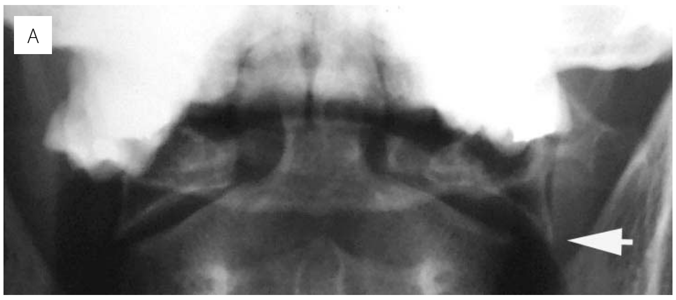


Fig. 1.8 Burst fracture of L3. (A) Lateral radiograph shows compression of the superior portion of the vertebral body as well as retropulsion of bone fragments from the posterior body (arrow). (B) Frontal radiograph shows widening of the interpedicle distance (double arrow). (C) Axial CT image shows the retropulsed bone fragment (*) narrowing the vertebral canal by 50%. (D) Sagittal reconstructed CT image shows the retropulsed fragment in the canal (arrowhead).



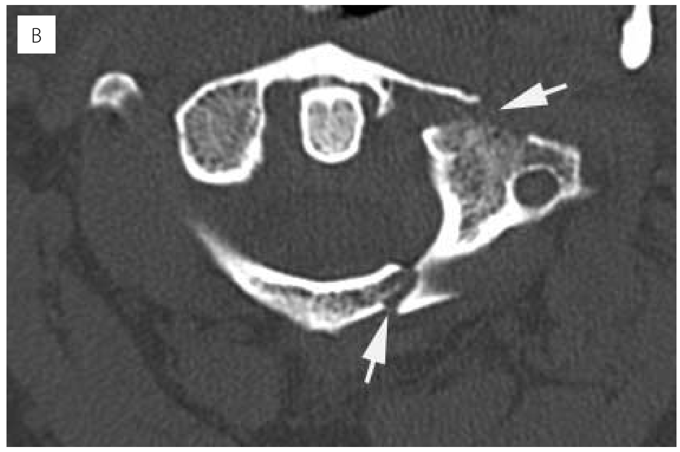


Fig. 1.9 Unilateral Jefferson fracture of C1on the left. (A) Open-mouth radiograph shows offset of the lateral mass of C1 on the left (arrow). (B) The CT image shows fractures of the anterior and posterior arches of C1 on the left (arrows).

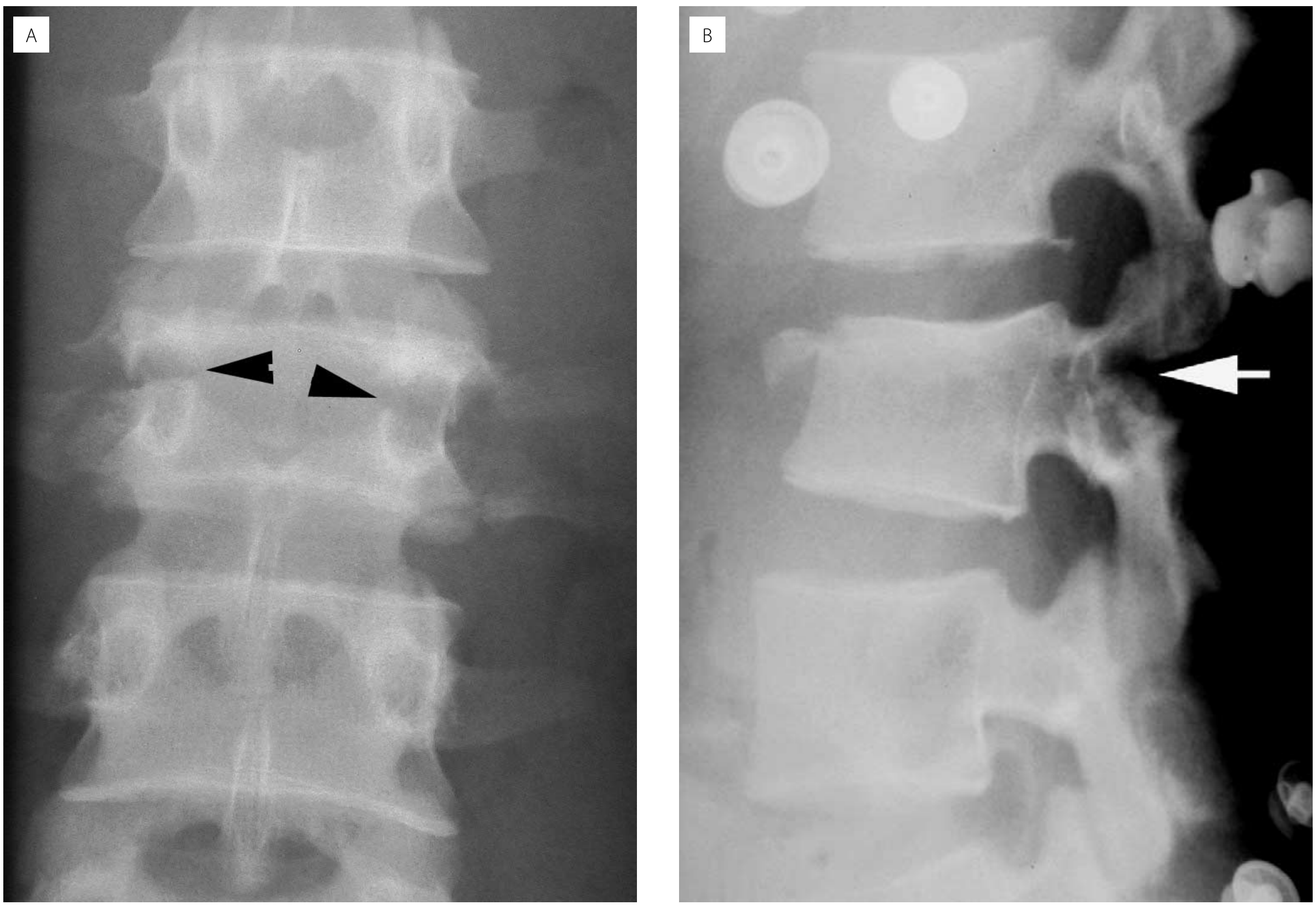


Fig. 1.10 Chance-type fracture of L2. (A) Frontal radiograph shows horizontal fractures through the body, pedicles (arrowheads), and transverse process processes. (B) Lateral radiograph shows the posterior extension of the fracture through the pedicles (arrow).

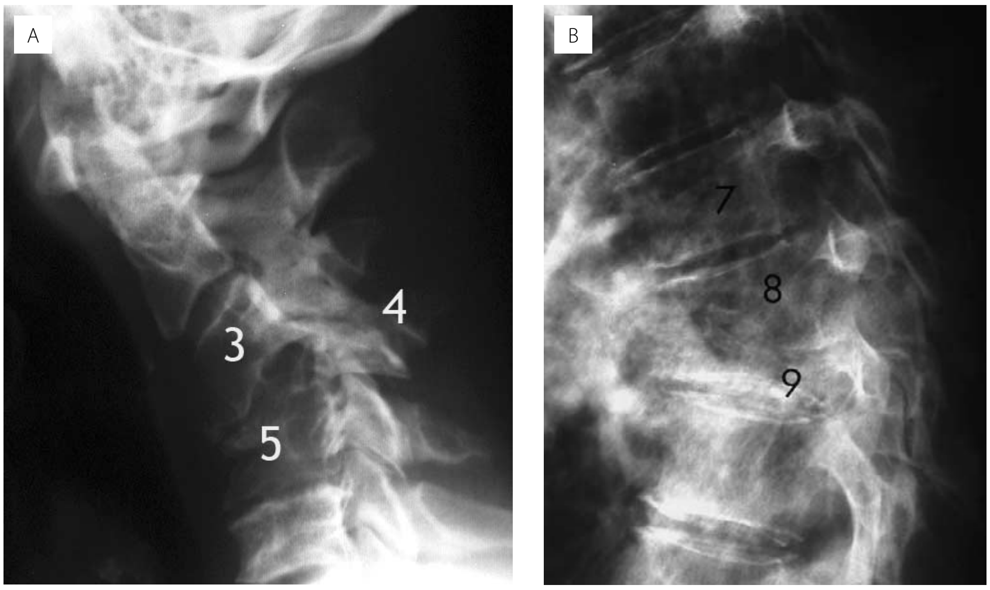


Fig. 1.11 Pathologic fractures. (A) Lateral radiograph shows complete collapse of the body of C4 with resulting kyphosis due to metastatic disease. There is destruction of C3 and C5. (B) Disc space infection has resulted in collapse of the bodies of T8 and T9.

Fig. 1.12 Extension injuries. (A,B) Lateral radiograph (A) and sagittal reconstructed CT image (B) show an extension teardrop fracture of the inferior body of C2 (arrows). Note the prevertebral soft tissue swelling in A (*). (C) Sagittal CT image shows a hyperextension sprain at C6–C7 in another patient. Note the wide disc space (arrow). (D) Sagittal short-tau inversion recovery (STIR) MR image shows the torn anterior longitudinal ligament (arrow) as well as an occult fracture of the body of C6 (arrowheads).

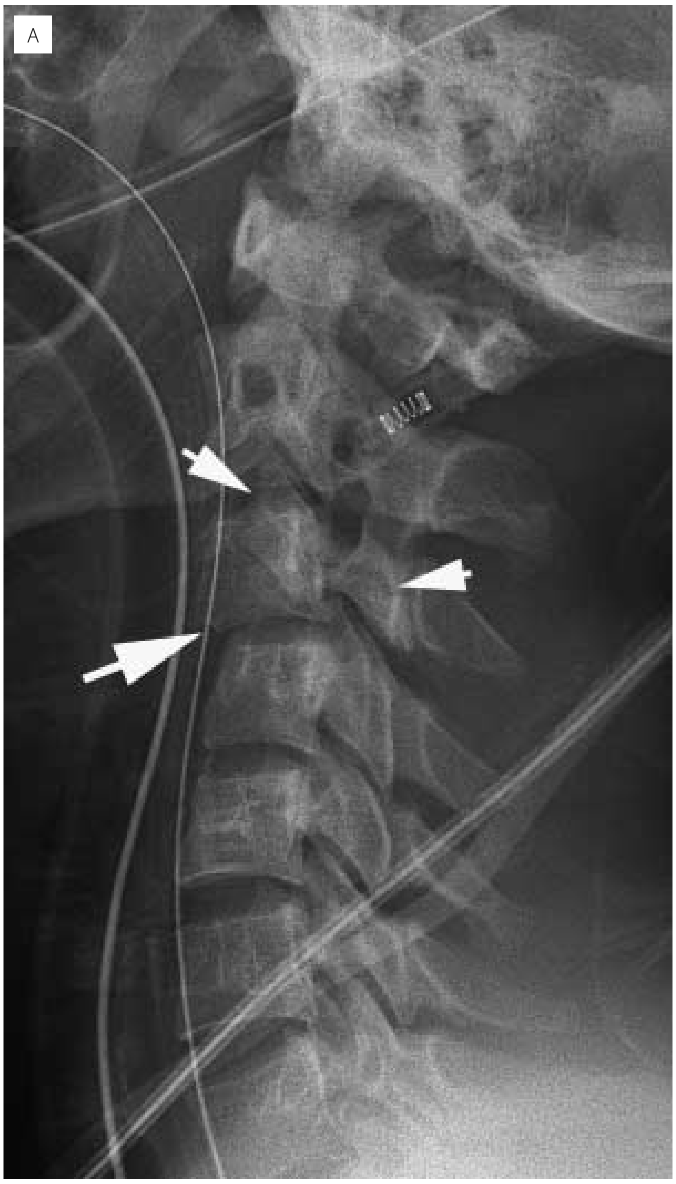


Fig. 1.13 Unilateral facet lock. (A) Sagittal CT image shows a fracture of the facet and locking (arrows). (B) Axial CT image shows severely comminuted fractures of the facet and lamina on the left as well as locking (arrow).

Etiology of vertebral injuries

Most vertebral injuries result from motor vehicle crashes [3,16,17], which account for 85% of the patients seen at the Trauma Center of Allegheny General Hospital. In almost all of these cases, three elements coincide: *speed*, generally greater than 15 miles per hour over the posted limit; *alcohol intoxication*, greater than 0.08 mg/dL (the legal limit in most states); and *lack of the use of seat belts*, which might have prevented most injuries. Interestingly, a higher incidence of soft tissue injury (sprains) occurs in belted vehicle occupants [18]. Although air bags have been available in the USA on all domestic and most foreign cars manufactured after 1993, not enough data have been gathered by trauma centers to determine their effectiveness in preventing vertebral injuries, particularly when seat belts are not used in conjunction with the air bag.

Approximately 14% of vertebral injuries encountered at my institution resulted from falls, primarily in patients over 65 years of age. Miscellaneous causes, such as diving accidents and missile (gunshot) injuries, account for the remaining 1% of injuries [1].

The Trauma Center of Allegheny General Hospital admits some 400 patients with vertebral injury each year. As a level I trauma center, we primarily treat victims of high-speed vehicular trauma, falls, and industrial accidents. Spinal cord injury is a frequent occurrence in patients with vertebral trauma; at my institution, it is found in 40% of spine-injured patients. Of patients with head injuries, 10–15% also have vertebral injury with spinal cord involvement. Not surprisingly, 75% of patients with spinal cord injury have associated injuries, many of which are life threatening. Furthermore, the conditions of up to 10% of patients with spinal cord injury were worsened by prehospital care, despite efforts to reduce the incidence through education of paramedical personnel. Surprisingly, these percentages have not changed in the quarter century I have been working at the Allegheny Trauma Center. Similar numbers are encountered by colleagues at other trauma centers in the USA.

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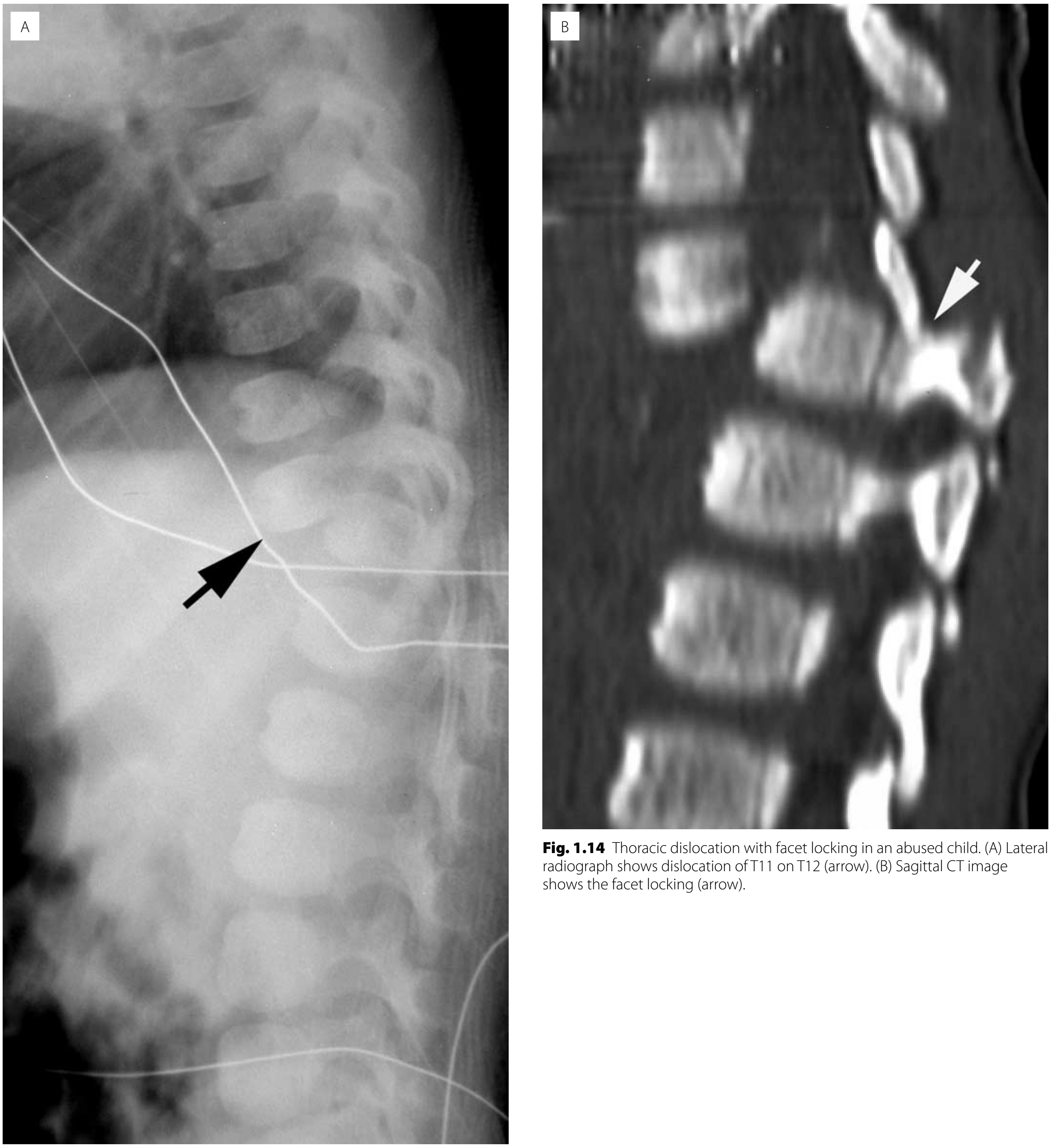

Fig. 1.14 Thoracic dislocation with facet locking in an abused child. (A) Lateral radiograph shows dislocation of T11 on T12 (arrow). (B) Sagittal CT image shows the facet locking (arrow).