Management of Traumatic Spondylolisthesis: Cervical and Lumbar

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Introduction

Spondylolisthesis refers to the anterior translation of one vertebral body in relation to another. It occurs most commonly in the lumbar spine but is also seen clinically in the cervical spine. It can be further classified with the commonly applied Wiltse classification based on etiology with dysplastic, isthmic, degenerative, pathological, and traumatic as the recognized subdivisions. Most commonly, spondylolisthesis is of the degenerative variety in the lumbar spine. Acute traumatic spondylolisthesis is rare and must be distinguished from acute isthmic spondylolisthesis occurring secondary to preexisting spondylolysis [1]. The most commonly recognized traumatic spondylolisthesis is that of the axis, or the so-called *hangman's fracture*. However, a variety of case reports in the literature describe traumatic slips within the subaxial cervical spine and the lumbar spine. It is generally recognized that mechanism of injury and anatomy play crucial roles in the development of traumatic fracture patterns, including the development of instability and spondylolisthesis. Furthermore, the nature of the injury and the degree of instability and/or degree of the slip dictate and guide appropriate management.

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Cervical Spine: Anatomic Considerations in Injury Patterns

The highest incidence of traumatic cervical injury occurs at the upper segments of the cervical spine. The specific injury pattern that results is directly related to the force applied and the anatomy of the region. In the craniocervical spine, the direction of the skull contact forces in part dictates the injury incurred, whereas in the subaxial spine, the pattern of injury relates to the forces applied directly to the vertebra, or a lever arm applied to several adjacent segments. The orientation of the facet joints in the cervical spine also predisposes the area to specific injury patterns. The coronal nature of the joints accounts for the higher occurrence of facet dislocations in this region of the spine [1, 2]. Bauze and Ardran [3], in 1978, reported their experience with experimental dislocation of the cervical spine in cadaveric specimens. The experiment attempted to simulate a naturally occurring event, and the authors concluded that the forward displacement of one vertebra on another seemed to be related to maximal force in combination with rupture of the posterior ligaments and stripping of the anterior longitudinal ligament (ALL) [3].

A.L. Wollowick and V. Sarwahi (eds.), *Spondylolisthesis: Diagnosis, Non-Surgical Management, and Surgical Techniques*, DOI 10.1007/978-1-4899-7575-1_20,

The axis also has unique anatomic considerations that can specifically predispose it to injury. It is a transitional vertebra, articulating superiorly with the atlas and inferiorly with a normal cervical vertebra. Synovial joints on the upper surface are relatively unyielding. Inferiorly, the intervertebral disc and coronally oriented facets share the weight and load bearing. Separating the two areas is a narrow isthmus of bone, which the foramen transversarium traverses and weakens. Furthermore, the axis is essentially a double vertebra and, from a mechanical standpoint, the dens increases the lever arm that can be applied to the body, thereby increasing the potential for fracture.

Traumatic Spondylolisthesis of the Axis

Traumatic spondylolisthesis of the axis (TSA; hangman's fracture) was first described in 1913 in an article titled "The Ideal Lesion in Judicial Hanging" [4]. The fracture produced as a result of the submental knot is created by distraction and extension [5]. However, distinctions exist between the classically described hangman's fracture and the commonly occurring TSA. Presently, the most common causes of TSA are motor vehicle collisions and falls. The commonly proposed mechanism is flexion or hyperextension with axial loading. Associated with TSA are high incidences of injuries to the head (16 %–46 %), other portions of the cervical spine (13 %), and thorax (43 %). Also associated with TSA are generally low incidences of neurological injury and nonunion [6].

TSA usually involves bilateral fractures through the neural arch of the axis and can result in anterior displacement of C2 on C3 [6]. Various classifications of TSA have been developed. Francis et al. [7] defined two categories based on the limits of stability proposed by Johnson et al.: [8] 3.5 mm of translation and 11° of angulation. Pepin and Hawkins [9] and Effendi et al. [10] classified the hangman's fracture based on radiographic displacement of the fracture [6, 11]. Effendi et al. [10] described the cervicocranial concept with which the cephalad element consists of the skull, atlas, dens, and body of the axis and the caudal element consists of the arch of the atlas, the third cervical vertebra, and the remaining cervical spine. They classified hangman's fractures based on appearance. Type I fractures are isolated hairline fractures of the ring of the atlas with minimal displacement of the body of C2. The mechanism is axial loading and hyperextension. Type II fractures are characterized by displacement of the anterior fragment with disruption of the disc and are caused by hyperextension and rebound flexion. Type III is fixed displacement and angulation of the anterior segment with locked facets caused by a flexion rotation moment. Levine and Edwards [12] further modified this classification scheme to include the Type IIa hangman's fracture, incorporating a flexion-distraction injury [11].

Management of TSA

In 1968, Cornish [5] presented his experience in the management of 14 cases of TSA. He asserted that treatment should be based on recognition of the deforming force and the extent of injury. Primary treatment of unstable lesions was recommended to allow for early stabilization and mobilization. Skull traction was discouraged because it runs parallel to the mechanism of injury and can further propagate the fracture [5]. The treatment algorithms proposed by Cornish rest on the premise that the fracture is inherently unstable. However, debate exists regarding the inherent stability of the injury.

Müller et al. [6] examined 39 patients who sustained hangman's fractures and were treated at one institution. The fractures were classified according to the Effendi classification, and the group proposed a stability scale for the different Type II fractures and a corresponding treatment rationale. Type I fractures were considered stable, and application of a rigid cervical orthosis remains the treatment method of choice. With Type II flexion injuries, or the Levine and Edwards Type IIa, the axis body fragment hinges around the intact ALL. Radiographic evaluation of these fractures usually reveals moderate to severe angulation of the body fragment with little to no anterior displacement. Treatment with rigid external immobilization is appropriate for the majority of the injuries. With Type II extension injuries, the axis fragment hinges around an intact posterior longitudinal ligament (PLL), and the ALL and anterior disc are ruptured. The group also found these lesions to be stable, with non-rigid immobilization advocated as the treatment of choice.

However, Type IIa spondylolisthesis injuries need to be carefully differentiated. These lesions are highly unstable secondary to rupture of the C2–C3 disc, in addition to the ALL and PLL. Nonoperative management of these fractures has been associated with a substantial rate of failure of stabilization (33 %) and nonunion (11 %) in a series of 39 patients [6]. In that series, solid fusion was achieved in all fractures treated with internal stabilization. Coric et al. [13] stated that as much as 6 mm of anterior displacement was tolerated in this group as long as the fragments were in stable position, but Müller et al. [6] maintained that internal stabilization is necessary. Images of a 23-year-old man with a Type II hangman's fracture are presented (Fig. 20.1).

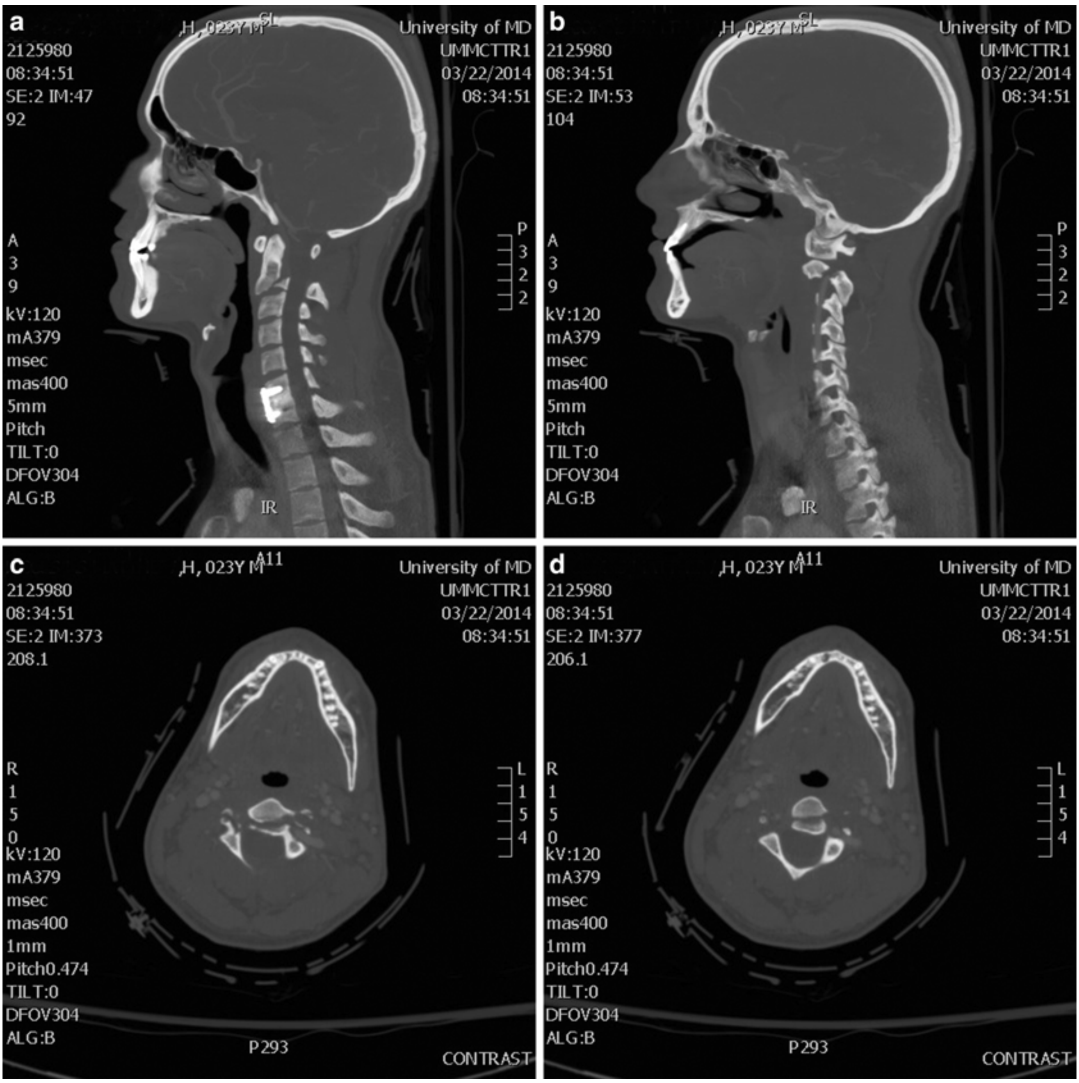

Fig. 20.1 Patient was a 23-year-old man who sustained a Type II Hangman's fracture after a motor vehicle collision. (**a**, **b**) Sagittal view CT scans. (**c**, **d**) Axial view CT scans

The patient was treated nonoperatively with a rigid cervical orthosis (Fig. 20.2).

Several biomechanical studies have been conducted to assess which method of stabilization is most appropriate for fracture fixation. Surgical options include anterior fusion, posterior fusion, or a combined anterior and posterior approach (more specifically, C2–C3 anterior cervical discectomy and fusion or C1–C3 versus C2–C4 posterior spinal fusion and instrumentation). Chittiboina et al. [11] examined anterior versus posterior fixation in human cadaveric specimens in which TSA was created. They found that posterior constructs had increased stiffness in all parameters tested in the biomechanics laboratory: rotation, flexion, extension, and lateral bending. However, posterior fixation that spans C1–C2 by default results in a clinically significantly decreased range of motion across the segment and increased dorsal pain. Furthermore, posterior fixation in this region can be technically challenging, with a narrow margin of error for screw placement. As such, the high stiffness afforded by posterior fixation might not warrant the associated risk, especially considering that anterior fixation constructs were adequate in restoring stiffness and clinically can yield identical fusion rates [11].

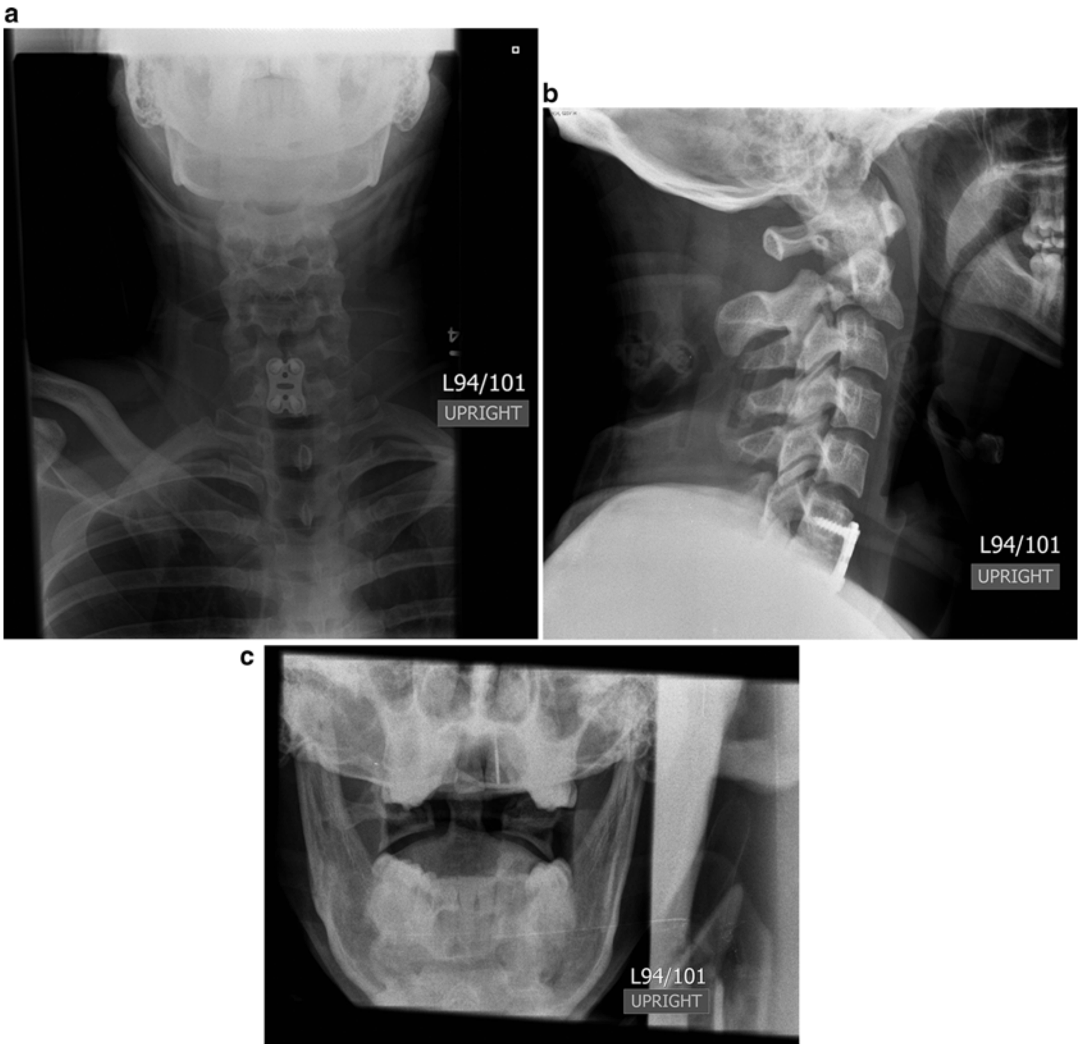

Fig. 20.2 Same patient shown in Fig. 20.1, with the collar applied. (**a**) Anteroposterior upright view. (**b**) Lateral upright view. (**c**) Open mouth upright view

Arand et al. [14] conducted a similar biomechanical study in which a clinically relevant instability model of traumatic spondylolisthesis of C2 was created such that various stabilizing constructs could be tested. The group found clinically relevant signs of destabilization across C2–C3 with only low-grade lesions of the anterior discoligamentous structures. They therefore concluded that from a biomechanical standpoint, the most accurate and stable method of stabilization was anterior plate fixation. Only in isthmus fractures of C2 without discoligamentous lesions was posterior fixation more suitable [14].

Traumatic Spondylolisthesis of the Subaxial Cervical Spine

Traumatic spondylolisthesis of the subaxial cervical spine is a rare occurrence, and few cases have been reported. Ido et al. [15] reported that the condition was first described by Perlman and Hawes in 1951. Patients usually present with a complete, or rarely a partial, neurological deficit with radicular symptoms. Historically, a combined anterior and posterior fusion procedure is advocated for these unstable injuries [16]. The vast majority of literature regarding traumatic spondylolisthesis of the lower portion of the cervical spine is in the form of case reports.

Srivastava et al. [16] presented their management of a C3–C4 spondyloptosis in a 35-year-old man who suffered a fall of approximately 20 feet and landed on his forehead. He had complete spondyloptosis of C3 on C4 with bilateral pedicle fractures at C3, fracture of the C1 arch, and bilateral C2 pedicle fractures secondary to severe hyperextension force with associated axial load. The patient was neurologically intact. Computed tomographic (CT) scanning and magnetic resonance imaging (MRI) were performed and revealed no lamina or facet fractures and no spinal cord compression or signal abnormality. MRI is essential in this patient population to rule out the presence of disc fragments within the spinal canal. The group elected to treat the patient first with a reduction maneuver. An awake, nasotracheal fiberoptic intubation was performed, and, with the patient awake, gradual weight was added to Gardner-Wells tongs and traction was applied. Fluoroscopic guidance was used to assess reduction. The neck was kept in neutral flexion-extension during the reduction maneuver. Once acceptable alignment was achieved and the patient remained neurologically intact, anterior cervical discectomy and fusion were performed at C3–C4. The group opted for anterior stabilization only, as opposed to a multi-stage anterior and posterior procedure, in an effort to avoid the destabilizing effects that can result from a posterior procedure. However, the requirement for anterior-only stabilization is anatomic reduction of the posterior elements with acceptable alignment and appropriate postoperative immobilization to allow for fracture healing. Furthermore, in cases in which neurological deficit is present, a posterior procedure might be necessary such that decompression can be performed [16].

Similarly, Shah and Rajshekhar [17] and Ido et al. [15] described, in their respective case reports, management of a C7–T1 spondyloptosis and C6–C7 traumatic spondylolisthesis, respectively. Again, both patients suffered a fall from height with associated hyperextension injuries and axial load. In each instance, a reduction maneuver was performed with careful assessment of neurological function. Anterior cervical discectomy and fusion were then performed. In each case, an anterior-only construct was thought to afford adequate stability and the patient was spared the morbidity of a combined approach [15, 17].

Lumbar Spine: Anatomic Considerations and Traumatic Spondylolisthesis

Traumatic spondylolisthesis of the lumbar spine is a rare entity, with only 100 reported cases since Watson-Jones [18] described the condition in 1940. The majority of reported cases are traumatic lumbosacral dislocations, with dislocation at the L5–S1 level. In the lumbar spine, the facets are able to slide past each other in extension. This minimizes the chance of facet fracture occurring secondary to hyperextension in the lumbar spine, as is often seen in the cervical spine. The facet joints in the lumbar spine are oriented in a sagittal plane, making them able to resist rotation but not flexion or translation. They do not support an axial load unless an extension posture is assumed. Furthermore, the angle of the sacrum in relation to the L5 body at the lumbosacral junction will impact the development of a pathological process in this region (i.e., the greater the lumbosacral joint angle is, the greater the applied translation force will be). The coronal nature of the facet joints at L5–S1 also explains why traumatic spondylolisthesis occurs most frequently at this level [1].

A variety of mechanisms have been proposed as the mechanism of injury in traumatic spondylolisthesis of the lumbar spine. Watson-Jones [18] suggested hyperextension stress, and Roaf [19] suggested hyperflexion, axial rotation, and compression forces. According to Deniz et al. [1], many cite hyperflexion and compression as the main deforming force for anterior or anterolateral lumbosacral dislocation, although some case reports of direct force tangential to the apophyseal joint and hyperextension with compression have been presented. The injury is characterized by disruption of the supra- and intraspinous ligaments and the joint capsules. The ALL, PLL, and disc might remain intact [20].

Vialle et al. [21] published a series of 11 patients who had suffered lumbosacral dislocation. The purpose of the study was to investigate the mechanism of injury, the nature of the injury, and the preferred treatment method. The group proposed a novel anatomic classification based on the injury patterns observed in the treatment group. Type I fractures represent pure dislocation of the articular facets in the absence of fracture. Type IA is unilateral rotatory dislocation, Type IB is bilateral facet dislocation with lateral displacement secondary to hyperflexion and lateral translation, and Type IC is bilateral facet dislocation with anterior slippage of the L5 vertebra secondary to flexion and distraction forces. Type II fractures are characterized by a unilateral articular process fracture dislocation. Type III is bilateral facet fracture dislocation with disc injury. Type IIIA fractures are caused by flexion-distraction forces, and Type IIIB fractures have rotational deformities [21].

Regardless of the mechanism of injury, Vialle et al. [21] found that traumatic spondylolisthesis of the lumbar and lumbosacral spine is produced by high-energy trauma. As such, the injury is rarely isolated and patients frequently suffer from associated pulmonary, abdominal, vascular, and brain injuries. The presence of transverse process fractures in the lumbosacral spine on initial imaging can serve as a “sentinel” sign and raise the suspicion for lumbosacral injury. CT scanning and MRI are essential to further define the injury and identify the potential presence of a disc herniation and compromise of the L5 neural foramen [21]. Operative intervention is the preferred management of choice for this injury, and all 11 patients in the group presented by Vialle et al. [21] were treated with posterior spinal fusion and instrumentation. Images of a 23-year-old woman with bilateral L5–S1 facet fractures, an S1 superior endplate fracture, and resultant traumatic L5–S1 spondylolisthesis are presented (Fig. 20.3). The patient was treated operatively with posterior spinal fusion and instrumentation. Interbody fusion was deferred secondary to the endplate fracture of S1 (Fig. 20.4).

Fabris et al. [20] presented their experience with the management of three patients with traumatic spondylolisthesis of L5–S1. All three patients were treated operatively with posterior stabilization. Open procedures with L5 laminectomy were advocated because they allow for direct visualization and control of the neural structures, which are essential if a reduction maneuver becomes necessary, in the setting of neurological compromise, or if fragments of disc require removal. Both groups [20, 21] advocate performing an interbody fusion if considerable disruption of the disc is shown by preoperative MRI. Interbody fusion allows for a higher degree of stability and a higher fusion rate, with the anterior support reducing the risk of implant failure. Interbody fusion can be performed from an anterior or posterior approach [1].

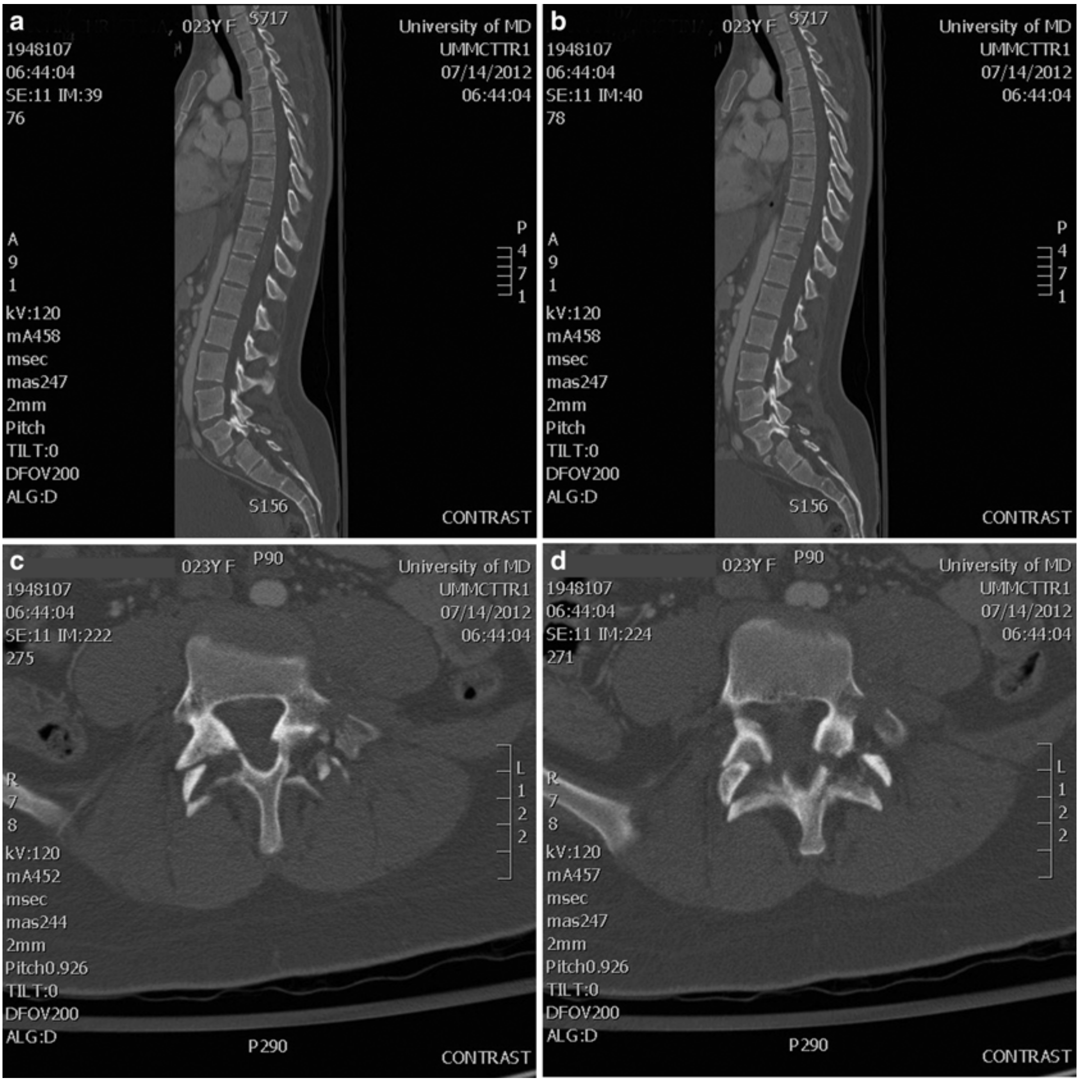

Fig. 20.3 Patient was a 23-year-old woman who sustained traumatic spondylolisthesis at L5–S1 after a motor vehicle collision. (**a**, **b**) Sagittal view CT scans, two different views. (**c**, **d**) Axial view CT scans obtained at L5–S1 reveal traumatic spondylolisthesis

Conclusion

Traumatic spondylolisthesis is a rare condition, usually the result of a high-energy mechanism. TSA, or a hangman's fracture, is the most commonly recognized traumatic spondylolisthesis. It is important to recognize the pattern of injury because it will guide the decision regarding operative versus nonoperative treatment. Traumatic spondylolisthesis of the subaxial cervical spine and the lumbar spine is less common, often associated with facet fractures and usually requiring operative intervention.

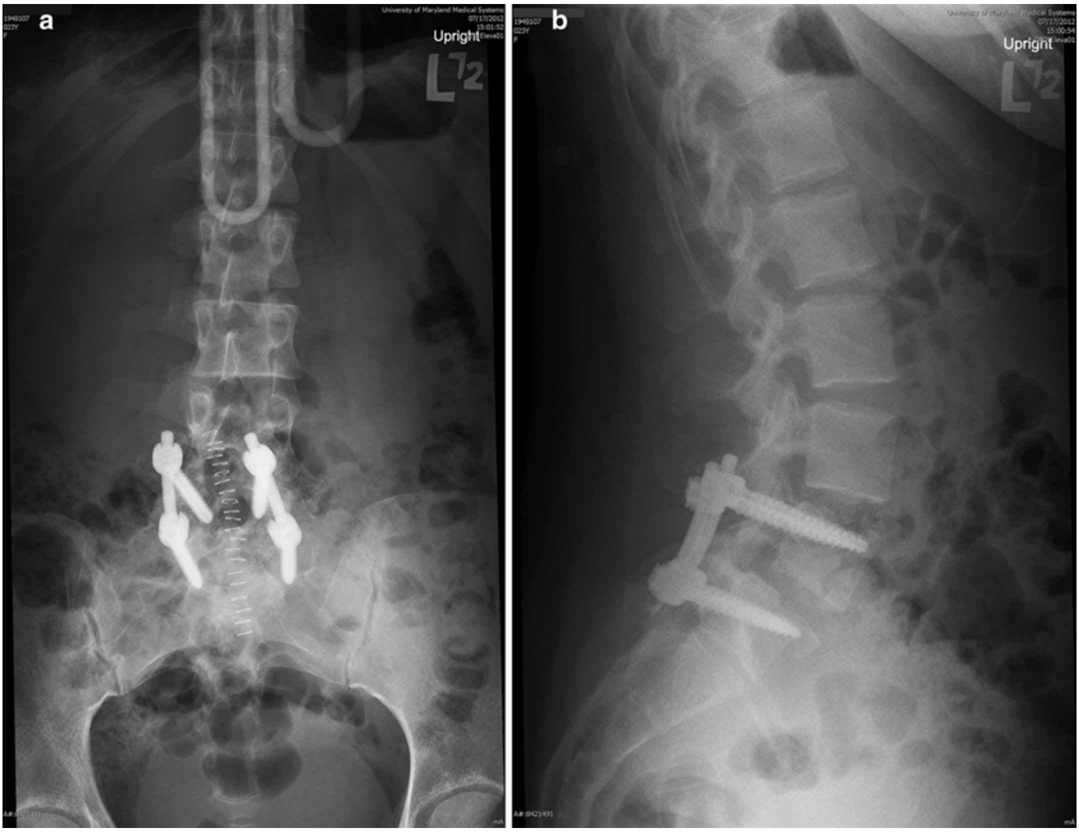

Fig. 20.4 Postoperative upright radiographs of same patient shown in Fig. 20.3. (**a**) Anteroposterior view. (**b**) Lateral view

Acknowledgment The authors thank Dori Kelly, MA, senior editor and writer, for editing the manuscript and formatting the figures.

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