Fracture Reduction and Fixation Techniques

Spine-Pelvis and Lower Extremity

Peter V. Giannoudis
Editor

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This book is dedicated to my wife Rania and children Marilena and Vasileios for their support and patience. Their unconditional love has been a great influence and inspiration to help surgeons and patients through the difficult journey of trauma.

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1 Cervical Spine Fracture-Dislocation

Peter Robert Loughenbury

Fracture Classification

Cervical spine fracture-dislocation includes a spectrum of injuries to the bony and ligamentous structures of the cervical spine. Injuries typically occur due to high-energy trauma that produces a mixture of flexion, distraction and rotational forces. The majority occur in the subaxial cervical spine (C3–7) but injury to the C7/T1 articulations can also occur. The pattern of failure is dependent on the energy of the injury and the force vectors applied.

Anatomical Classification of Fracture-Dislocation

- **Unilateral facet dislocation** occurs as a result of flexion and rotational forces. This typically produces an anterolisthesis (forward displacement of the cranial vertebral body over the caudal vertebral body) of approximately 25% (Fig. 1.1). This is often missed on plain radiographs and can be visualised more easily with CT imaging. Unilateral facet dislocations may present clinically with cervical radiculopathy as the exiting nerve root is compressed at the site of dislocation.
- **Bilateral facet dislocation** occurs as a result of flexion and compression forces. This mechanism can be seen in a patient injured when diving head first into a shallow pool or injured when a quad bike flips over—causing the driver to land head first underneath the

Fig. 1.1 Midsagittal CT showing unifacetal dislocation (producing approximately 25% anterolisthesis)

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bike. This typically produces an anterolisthesis of approximately 50%, when the facet joints have 'jumped', and is easier to identify on plain radiographs or CT images (Fig. 1.2). The facet joint on one or both sides can become locked in a 'perched' position, and this produces a lesser degree of anterolisthesis. There is often an associated spinal cord injury.

- **Isolated facet fractures** can occur due to both flexion and compression forces. They typically involve the inferior articulating facet of

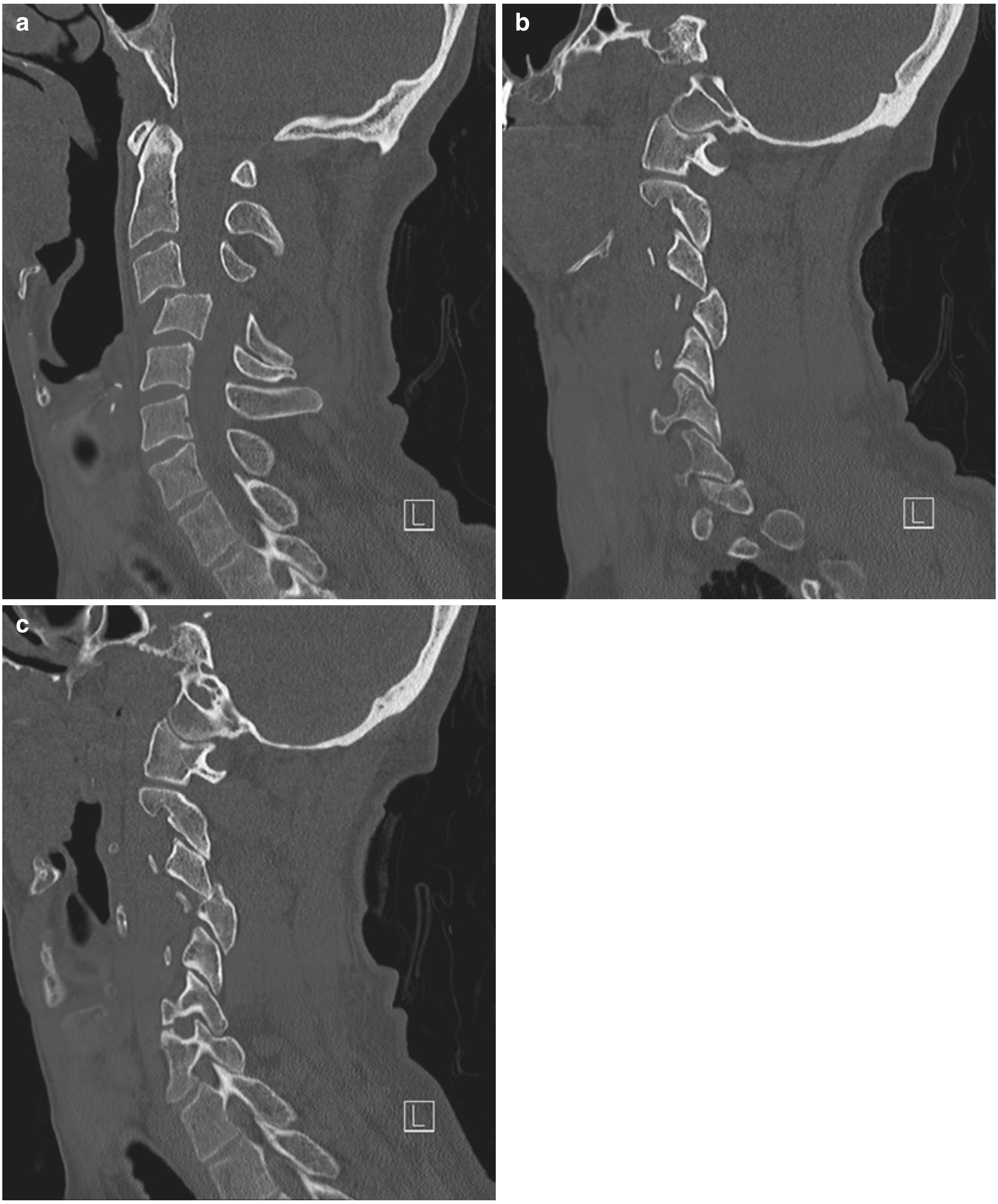

Fig. 1.2 (**a**) Midsagittal CT showing bifacetal dislocation (producing approximately 50% anterolisthesis) plus parasagittal views showing (**b**) left- and (**c**) right-sided facet dislocations

Fig. 1.3 Unilateral facet fracture identified on parasagittal CT imaging

the cranial vertebra (Fig. 1.3) and can be unilateral or bilateral.

- **Vertebral body compression fractures** occur as a result of flexion and compression forces, and these can be seen alongside unilateral or bilateral facet joint injuries. A severe flexion and distraction injury with a significant compression fracture is called a **'teardrop fracture'** (Fig. 1.4).

Allen and Ferguson Classification

The Allen and Ferguson classification [1] provides a comprehensive classification system for subaxial cervical spine fractures that is based on the mechanism of injury and the deforming

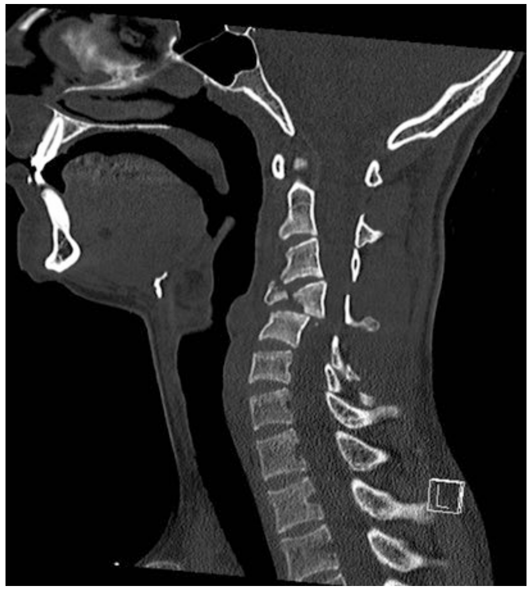

Fig. 1.4 'Teardrop' fracture dislocation identified on CT imaging

forces applied to the column. Plain radiographs are used for assessment, and injuries can be divided into six common patterns:

1. Flexion-compression
2. Flexion-distraction
3. Vertical compression
4. Extension-compression
5. Extension-distraction
6. Lateral flexion

Each pattern is further subdivided into a series of stages that describe the stepwise failure of bony and ligamentous structures during loading. This produces a complicated classification system that can be difficult to use in a clinical setting but is useful in guiding treatment decisions. Details of the complete system are outside the scope of this chapter but the three most common modes of failure are described here.

Flexion-distraction injuries are the most common mechanism seen and lead to a graded instability across the injured level. Four stages are observed:

- Stage 1: Facet subluxation
- Stage 2: Unilateral facet dislocation (25% anterolisthesis)

- Stage 3: Bilateral facet dislocation (50% anterolisthesis)
- Stage 4: Bilateral facet dislocation with complete displacement of the vertebral body (>100% anterolisthesis)

These injuries should be treated with either closed or open reduction and then stabilised with either anterior or posterior fusion.

Extension-compression injuries are the second most common and can occur when a patient receives a hyperextension injury to the neck. The anterior longitudinal ligament remains intact until late in the injury pattern, so the force is initially applied as a compressive force across the posterior elements. As the articular processes, and then anterior longitudinal ligament, fail the vertebral body is pushed *forward*. Allen and Ferguson described the stages of failure as:

- Stage 1: Unilateral laminar fracture
- Stage 2: Bilateral laminar fracture
- Stage 3: Bilateral non-displaced fracture
- Stage 4: Bilateral partially displaced fracture
- Stage 5: Fully displaced fracture

Stages 1–3 are undisplaced and can be successfully treated in a cervical orthosis or Halo vest immobilisation. Stages 4 and 5 are displaced and require fixation with posterior stabilisation and fusion. Forsyth [2] first described this mechanism of failure, and extension-compression injuries are therefore often referred to as 'Forsyth fractures'.

Extension-distraction injuries are the third most common and occur due to hyperextension movements accompanied by an upward force, such as would be experienced during a blow or a fall to the chin or face. Taylor and Blackwood [3] first described this mechanism of injury. In contrast to extension-compression fractures, the cranial vertebral body is pushed *backwards* as the neck is hyperextended (Fig. 1.5). Allen and Ferguson described the stages of failure as:

- Stage 1: Anterior longitudinal ligament injury with transverse body fracture
- Stage 2: Displacement of the vertebral body backwards due to posterior ligamentous injury

Fig. 1.5 Sagittal MRI showing extension-distraction injury with widening of the C6/7 disc space and posterior displacement of C6 on C7

Stage 1 injuries can be treated with Halo vest immobilisation, whilst stage 2 injuries require anterior decompression and stabilisation.

The remaining three patterns of injury described by Allen and Ferguson (flexion-compression, vertical compression and lateral flexion) are similarly subdivided into stages of failure. These modes of injury are less common and are not considered in detail here.

Preoperative Planning

Clinical Assessment

Clinical assessment must include a careful history and examination, paying particular attention to the mechanism of injury. A full neurological examination should be performed and the findings recorded using an American Spinal Cord Injury Association (ASIA) and International Spinal Cord Society (ISCoS) examination chart. These charts are freely available online. Unilateral facet subluxation or dislocation will often present with a radiculopathy. A C5/6 subluxation would produce a C6 radiculopathy and would be seen clinically as weakness of wrist extension (C6 myotome) and numbness in a C6 dermatomal distribution (thumb). A C6/7 subluxation would produce a C7 radiculopathy and would be seen clinically as weakness of elbow extension (C7 myotome) and numbness in a C7 dermatomal distribution (middle finger). A spinal cord injury is more commonly seen with bilateral facet dislocations and significant vertebral body compression fractures.

Imaging

Plain radiographs are often performed, and the lateral view shows the degree of subluxation of the vertebral body (anterolisthesis). Plain radiographs form the basis for the Allen and Ferguson classification but more recently *CT* has become the standard imaging modality to show the fracture pattern and identify the anatomy of the injured facet joint complexes. CT also allows subtle pedicle and lamina fractures to be recognised.

MRI can show the degree of injury to the intervertebral disc and any extruded disc fragments. The degree of posterior ligamentous injury and presence of signal change within the spinal cord can also be identified. The timing of MRI remains controversial and depends on the severity of neurological injury and the availability of MR imaging. Closed reduction can be performed with the patient awake but an MRI should be completed before any subsequent stabilisation procedure. An MRI should also be performed if there is neurologic deterioration during closed reduction or if closed reduction fails and open reduction is planned. If the patient is obtunded, an MRI must be performed before a closed reduction is attempted. If extruded disc material is identified on MRI, open reduction and removal of the disc fragment are required. This is because the extruded disc fragment may cause cord compression as the dislocation is reduced.

Patient Positioning

Acute management of cervical fracture-dislocations includes reduction of the dislocated joints and realignment of the fractured levels. This can be achieved with closed axial traction or open reduction and stabilisation. Supine positioning is used for closed reduction and for open anterior reduction plus stabilisation. Prone positioning is needed for posterior open reduction and stabilisation.

Supine Positioning

Initial attempts at reduction are performed with the patient supine and with the head end of the table slightly elevated to provide counter-traction and prevent the patient migrating towards the top of the bed (Fig. 1.6). An intrascapular shoulder roll can be used to help extend the neck. The head should remain in a neutral or slightly extended position. Padding should be used for all prominent bony areas including the elbows, knees and ankles. The arms should rest at the side of the patient with thumbs facing upwards. Visualisation of the lower cervical levels on intraoperative radiographs can be hampered by the position of the shoulders. Taping the shoulders down using zinc oxide tape can optimise visualisation of the lower cervical spine. Tape is applied to the upper arms and then fastened to the table once the shoulders have been pulled down to expose the neck. Alternatively, the arms can be pulled downwards as the radiographs are taken, with traction being applied through the wrists in line with the body by an operating department practitioner. Calf pumps should be used for intraoperative venous thromboprophylaxis.

Fig. 1.6 Supine positioning for closed reduction or for anterior open reduction and stabilisation

Prone Positioning

Patient is positioned prone on a standard operating room table or a radiolucent 'Jackson' table. The arms are tucked by the side and secured with a wrap-around sheet or dedicated straps, so that they don't interfere with intraoperative radiographs. Thumbs should always face down. All pressure points should be fully protected. A Mayfield skull clamp is used to provide a rigid intraoperative head position (Fig. 1.7) and is applied with the neck in a neutral position. Slight reverse Trendelenburg position is used to prevent venous pooling in the neck (Fig. 1.8). The shoulders are taped down with zinc oxide tape to allow visualisation of the lower cervical levels using image intensification. This tape can also be used on the skin overlying the posterior neck, and this is then pulled taut and attached to the table.

Closed Reduction

Gardner-Wells cranial pins and tongs are used to allow traction to be applied across the cervical spine. Pins are inserted bilaterally 1 cm above the pinna, in line with the external auditory meatus and below the equator of the skull (Fig. 1.9). These are tightened until the spring-loaded indicator protrudes 1 mm above the surface and can be tightened using finger pressure alone. Axial traction can now be applied using weights suspended over a pulley (Fig. 1.10). An

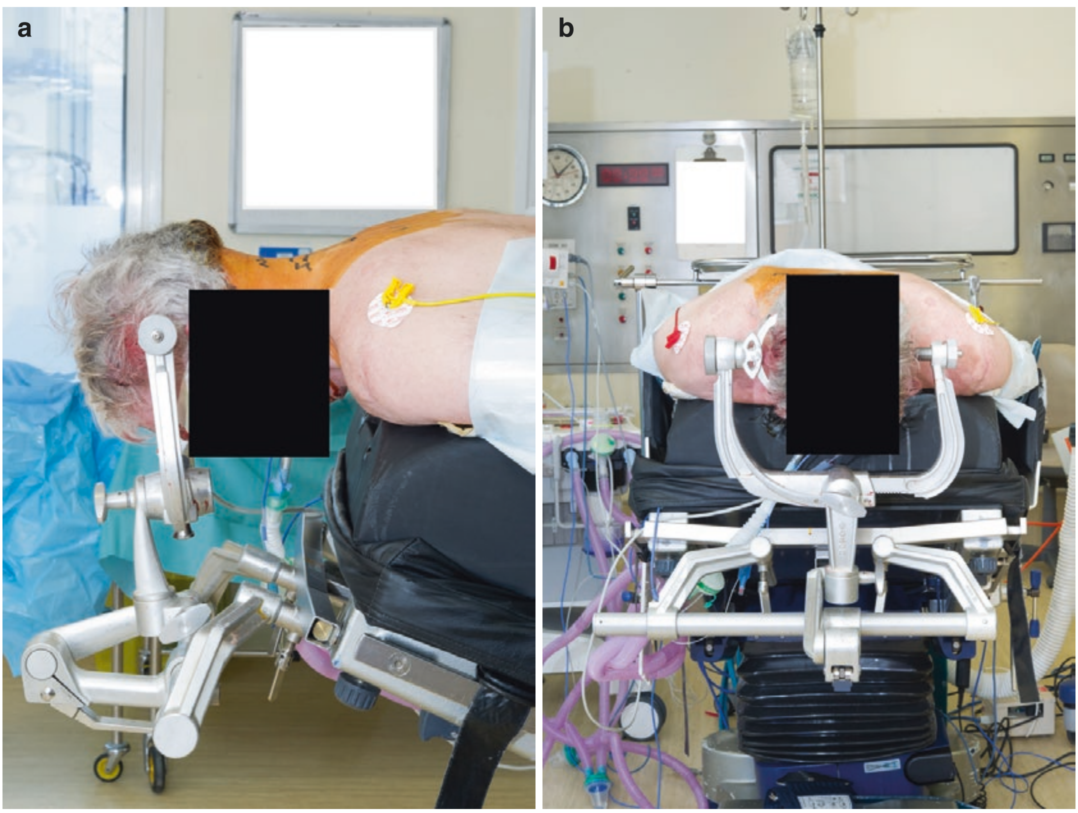

Fig. 1.7 (**a**, **b**) A Mayfield clamp is used to provide a rigid intraoperative head position during prone positioning

initial 10 lb (4.5 kg) of traction is applied, and this weight is then increased in increments of 10 lb. There is no clear consensus as to the exact timing of incremental traction and the maximum weight that can be applied. However, serial radiographs taken using an image intensifier can allow the effect of traction to be seen (Fig. 1.11). The author recommends using no more than 70 lbs of traction using this method. Reduction of the facet joints is accompanied by an audible 'clunk' and can be seen on the image intensifier.

If the facets fail to reduce with axial traction, manipulation of the neck may be required. This involves recreating the deforming force using flexion and distraction to allow the joints to realign. Rotation of the head may be needed (applied alongside traction) towards the side of dislocation to approximately 40°. Closed reduction should be performed with the patient awake and is therefore contraindicated in patients who are obtunded or have an altered mental status. Significant head injury or skull fractures may prevent the use of cranial tractions pins.

If closed reduction cannot be achieved, or if there is deterioration in neurology during closed reduction, urgent open surgical reduction is required. An MRI scan is performed before this to identify extruded disc fragments that may cause neurological injury during open reduction. In many cases, where the surgeon feels that open reduction will be required as a definitive procedure, open reduction is chosen as the primary treatment and there is no need to attempt a closed reduction.

Fig. 1.8 Prone positioning for posterior open reduction or stabilisation

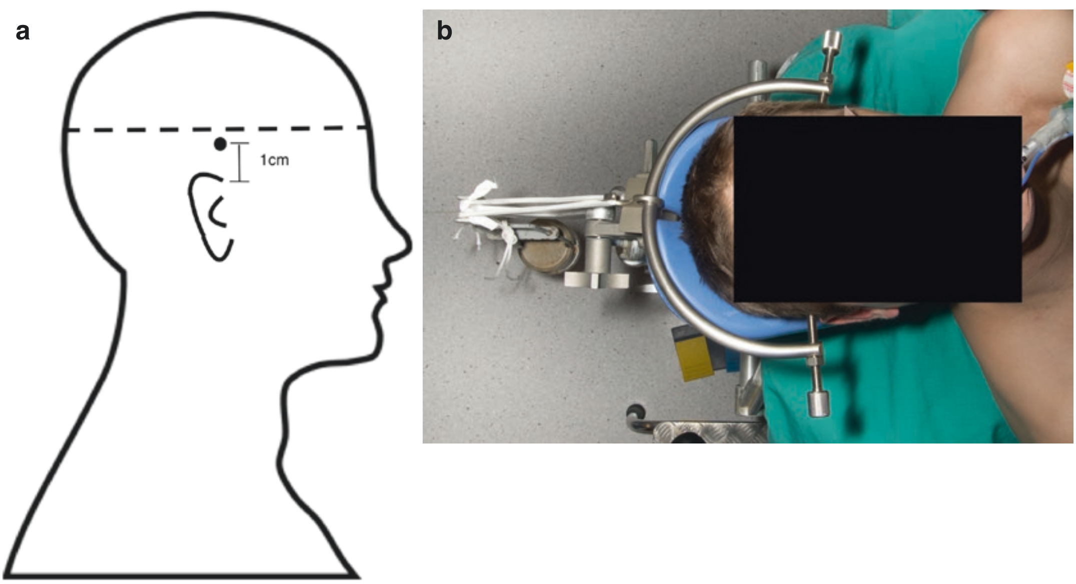

Fig. 1.9 (**a**) Pin position for Gardner-Wells tongs and (**b**) Gardner-Wells tongs in place

Fig. 1.10 Application of axial traction using a pulley

Surgical Approach

Open reduction can be used to restore spinal alignment, allow rigid stabilisation and permit decompression of the spinal cord and nerve roots. Both anterior and posterior procedures can be used to achieve this, and there is no consensus on the optimum surgical strategy. However, as a general rule:

- If *closed reduction is successful,* then subsequent surgery can be performed using anterior, posterior or combined anterior and posterior stabilisation.
- If *closed reduction fails and MRI identifies extruded disc* material, then an anterior discectomy with reduction and decompression is recommended. A subsequent posterior stabilisation may be required if anterior reduction cannot be achieved or as an additional procedure to augment the anterior stabilisation.
- If *closed reduction fails and no extruded disc material is seen on MRI,* then surgery can be performed using anterior, posterior or a combined anterior and posterior stabilisation.
- *Open reduction* is often chosen as the primary reduction manoeuvre, and this allows definitive stabilisation to be performed at the same time. Anterior, posterior or combined anterior and posterior stabilisation can be performed.

Anterior Cervical Approach

The subaxial cervical spine can be accessed using the Smith-Robinson approach [4]. A right- or left-side approach is used according to surgeon preference. The recurrent laryngeal nerve is at slightly higher risk during a right-sided exposure because the right recurrent laryngeal nerve has a more variable course and passes slightly more anterolateral, as it passes from lateral to medial, after hooking around the right subclavian artery. However, many surgeons prefer the right-sided approach if they are right-hand dominant.

- A transverse incision is made along the skin crease and extends from the midline to the anterior border or sternocleidomastoid (SCM).
- The platysma muscle is divided in line with the incision and undermined cranially and caudally.
- Superficial dissection is between SCM laterally and the strap muscles medially, making use of the inter-nervous plane between the spinal accessory nerve (SCM) and the cervical plexus (strap muscles).
- Deep dissection is between the carotid sheath laterally and the midline structures medially, allowing blunt dissection through the pretracheal fascia. This exposes the prevertebral fascia and longus colli muscles.

An anterior disc injury will be visible as the anterior vertebral column is approached. Nevertheless, a level check should be performed using intraoperative image intensification. This can be achieved with a needle placed into the disc or into one of the vertebral bodies. Once the correct level has been confirmed, a complete discectomy should be performed and the posterior longitudinal ligament should be taken down to allow decompression of the spinal cord. Any extruded disc fragments should be excised prior to any attempted reduction.

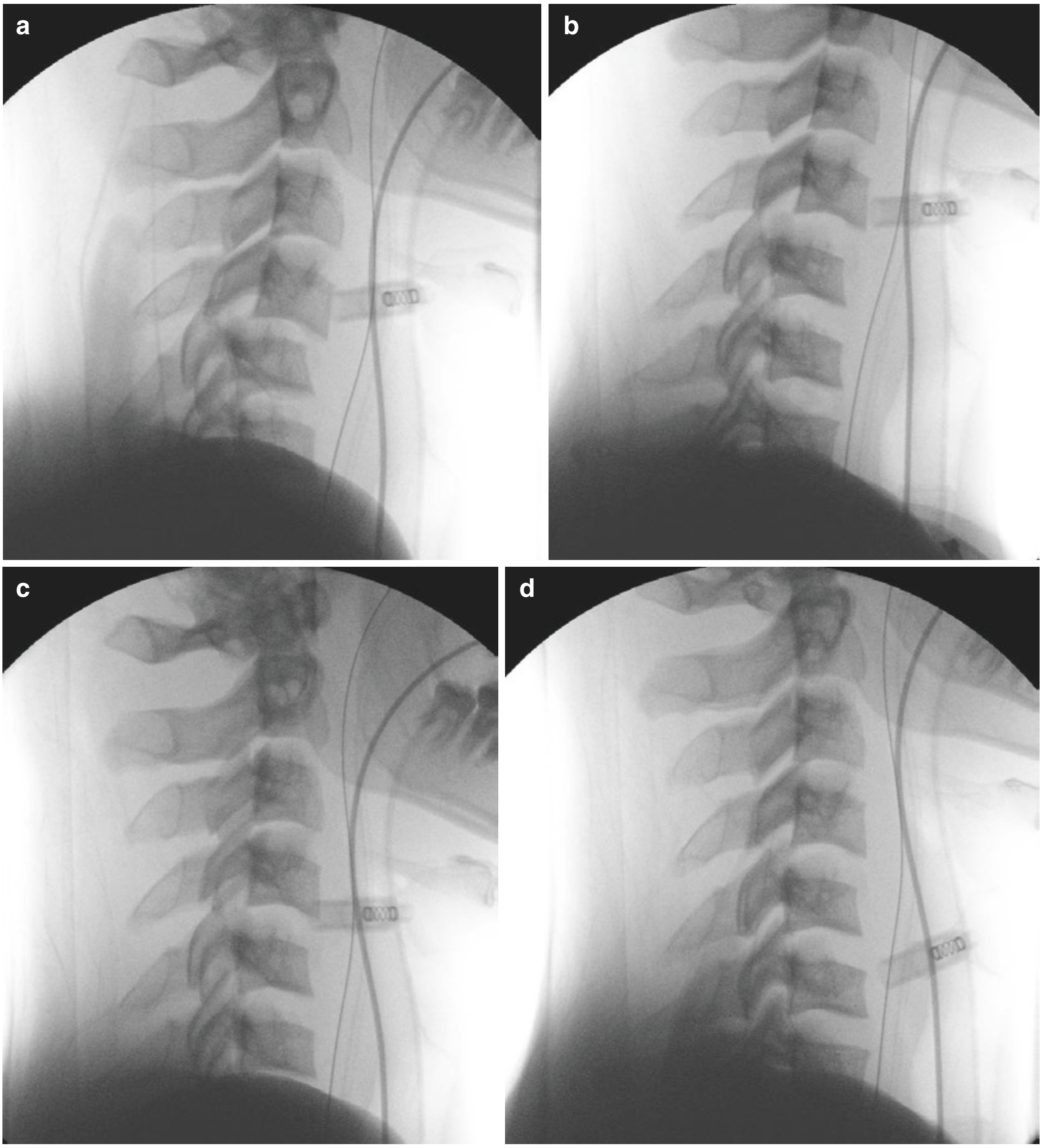

Fig. 1.11 (**a**–**d**) Stepwise closed reduction of dislocation monitored using image intensifier

Posterior Cervical Approach

The approach to the posterior cervical spine allows access to perform reduction of a fracture-dislocation, achieve rigid instrumented stabilisation and decompress the neural structures. The spinous processes can be palpated and marked after the patient has been positioned. The largest spinous processes are usually C2 and C7, and the spinous processes of C3–6 are typically bifid.

- A midline incision is made, and a direct interfascial approach is used to the spinous processes.
- Subperiosteal exposure allows visualisation of the posterior elements. Care should be taken to preserve the facet joint capsules.

- The vertebral artery is at risk in the upper part of this exposure as it passes along the posterior superior arch of C1.

Open Reduction Manoeuvres

Anterior reduction is indicated where there has been a failure of closed reduction or may be chosen as a primary reduction method. In some cases, open reduction may be considered safer than a closed reduction because there is direct visualisation of the cord and it is possible to ensure that the cord is fully decompressed during the reduction manoeuvre. Use of an anterior reduction may also remove the need for a combined anterior and posterior stabilisation. A number of different techniques can be used to achieve an anterior reduction.

Reduction with Casper Pins

Casper reduction pins can be inserted into the vertebral bodies and used to manipulate the facets to the normal anatomical position. The shafts of the pins should be at 20° to make it easy to apply a flexion reduction force. This is achieved by bringing the ends of the pins together (Fig. 1.12a). Use of the pin distracter (Fig. 1.12b) allows a gradual and controlled distraction force to disengage the facets until the cranial levels falling backwards at the facets are reduced. If there is a unifacetal dislocation, the pins can be placed at 15° to one another in the coronal plane to allow rotational reduction forces as the pins are brought together.

Reduction with a Cobb Elevator

A long-handled instrument such as a Cobb or curette can be used to reproduce these reduction forces. The Cobb is inserted into the disc space so that elevation of the Cobb produces distraction at the injured level and allows the facets to relocate (Fig. 1.13).

Reduction with a Lamina Spreader

Distraction across the disk space can also be achieved using a lamina spreader. Again, this provides a gradual controlled distraction that will allow reduction of the facet joints.

Care should be taken during open anterior reduction manoeuvres as overdistraction may result in neurological injury.

Posterior Reduction

Posterior reduction is indicated when there is a block to reduction (such as a fracture of the facet joints) or a significant posterior soft tissue injury. Direct reduction can be achieved by controlling the spinous processes above and below the dislocation using surgical clips. Flexion and distrac-

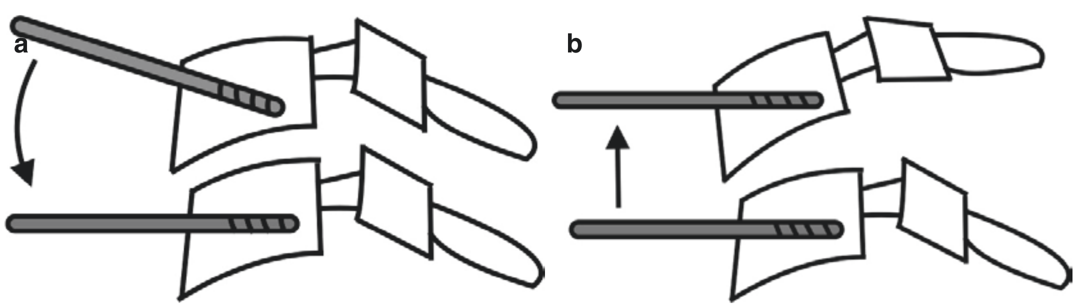

Fig. 1.12 Open anterior reduction using Casper pins: (**a**) initial position of pins inserted at 20° to apply a flexion reduction force with (**b**) use of pin distracters to provide a controlled distraction force

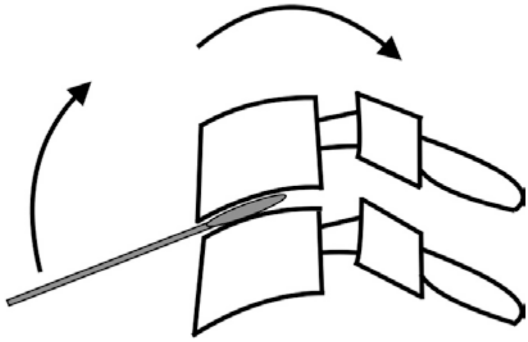

Fig. 1.13 Open anterior reduction using a Cobb elevator

tion forces are applied to achieve reduction of the facet joints. If this fails, the facet joints can be excised by drilling the superior articular process of the caudal level, allowing the injured level to realign without need for further reduction manoeuvres. Rigid stabilisation is then required to hold the spine in the reduced position.

Implant Insertion

Anterior Stabilisation and Fusion

Once the fracture-dislocation has been reduced and normal spinal alignment has been achieved, rigid immobilisation of the injured segment is required to hold the reduction. Tricortical bone graft taken from the ipsilateral iliac crest can be used to fill the disc space and fixed with an anterior cervical plate (Fig. 1.14). Alternatively, a cervical cage can be used alongside local or allograft bone to maintain the disc height without the need for iliac crest bone graft (Fig. 1.15). Care should be taken to ensure that screws are placed into the centre of the vertebral bodies and that the plate sits away from the discs at the levels above and below the injury.

Where there is loss of the structural integrity of the vertebral body, such as in a teardrop fracture, a corpectomy may be required. Whether iliac crest bone graft or a cervical cage is be used to fill the defect and provide anterior support (Fig. 1.16), a plate should be used to provide rigid fixation of the implant.

Fig. 1.14 Tricortical bone graft and anterior cervical plate used to achieve anterior stabilisation

Fig. 1.15 Cervical cage and plate used to achieve anterior stabilisation

Posterior Stabilisation and Fusion

Posterior stabilisation can be achieved using lateral mass screws above and below the injured level. A rigid construct is created using bilateral rods, and fusion is achieved with posterior decortication, with excision of the facet joints, and use of local bone or allograft along the lateral gutters. If a stand-alone posterior stabilisation is performed, it is recommended that two levels above and below the injury are included in the stabilisation due to the likelihood of poor purchase in the lateral masses at the injured levels.

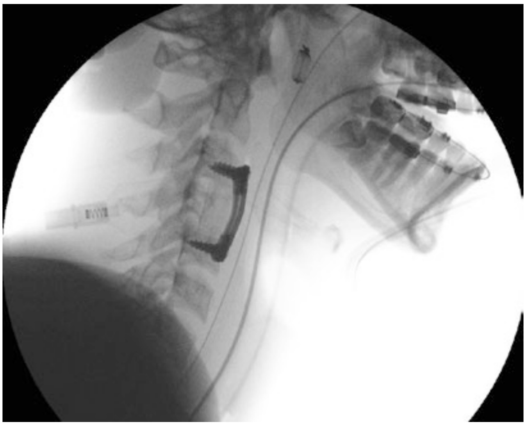

Fig. 1.16 Tricortical bone graft used for anterior column reconstruction during a corpectomy—performed to provide anterior support following a teardrop fracture

Combined Anterior and Posterior Stabilisation

Use of both anterior and posterior stabilisation is required if there is a significant posterior ligamentous injury or if there are concerns over the stability of the anterior fixation (Fig. 1.17). This produces maximal stability across the injured level. It is also performed if there is a failure of open anterior reduction and can form part of a three-stage (anterior decompression, posterior reduction and stabilisation, anterior stabilisation) procedure. Alternatively, if a satisfactory anterior reduction cannot be achieved, the bone graft can be inserted into the disc space and the plate fixed to the superior vertebral body alone (leaving no attachment to the inferior level). A posterior reduction is then completed, and plate will be pulled against the inferior level as the spine is realigned, preventing anterior displacement of the graft. This technique can remove the need for a second anterior stage.

Choice of stabilisation strategy is dependent on the mode of injury, success of reduction manoeuvres and surgeon preference. Both ante-

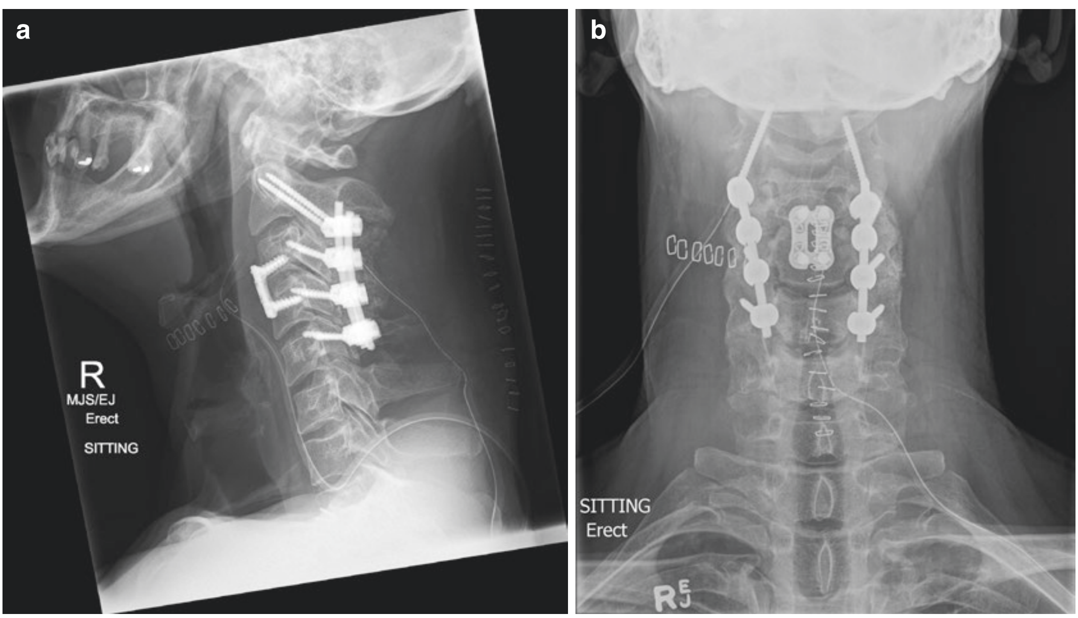

Fig. 1.17 Combined anterior and posterior stabilisation

rior and posterior stabilisations have shown high success rates, so the approach should be chosen based on the ability to allow adequate decompression, reduction and stabilisation. Kwon et al. [5] performed a prospective randomised trial comparing posterior and anterior stabilisation for unilateral facet joint injury in 42 patients. Anterior procedures had a higher post-operative fusion rate, lower rates of wound infection and less post-operative pain. However, they had a higher risk of post-operative swallowing problems. There was no difference in outcome measures suggesting equal efficacy between the two techniques.

Summary

- Cervical fracture-dislocation injuries usually result from high-energy trauma.
- The mechanism of injury is important in determining the deforming forces that led to the fracture-dislocation, as these may need to be repeated to aid reduction.
- Initial assessment includes a careful assessment of neurology, with CT and MRI imaging to identify the fracture pattern and any extruded disc material.
- Acute management of the injury includes reduction of the dislocated facet joints and realignment of the fractured levels. This can be achieved by open surgical intervention or closed reduction using axial traction.
- Care should be taken during all reduction manoeuvres to avoid overdistraction and further neurological injury.
- If there is an extruded disc fragment, open anterior reduction and decompression should be performed and stabilisation achieved with tricortical bone graft (or a cervical interbody cage) and a plate.
- If there is a significant flexion injury and damage to the posterior ligamentous complex, a posterior stabilisation is required.

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Thoracolumbar Fractures

2

Robert A. Dunsmuir

Anatomical Fracture Location

Fractures in the thoracolumbar spine are common and frequently associated with poly-trauma. The association between poly-trauma and spinal injury is well recognised, and this association is exemplified by the specific examination techniques developed to search for spinal injuries when such patients arrive at the emergency room (e.g., advanced trauma life support (ATLS)). However, many such injuries occur in isolation. Isolated injuries have potentially more scope for nonoperative treatment. Relatively simple spinal injuries in poly-trauma patients may require operative stabilisation to optimise rehabilitation of the multiply injured patient.

Treatment of these injuries depends on a sound knowledge of the injury patterns and the forces applied to the spine to produce these deformities. Many spinal fractures are relatively stable and do not require operative fixation. Some injuries are clearly unstable and will always require stabilisation with possible vertebral body reconstruction. Similarly, some spinal injuries can be treated by either method, and the decision about which treatment route to follow is dependent on multiple factors.

A number of classification systems have been developed over the years to help clinicians better understand the morphology and mechanism of propagation of fracture patterns. Holdsworth [1] described fracture patterns and allocated descriptions of injuries by presumed mechanism of injury (burst, extension, wedge compression, dislocation and rotational fracture dislocation). Further descriptions were published on specific fracture patterns. Flexion distraction injuries, typically caused by lap belts in cars, were described by Chance [2]. This description related to one particular injury type and highlighted methods to identify these injuries on plain radiographs and in later years CT scanning and MRI scanning. These classifications described the morphology of the fracture and implied that greater displacement of fracture fragments suggested increased instability.

Denis [3] introduced his three-column theory of the vertebra, suggesting that the greater number of columns injured, the greater the fracture instability. This was generally interpreted by clinicians that three-column injuries required operative fixation. The AO group [4] developed a more comprehensive classification system that encompassed all the pre-existing systems but better described the large variation in spinal fracture patterns but also addressed the possible effect of soft tissue injury in the spine (Fig. 2.1). This is a mechanism-based system and broadly divides fractures into compression, distraction or rotational injuries. Each of these fracture pat-

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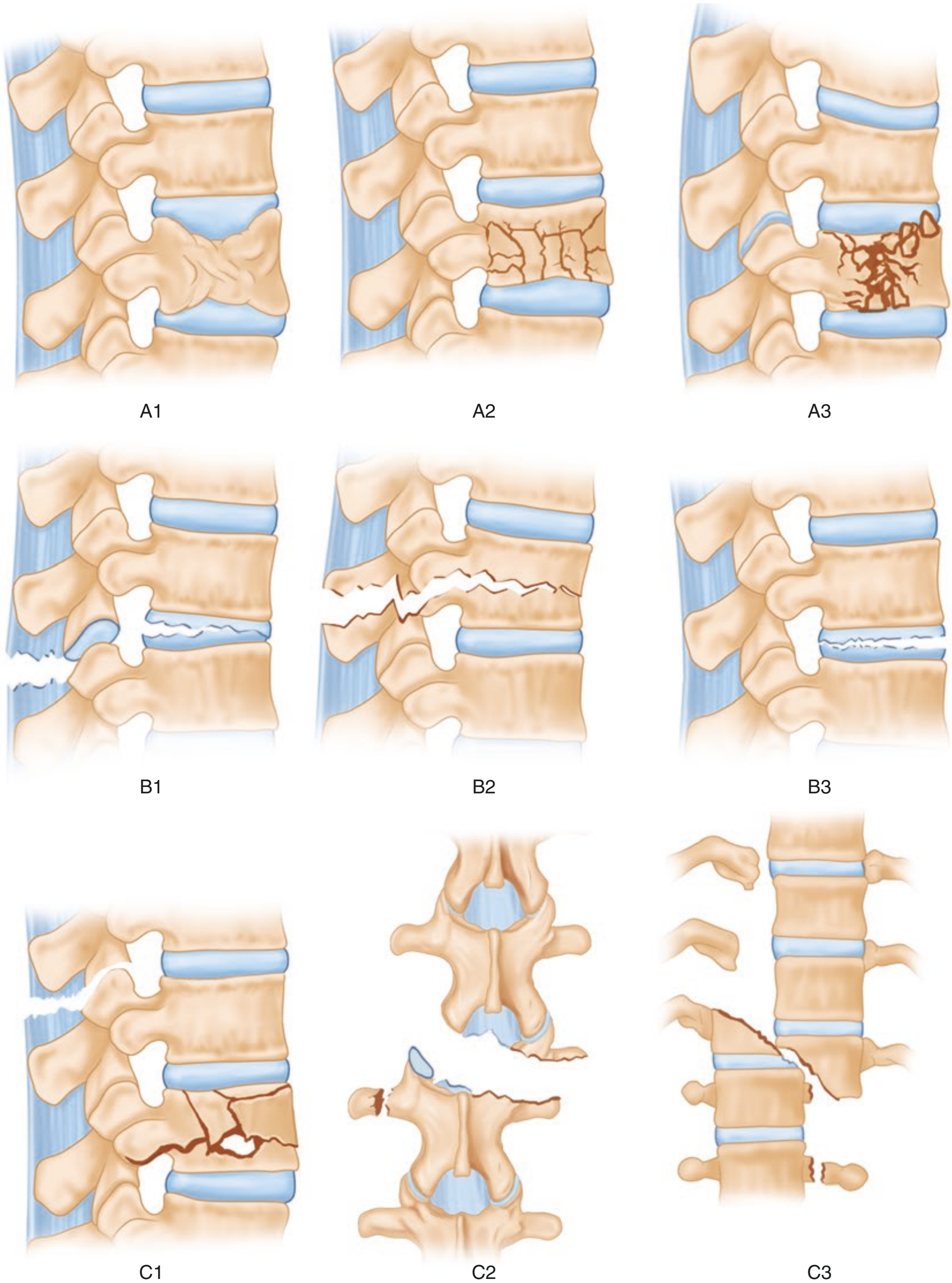

Fig. 2.1 The AO classification of spinal fractures (adapted from Magerl F et al. Eur Spine J 1994:3(4):184–201)

Fig. 2.2 The TLICS fracture classification system

The TLICS fracture classification system			
1 Morphology	Compression	1	X-ray, CT
	Burst	2	X-ray, CT
	Translation/Rotation	3	X-ray, CT
	Distraction	4	X-ray, CT
2 Posterior Ligamentous Complex	Intact	1	MRI
	Suspicious	2	MRI
	Injured	3	MRI
3 Neurological Status	Intact	0	Examination
	Nerve root	2	Examination
	Complete cord	2	Examination
	Incomplete cord	3	Examination
	Cauda equina	3	Examination

If after assessment the TLICS score is 0-3 - non-surgical treatment
4 - surgeon's choice
>4 - operative treatment

After physical and radiological examination the clinician can determine the total TLICS score and this will guide clinician to operative/non-operative treatment.

(adapted from Vaccaro et al. A new classification of Thoracolumbar Injuries. The importance of injury morphology, the integrity of the posterior ligamentous complex and neurological status. Spine. 2005;30;2325-2333)

terns is further subdivided according to the extent of bony and soft tissue injury. As one progresses through each subsection (anatomical fracture location, brief preoperative planning and patient set-up in theatre) and through the system (A–C), the fracture patterns become increasingly unstable.

All these classification systems have been descriptions of the radiological appearance of fracture. The possible effect of neurological injury and other non-axial injuries was not taken into account. Subsequently, more recent spinal injury classification systems have sought to address these other clinical factors into the decision-making process about the need for operative intervention in spinal injury.

Vaccaro et al. [5, 6] have described the Thoracolumbar Injury and Classification Severity Score (TLICS). This system (Fig. 2.2) requires radiological investigation to assess the morphology of the bony injury. This is usually best appreciated on CT scan. The integrity of the posterior ligamentous complex is also assessed. Whether the posterior ligaments are damaged or not can be assessed from CT but is best appreciated by MRI scanning. Finally, careful clinical examination is required to look for signs of neurological compromise. These three factors are scored, and the total score from these three assessments are summed. The total TLICS score can then suggest whether operative intervention is necessary. The AO classification has also been updated to take account of clinical findings.

These classification systems can be used as good general tools to help making decisions about operative interventions in spinal injuries. However, no system is foolproof. There are a number of clinical conditions where these systems are not so useful. In patients with metabolic bone disease, ankylosing spondylitis and diffuse skeletal hyperostosis (DISH), simple fractures are difficult to deal with nonoperatively. Where the spine is solidly fused, a bony three-column injury has a high incidence of non-union and pseudarthrosis. Some simple thoracic injuries may not be suitable for bracing because of associated rib fractures. Thoracic fractures in the presence of sternal fractures can be very unstable, and therefore a simple wedge fracture in this area may require surgical stabilisation. Some simple fractures in poly-trauma patients may be better being stabilised to aid patient rehabilitation.

In writing this chapter, the author has chosen to use the AO classification as a descriptor for spinal fractures. It is presumed that the fracture will require surgery and reduction techniques differ for each of these fracture patterns.

Brief Preoperative Planning

It is assumed that all patients have been admitted to hospital through their emergency room and been assessed using advanced trauma life support (ATLS) protocols.

On admission to the ward, the patient will have had regular neurological examinations to ensure no deteriorating changes to their neurological status. Proper radiological assessment will have been made of the spinal injuries. This includes plain radiographs, CT scanning and where appropriate MRI scanning of the whole spine (in the presence of an identified spinal fracture there is a 20% chance of a second spinal fracture).

These assessments will determine if the spinal injury is an A-type, a B-type (these include extension-type injuries, AO B3) or a C-type injury pattern.

A-Type

These injuries will generally be associated with localised kyphosis at the fracture site (Fig. 2.3). The role of surgery is to stabilise the fracture and to try to restore the spinal alignment and reduce to localised kyphosis associated with the fracture.

B-Type (AO B1 and AO B2)

These injuries will generally be associated with localised kyphosis at the fracture site (Fig. 2.4). The role of surgery is to stabilise the fracture and to try

Fig. 2.3 Sagittal trauma CT showing burst fracture of L4 vertebral body

to restore the spinal alignment and reduce to localised kyphosis associated with the fracture. If the injury to the anterior columns in the spine is through the disc space, consideration may need to be given to removal and grafting of the disc space to achieve fusion and stability anteriorly in the spine.

B-Type (AO B3)

These injuries will generally be associated with localised lordosis at the fracture site (Fig. 2.5). The role of surgery is to stabilise the fracture and to try to restore the spinal alignment and reduce the localised lordosis associated with the fracture. If the injury to the anterior columns in the spine is through the disc space, consideration may need to be given to removal and grafting of the disc space to achieve fusion and stability anteriorly in the spine.

Fig. 2.4 Sagittal trauma CT showing bony Chance fracture

Fig. 2.5 Sagittal trauma CT showing extension fracture (AO B3) through area of diffuse skeletal hyperostosis at the T7/8 level

C-Type

These injuries are rotationally unstable (Fig. 2.6). These injuries also have associated A-type or B-type injury patterns. The principles of fracture fixation in C-type injuries is to treat the underlying A-type or B-type fracture pattern but also to achieve rotational stability. The latter is usually achieved by extending the fractures stabilisation to two or more vertebrae on either side of the area of injury. Stability may occasionally be only achieved by surgery to the posterior and anterior elements in the spine. Surgery to the back and front of the spine may be required to be done at a single operation or be staged to two operations performed on different days.

In general, stabilisation of all these fracture patterns can be achieved using a posterior approach to the spine. In some cases, anterior surgery may be required. Anterior surgery may be necessary if the intervertebral disc is disrupted, particularly if the disc fragments have migrated posteriorly into the vertebral canal.

Patient Set-Up in Theatre

Stabilisation of the spine will generally require placing pedicle screws into vertebrae on either side of the fracture. This will require a radiolucent

Fig. 2.6 Sagittal trauma CT showing fracture dislocation at T11/12. The fracture line extends along the T12 vertebral body just below the superior endplate

table that will allow the spine to be visualised in the anteroposterior (AP) and lateral directions. In our hospital, we use the OSI table which may have a Wilson frame (Fig. 2.7) or Jackson pads (Fig. 2.8). These tables will be used depending on which area of the spine has to be instrumented. The Jackson pads are used when pedicle screws are to be inserted to the upper and middle thoracic spine. The decision about which system to use is determined by the site of the fracture, the morphology of the fracture, what operation is planned and surgeon preference.

These tables allow easy access for the image intensifier to swing from the AP to the lateral position (Fig. 2.9) and to allow adequate imaging of the spine to be obtained to allow safe insertion of pedicles screws. The monitor needs

Fig. 2.8 The OSI table with Jackson pads and prone view

Fig. 2.7 The OSI table with Wilson frame and prone view

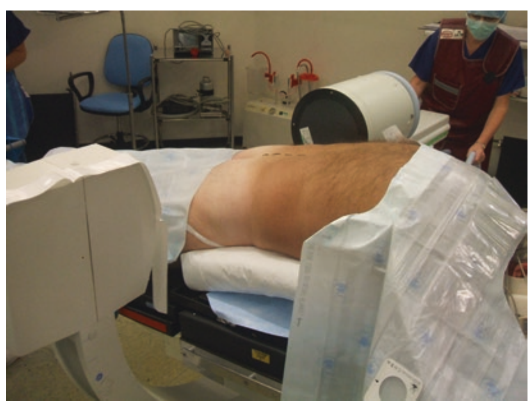

Fig. 2.9 Using the image intensifier to localise the area of spinal injury

Fig. 2.10 Patient positioning and using the prone view

Fig. 2.11 The patient fully draped and ready to start surgery

to be placed where the operating surgeon can most easily view the images. Generally, the monitor would be placed towards the head of the patient on the opposite side from the operating surgeon. Assistant surgeons will stand opposite the main surgeon on the other side of the patient.

Patients should be transferred onto the operating table using full log-rolling precautions. Patients will be prone resting on the Wilson frame or Jackson pads. The anaesthetist guides the transfer of the patient onto the operating table.

The patient is rolled prone onto the operating table on top of the Wilson frame. The patient's head is rested in the prone view (Fig. 2.10). The Wilson frame is flexed into the position which best reduces the fracture by closed means.

Precautions:

- Ensure that there is no pressure on the patient's axillae.
- Ensure that the patient's knees and ankles are not overextended.
- Ensure that the patient's eyes are visible using the 'prone view' especially after the frame has been flexed up to its maximum position. The patient can 'slip' distally during this procedure, and pressure can be applied to the orbits.
- Ensure no pressure applied to abdomen and its contents. This will minimise back pressure from abdominal veins anastomosing with epidural veins.

Potential problems:

- Pressure problems on skin of chest, flanks and knees
- Brachial plexus stretching
- Pressure on eyes

No matter what patient position is used, calf pumps are always applied for intraoperative DVT prophylaxis.

Draping

The skin is prepped with the antiseptic solution of choice. Adhesive paper drapes are applied and the operative field covered with an occlusive dressing (e.g. Opsite) (Fig. 2.11).

Closed Reduction Manoeuvres

For extension injuries (AO B3), the Wilson frame can be adjusted to increase the arc of frame. This will often lead to a satisfactory indirect reduction of the fracture, thus making the fracture site more kyphotic.

For kyphotic deformities, either the Wilson frame or the Jackson pads can be used. Jackson pads will tend to align the thoracolumbar junction and lumbar spine into a more natural position. However, either frame or pads can be reliably used for AO A-type, AO B1 and AO B2 fractures.

Reduction Instruments

Different existing fracture sets offer different options for fracture reduction and stabilisation. Standard pedicle screws can be inserted into the uninjured bones on either side of the damaged bone. If using normal pedicle screws, correction can be achieved by creating a lordosing curve in the connecting rods. Thus, as the rods are tightened onto the screws, the kyphosis is corrected by indirect reduction/correction (Fig. 2.12). This technique can be problematic in that the degree of lordosis of the rods cannot be changed during the correcting procedure. The surgeon must use monoaxial screws only for fracture correction (a solid screw with no moving parts) (Fig. 2.13). If polyaxial screws are used for fracture correction, there is a danger that in the longer term the correction achieved at surgery will fail because the screw shaft moves in relation to the rod (Fig. 2.14a, b).

Surgical Approach

Level Checking

The image intensifier is used to check the operative level is correct. The palpable spinous processes are marked with a permanent marker pen.

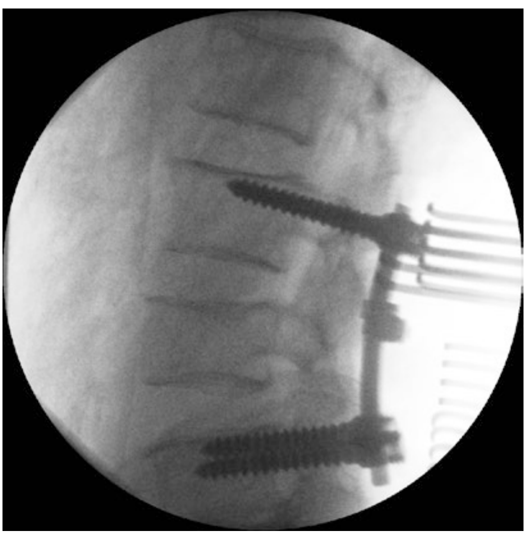

Fig. 2.12 Intraoperative image intensifier view showing the use of pedicle screws and rods to achieve fracture stabilisation and re-create lumbar lordosis

Fig. 2.13 A monoaxial pedicle screw. Note there are no moving parts on the pedicle screw

An epidural needle is pushed through the skin perpendicular to the skin surface. The needle is passed through the soft tissue until near the spinal column (Fig. 2.15). An X-ray image is obtained. This will determine if the selected level is over the fracture to be operated upon. If the needle is not correctly positioned, remove the needle and reinsert it more proximally or distally as directed by the original needle position. Repeat this until you are happy that the needle is directly over the correct area to perform the surgery.

Surgical Exposure

Posterior Approach

The posterior approach to the spine can be utilised for most fracture types. This approach is generally used for A-, B- and C-type fracture patterns.

The skin incision is made over the predetermined level. The incision needs to extend for a length appropriate to allow insertion of pedicle screws into the vertebrae either side of the fracture. The more unstable the fracture, the longer the incision required to accommodate the larger number of screws. The superficial and deep fascial layers are divided in line with the skin incision until the thoracolumbar fascia is identified. The thoracolumbar fascia is incised along the length of the wound close to the tips of the spinous processes. This allows the periosteum on the spinous process to be peeled from the bone.

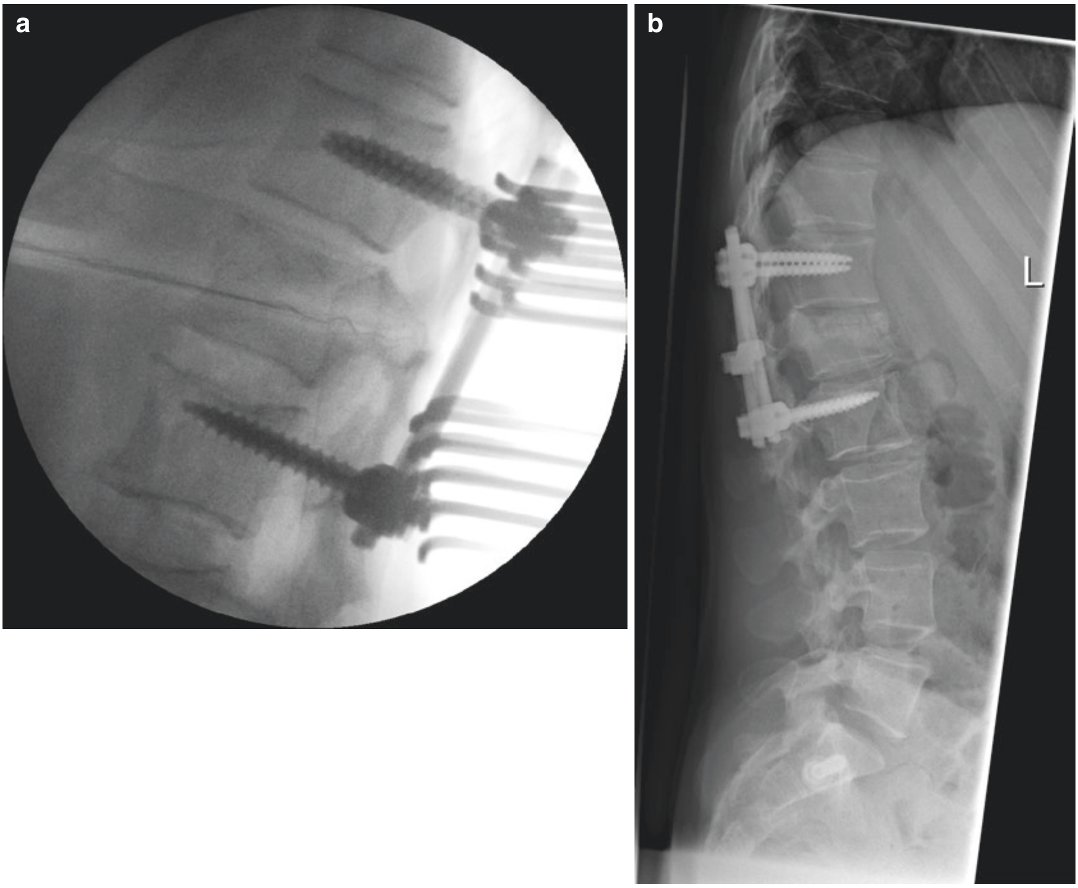

Fig. 2.14 (**a**, **b**) Images showing loss of kyphosis when fracture stabilised using polyaxial pedicle screws

Fig. 2.15 Using spinal needle and skin marking to localise operative site

This process of peeling the periosteum from bone can be extended along the lamina towards the facet joint. The adjacent spinous process is similarly treated. The remaining soft tissue between adjacent spinous processes can be detached by monopolar diathermy or blunt dissection using Lexel biters.

The above process is repeated at each level up the spine on both sides until the relevant vertebral transverse processes are exposed where pedicle screws will be inserted.

This approach allows access to the appropriate entry points for pedicle screw insertion, allows posterior decompression of the spinal canal (if required) and allows access to the spine for other procedures such as costo-transverectomy (Fig. 2.16).

Anterior Approach

All B-type and C-type fractures can have anterior A-type injuries that may require to be dealt with separately. Some A-type fractures can be treated by anterior surgery alone.