Clinics in diagnostic imaging (214)

Figure 1: Lateral radiograph of the cervical spine.

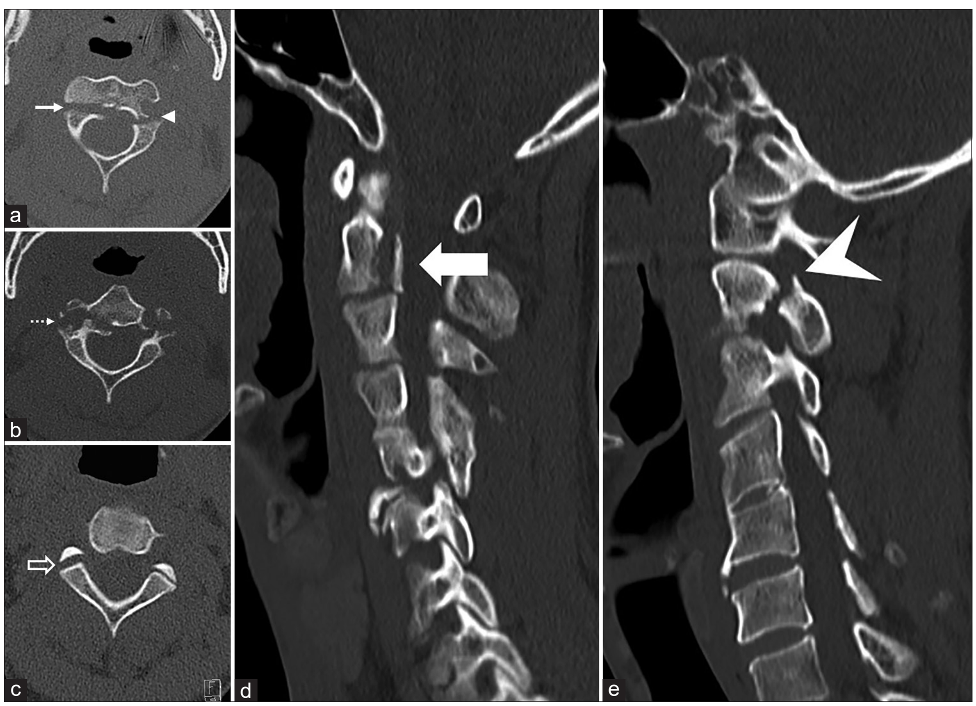

Figure 2: CT images of the cervical spine: (a-c) axial images, (d) right and (e) left sagittal images.

CASE PRESENTATION

A 42-year-old man with no significant past medical history presented to the emergency department with severe neck pain after falling from a bicycle. Physical examination revealed multiple abrasions and bruises on his scalp and extremities. There was tenderness over the occipital region. The range of motion of his neck was significantly limited due to pain. No neurological deficits were detected. Radiography and computed tomography (CT) of the cervical spine were performed. What do the lateral radiograph [Figure 1] and CT images [Figure 2a-e] show? What is the diagnosis?

Table 1. Levine-Edwards and Effendi classifications of hangman's fractures.

Type	Levine-Edwards		Effendi	
	Definition	Mechanism	Definition	Mechanism
Type I	Bilateral pars fractures without angulation or translation (<3 mm)	Hyperextension and axial loading	Isolated hairline fractures of the ring of the axis with minimal displacement of the body of C2	Axial loading and hyperextension
Type II	Significant angulation (>11 degrees) and anterior translation (>3 mm)	Hyperextension and axial loading followed by (rebound) hyperflexion	Displacement of the anterior fragment, with an abnormal disc below the axis	Hyperextension and rebound flexion
Type IIa	Significant angulation without translation	Flexion distraction	-	-
Type III	Combined anterior translation and severe angulation with facet joint dislocation	Hyperflexion and compression	Displacement of the anterior fragment with the body of the axis in the flexed position, and dislocated and locked C2-3 facet joints	Primary flexion and rebound extension

IMAGE INTERPRETATION

The lateral radiograph of the cervical spine [Figure 1] shows a vertical fracture through the posterior aspect of the C2 vertebral body. There is abnormal angulation (approximately 30 degrees) and anterior translation up to 5 mm of the anterior fragment of the C2 vertebral body in relation to C3 with an anterior widening of the C2-3 disc space. The finding is consistent with a hyperextension injury.

A CT scan of the cervical spine [Figure 2] demonstrates fractures through the right posterior vertebral body (solid arrow in Figure 2a and 2d) and left pars interarticularis (arrowhead in Figure 2a and 2e) of C2. The fracture of the C2 vertebral body involves the right foramen transversarium (dotted arrow in Figure 2b) and extends inferiorly into the C2-3 disc space. There is a widening of the right C2-3 facet joint (hollow arrow in Figure 2c), indicating injury to the joint capsule. The atlantoaxial articulation and subaxial vertebral alignment are preserved.

DIAGNOSIS

Atypical hangman's fracture.

CLINICAL COURSE

The patient underwent magnetic resonance imaging (MRI) of the cervical spine [Figure 3a and b] which demonstrated an atypical hangman fracture involving the right foramen transversarium, right posterior vertebral body and left pars interarticularis of C2. There was associated disruption of the anterior longitudinal ligament (ALL) and injury to the C2-3 disc. The adjacent right vertebral artery shows normal calibre and flow void on MRI (image not shown). The patient was immobilised with an Aspen rigid cervical collar and underwent a C2-3 anterior cervical discectomy and fusion (ACDF) with plate fixation and intervertebral cage insertion via a right-sided subhyoid pre-sternocleidomastoid approach on the following day. The postoperative cervical spine radiograph [Figure 4] showed satisfactory alignment. The patient recovered uneventfully, and he was discharged from the ward on a postoperative day. Follow-up at the outpatient clinic about

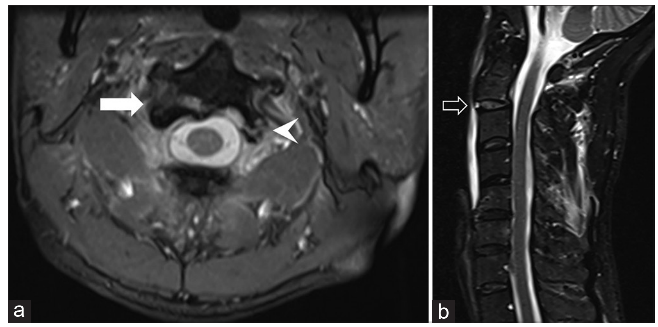

Figure 3: (a) Axial 2D gradient echo image of MRI cervical spine shows the fracture involving the right posterior vertebral body (solid arrow) and left pars interarticularis (arrowhead) of the C2 vertebra. There is a mild focal indentation of the ventral thecal sac by the posterior fragment of the C2 vertebral body. (b) Sagittal turbo inversional recovery magnitude (TIRM) image shows anterior translation and angulation of the C2 vertebral body. There is mild intradiscal oedema in the C2-3 disc. Focal discontinuity with an abnormal fluid signal of the ALL at the C2-3 level is consistent with a tear. There are associated prevertebral fluid extending from C2 to C5 and mild posterior paraspinal oedema.

1 month later was unremarkable, save for a mild reduction in neck mobility.

DISCUSSION

The hangman fracture, also known as traumatic spondylolisthesis of the axis, was first used in 1965 by Schneider *et al.* to describe a type of C2 fracture with a similar pattern of injury seen in judicial hangings.[1] In modern days, most of these fractures result from motor vehicle accidents and falls. They reflect a variety of mechanisms, distinct from hanging injuries.

The hangman fracture typically involves the bilateral pars interarticularis of the axis but may affect any part of the neural arch with or without resultant angulation and/or anterior translation. An asymmetric fracture pattern is frequently seen. A variety of classification systems have been proposed based on the pattern and mechanism of the hangman fracture. The most widely used classification system was introduced by Effendi and later modified by Levine and Edwards describing a continuum of mechanisms [Table 1].[2,3] The Levine–Edwards classification provides a general guide in managing hangman fractures based on morphology and stability. For example, type I fractures are usually considered mechanically and neurologically stable, whereas the least common type III are unstable fractures. The stability of type II and IIa fractures is controversial and may vary depending on underlying ligamentous and disc injury.[4] By and large, disruption of the C2-3 disc with anterior translation, fragment displacement and angulation are indications of instability. There is a low incidence of neurological deficits associated with these fractures, attributable to the expansion of the spinal canal and decompression effect.[2,3]

The term 'atypical hangman's fracture' is used when the fracture lines run through the posterior aspect of the C2 vertebral body without the involvement of the pars interarticularis.[5,6] This type of fracture is considered clinically significant because of complications associated with conservative management such as difficulty in obtaining closed reduction, greater instability, and delayed or non-union which are presumably due to more extensive ligamentous damage and interposition of soft tissues between the fracture fragments of the atypical components.[6] Several studies reported a higher incidence of neurological deficits in atypical hangman's fractures, possibly attributable to the compromise of the spinal canal and compression of the spinal cord by the posterior vertebral body fragment, which

Figure 4: Lateral radiograph of the cervical spine shows interval anterior cervical discectomy and fusion at C2-3 with interbody cage graft insertion. The alignment is satisfactory.

may alter the treatment strategy.[5,7,8] Li *et al.* proposed a new classification for atypical hangman's fractures [Table 2] based on the fracture pattern, incidence and mechanism.[7] In their series, 46 of 62 cases (74.2%) were atypical hangman's fractures which consist of 27 type A1 (58.7%), 12 type A2 (26.1%), 5 type B1 (10.9%) and 2 type B2 (4.3%).[7] The incidence of neurological deficits was 26% among atypical hangman's fractures and highest in type A2 (41.7%).[7] Al-Mahfoudh *et al.* reported a similar incidence of atypical hangman's fractures (68%, 28/41) in their study and also proposed a classification: type 1 is a coronally orientated fracture line through the body of C2, which may or may not leave the ring of the axis intact; type 2 is a unilateral oblique fracture through the C2 body extending into the canal, with contralateral fracture of the pars interarticularis (type 2a) or the lamina (type 2b).[8] However, there were a few obvious drawbacks in the study by Al-Mahfoudh *et al*.[8] Hence, we prefer the Li-Wang classification. According to Li *et al.*,[7] the classification of atypical hangman's fractures should be considered complementary to the Levine–Edwards classification. They suggested that the fractures be initially assessed on radiographs using the Levine–Edwards classification and further characterised on CT scans to identify any atypical fracture pattern. Our current case can be classified as a Levine–Edwards type II and Li-Wang type A1 atypical hangman's fracture. A companion case with a similar pattern of fracture is included [Figure 5a, 5b and 5c].

There is no consensus on standard treatment for hangman's fractures. Most of the management guidelines are based on level C evidence and stability of the injury. External immobilisation such as a halo vest or rigid collar is recommended as the initial management of hangman's fractures.[4] Most Effendi and Levine–Edwards type I and II fractures without neurological deficits are considered stable injuries and are treated with external immobilisation.[2,3] Surgical stabilisation and fusion are reserved for patients with unstable fractures, delayed instability/non-union or other combined fractures in cervical spine fractures.[4] Reduction of facet joint dislocation in Effendi and Levine–Edwards type III fracture is suggested, followed by fixation and fusion of C2 and C3.[2,3] Li *et al.* recommended surgical fixation

Table 2. Li-Wang classification of the atypical hangman's fractures.

Type	Feature	Mechanism
A1	Fracture line through the posterior aspect of the C2 body with contralateral pars fracture	Hyperextension and axial loading, with a rotational component; the most common
A2	Fracture line through the posterior aspect of the C2 body with contralateral lamina fracture	Similar to type A1 but with a more rotational injury force; highest incidence of neurologic deficit
B1	Bilateral oblique fracture lines through the posterior aspect of the C2 body	Hyperextension and axial loading, a rotational component, and a vertical compression impacting the parietal skull which is blocked by C2/3 facet joints
B2	Bilateral fracture lines through the posterior aspect of the C2 body; one is oblique and another is vertical	Similar to type 1 with a stronger rotational injury force; the least common

Figure 5: (a) Lateral radiograph of the cervical spine shows a minimally displaced fracture of C2 posteroinferior vertebral body cortex and pars interarticularis without apparent angulation or anterior translation. (b) Axial image of the CT cervical spine shows fracture lines through the right posterior aspect of the vertebral body and left pars interarticularis of C2. (c) Sagittal image of the CT cervical spine shows an oblique fracture line through the posteroinferior corner of the C2 vertebral body extending into the C2-3 disc space with mild retropulsion of the posterior fragment.

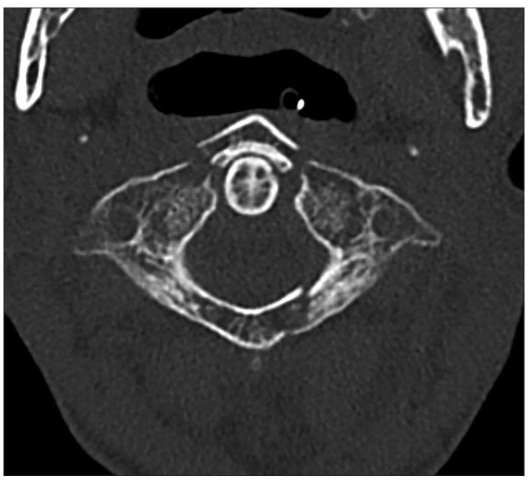

Figure 6: Axial image of the CT cervical spine shows a three-part fracture of the atlas involving both sides of the anterior arch and the left side of the posterior arch. The anterior fragment is mildly displaced anteriorly. There is an asymmetric mild widening of the left odontoid-lateral mass distance due to a subtle left atlantoaxial offset. The atlanto-odontoid articulation is maintained.

for Levine–Edwards type I fractures with neurological deficit and/or additional ligamentous or disc injuries due to instability.[7] Early surgery is also preferred over rigid immobilisation to reduce the duration of treatment. In our current case, the significant anterior translation and angulation of the anterior fracture fragment with additional soft tissue injuries involving C2-3 disc and were considered potentially unstable, thus requiring surgical fixation.

Several other common types of cervical spine fractures are included in this discussion.

The atlas fractures comprise approximately 10% of acute cervical spine fractures.[9] The classic Jefferson fracture is a burst fracture of the ring of the atlas involving both the anterior and posterior arches [Figure 6], which is thought to result from an abnormal axial load transmitted downwards from the skull base.[10] Disruption of the ring of the atlas causes the displacement of the lateral masses and the typical appearance of bilateral (occasionally unilateral) atlantoaxial offset on an open-mouth-view radiograph. According to 'the rule of Spence', the transverse ligament is probably torn when the sum of the displacement of lateral masses exceeds 6.9 mm on a radiograph with an atlas burst fracture.[11] Neurological deficits are rarely observed in atlas fractures unless there is a concomitant axis or subaxial fracture or transverse ligament injury.[10] External immobilisation is considered adequate for isolated atlas fractures, whereas surgical fixation and fusion may be required if instability is present.

Odontoid fracture makes up the majority (up to 59%) of the fractures of the axis.[12] The mechanisms of the injury are various, including flexion, extension and rotation. The most widely accepted classification system was proposed by Anderson and D'Alonzo in 1974.[13] Type I is an oblique fracture through the upper part of the odontoid process and probably represents an avulsion fracture of the alar ligament attachments. Type II is the most common, occurring at the junction of the odontoid process and the axis body [Figure 7]. Type III is the second most common, with the fracture line extending downward into the cancellous portion of the axis body. Anatomical variants such as os odontoideum and os terminale may also mimic odontoid fractures and must be distinguished from type I or type II odontoid fractures [Figure 8a and 8b]. Immobilisation for type I and III fractures usually produces satisfactory results, whereas internal fixation and fusion may further improve the fusion rate of type III fractures. Type II fractures on the other hand have a high non-union rate following conservative management, which can be attributed to the disruption of blood supply in the watershed area at the base of the dens and the distraction effect by the apical ligament.[14] Risk factors of non-union in type II fractures include initial dens displacement of 6 mm or more, and age older than 50 years, which warrant early surgical

Figure 7: Coronal image of the CT cervical spine shows an undisplaced transverse fracture through the base of the odontoid. The alignment of bilateral lateral atlantoaxial joints is maintained.

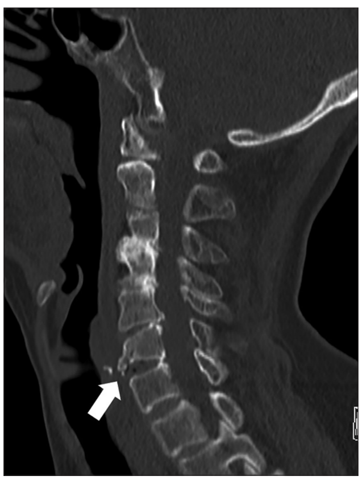

Figure 9: Sagittal image of the CT cervical spine shows a mildly anteriorly displaced triangular fragment (solid arrow) from the anteroinferior lip of the C6 vertebra. There is mild height reduction with anterior wedging of the C6 vertebral body.

fixation.[14] Posterior fixation of type II fractures has a high fusion rate. Anterior odontoid screw fixation may achieve a similar result and maintain atlantoaxial rotational mobility at the same time.[14]

Teardrop fractures can be divided into two types according to the mechanism of the injury, extension and flexion.

A flexion teardrop fracture usually occurs in the lower portion of the subaxial cervical spine, predominantly at C5 and C6, and results from flexion and compression forces.[15] The fracture classically produces a minimally displaced triangular or quadrangular anterior fragment off the anteroinferior lip of the vertebral body [Figure 9]. The larger posterior fragment may be retropulsed into the spinal canal. In more severe cases, there may be an injury of one or more of the following structures: the intervertebral disc, posterior ligamentous

Figure 8: (a) Sagittal image of the CT cervical spine shows a smoothly corticated ossicle interposed between the basion and the axis body, consistent with an os odontoideum. The axis body shows a convex upper margin with a hypoplastic dens. The anterior arch of the atlas appears hypertrophic and rounded. Note the mild anterior position of the ossicle in relation to the axis body with a wide gap between them. (b) Sagittal TIRM image of the MRI cervical spine shows no marrow oedema or prevertebral fluid. Fluid signal within the gap between the ossicle and axis body probably represents normal synovial fluid. There is myelomalacia at the C1 level evidenced by cord atrophy and central high signal, indicating chronic repetitive injury due to atlantoaxial instability distinct from acute central cord syndrome.

Figure 10: Sagittal image of the CT cervical spine shows a tiny triangular fracture fragment at the anterior lower end plate of the C6 vertebra (solid arrow) without significant displacement.

complex, facet joint and spinous process due to hyperflexion. Imaging features such as focal kyphotic deformity, reduction of vertebral body height, narrowing of disc height inferior to the posterior fragment, widening of interspinous space and uncovered facet joint can occur at the level of injury. Rupture of the anterior and posterior longitudinal ligaments can also occur. These fractures are therefore considered highly unstable, and any associated spinal canal compromise may lead to severe neurological consequences, particularly the anterior cord syndrome.[15]

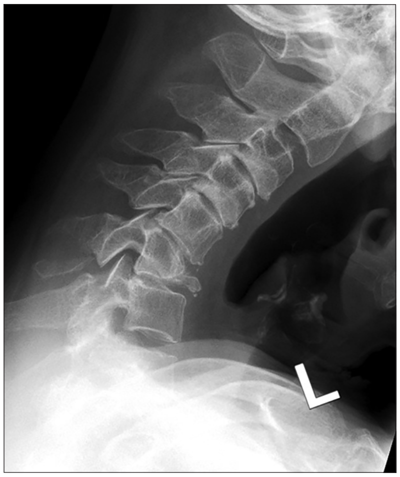

Figure 11: Lateral radiograph of the cervical spine shows a displaced oblique fracture through the C6 spinous process. Note the associated flexion teardrop and anterior wedge deformity of the C6 vertebral body. Widening of C5-6 and C6-7 facet joint spaces and C5-6 interspinous space are suggestive of concurrent capsuloligamentous complex injury.

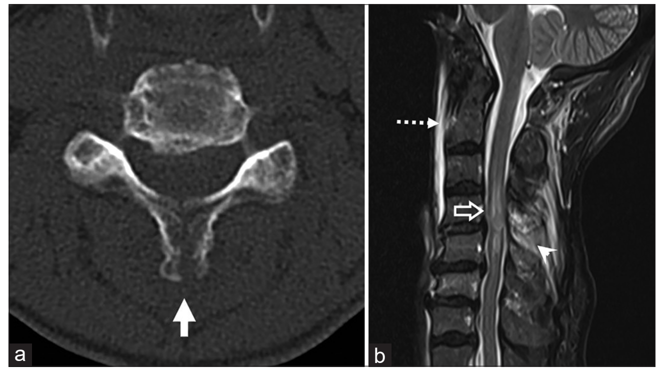

Figure 12: (a) Axial image of the CT cervical spine shows a mildly displaced split fracture (solid arrow) through the midline of the neural arch of the C4 and spinous process. (b) Sagittal TIRM image of the MRI cervical spine shows marrow oedema in the posterior elements of C4 resulting from the lamina and spinous process fracture. Note a short segment of an intramedullary abnormal high T2W signal at C4 and C5 levels (hollow arrow) consistent with central cord syndrome. The interspinous ligament of C4-5 shows oedema suspicious for a partial tear (arrowhead). The ALL anterior to the C2 vertebral body is also likely torn (dotted arrow), associated with extensive prevertebral fluid spanning C1 to C4.

An extension teardrop fracture is a small triangular avulsion fracture off the anterior lower end plate to which the ALL is attached [Figure 10]. It is often associated with widening of the anterior disc space and transient hyperextension dislocation with extensive supporting soft tissue and spinal cord injury in more severe cases. Acute central cord syndrome can be seen in up to 80% of the cases.[16] MRI evaluation is often necessary because radiography and CT may underestimate the extent and severity of these injuries.

Clay-shoveler's fracture is a rare avulsion fracture involving the lower cervical or upper thoracic spinous processes found among clay shovelers in the old days. The most common location is C7 and/or T1 vertebra. It is a less severe type of cervical spine flexion injury, caused by sudden muscle contraction or direct blows to the spine. The fracture runs vertically or obliquely through the affected spinous processes with significant displacement of the fracture fragments but should not interrupt the spinolaminar line [Figure 11]. However, it can be easily missed on radiographs owing to projection and overlying shadows. Proper positioning and careful scrutiny are necessary. The treatment is usually conservative with good functional outcomes despite the high incidence of non-union.[17]

Laminar fracture is frequently associated with other fractures or soft tissue injuries and rarely occurs in isolation. An isolated unilateral or bilateral laminar fracture may result from a hyperextension injury or direct blow to the posterior neck, which often extends into the adjacent spinous process [Figure 12a and 12b]. The fracture is mechanically stable but may cause neurological deficits due to the compromise of the spinal canal. A conventional radiograph is not sensitive in detection and CT is often required in suspected cases.[18] Surgical management is required when there are other accompanying fractures, instability or neurological deficits.

Multidetector CT has proven its superiority over plain radiography and become the modality of choice for the initial assessment of cervical spine injuries.[19] The National Emergency X-Radiography Utilization Study (NEXUS) criteria and Canadian Cervical Spine (CCS) rules are widely used tools to avoid unnecessary imaging in cervical spine injury. MRI may be considered under certain circumstances such as progressive neurological deficits, persistent pain despite a negative multidetector CT scan, and further evaluation of soft tissue, posterior ligamentous complex and spinal cord injury, as well as surgical planning. However, there are a few disadvantages of MRI including high cost, limited availability and long scan time. In addition, several prospective studies suggested MRI has little added value in management when the initial CT study is negative.[20,21]

In conclusion, it is important to distinguish an atypical hangman fracture from the typical hangman's fracture on imaging as it may influence decisions in management. Regardless of the types of C2 fractures, the principles of management are based on the stability of the injury with guidance from the Levine–Edwards classification. Multidetector CT is the modality of choice for the initial assessment of cervical spine injuries.

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Conflicts of interest

There are no conflicts of interest.

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SMC CATEGORY 3B CME PROGRAMME

Online Quiz: https://www.sma.org.sg/cme-programme

Deadline for submission: 6 pm, 16 December 2022

Question	True	False
1. Typical hangman's fractures involve:		
(a) C2 vertebral body.		
(b) C2 pars interarticularis bilaterally.		
(c) Unilateral C2 foramen transversarium and contralateral lamina.		
(d) C2 pedicles bilaterally.		
2. Regarding hangman's fractures, surgical fixation is recommended when there are:		
(a) Unstable fracture fragments.		
(b) Neurological deficits.		
(c) Concurrent cervical spine fractures at other levels.		
(d) Failed conservative management.		
3. Regarding odontoid fractures:		
(a) Type III fracture is the most common.		
(b) Os odontoideum is a frequent complication.		
(c) Type II fracture is best treated conservatively due to a high union rate.		
(d) The Levine–Edwards classification is a widely accepted classification system.		
4. The imaging features of a flexion teardrop fracture may include:		
(a) Abnormal signal in the spinal cord.		
(b) Wedge compression of the vertebral body.		
(c) Extensive signal abnormality in the posterior ligamentous complex.		
(d) A quadrangular fracture fragment at the posteroinferior corner of the vertebral body.		
5. Regarding cervical spine injuries:		
(a) Magnetic resonance imaging is the modality of choice for the initial assessment.		
(b) Radiography is more sensitive compared with computed tomography.		
(c) Surgical fixation should be performed to prevent complications.		
(d) Application of National Emergency X-Radiography Utilization Study criteria and Canadian Cervical Spine rules significantly reduces the rate of unnecessary imaging.		