2 Thoracolumbar Fractures

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.

R. A. Dunsmuir (✉)
Department of Spinal Surgery, Leeds General Infirmary, Leeds, UK
e-mail: robert.dunsmuir@nhs.net

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-

P. V. Giannoudis (ed.), *Fracture Reduction and Fixation Techniques*,
https://doi.org/10.1007/978-3-030-24608-2_2

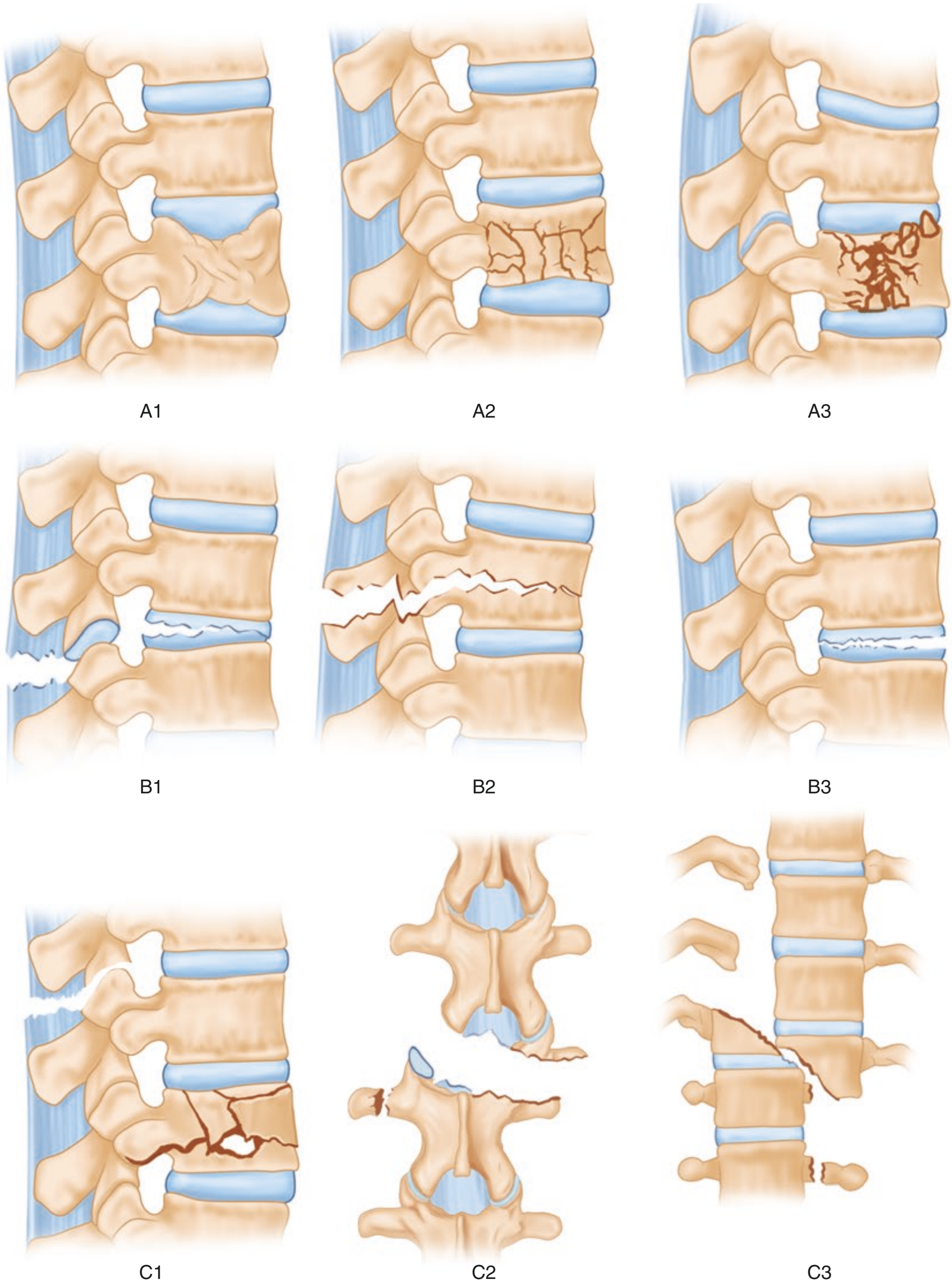

Fig. 2.1 The AO classification of spinal fractures (adapted from Magerl F et al. Eur Spine J 1994:3(4):184–201)

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.

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

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

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.

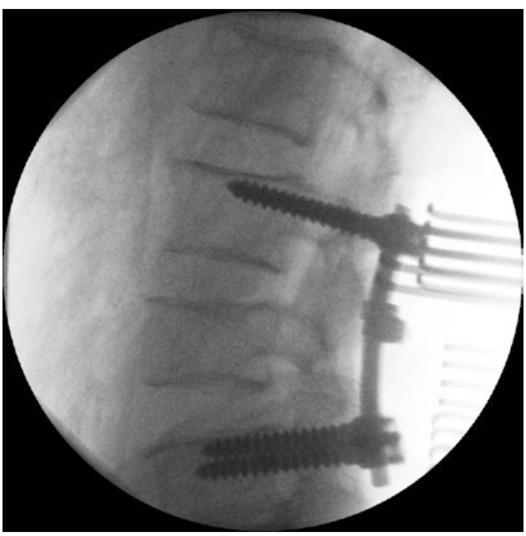

Fig. 2.12 Intraoperative image intensifier view showing the use of pedicle screws and rods to achieve fracture stabilisation and re-create lumbar lordosis

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.

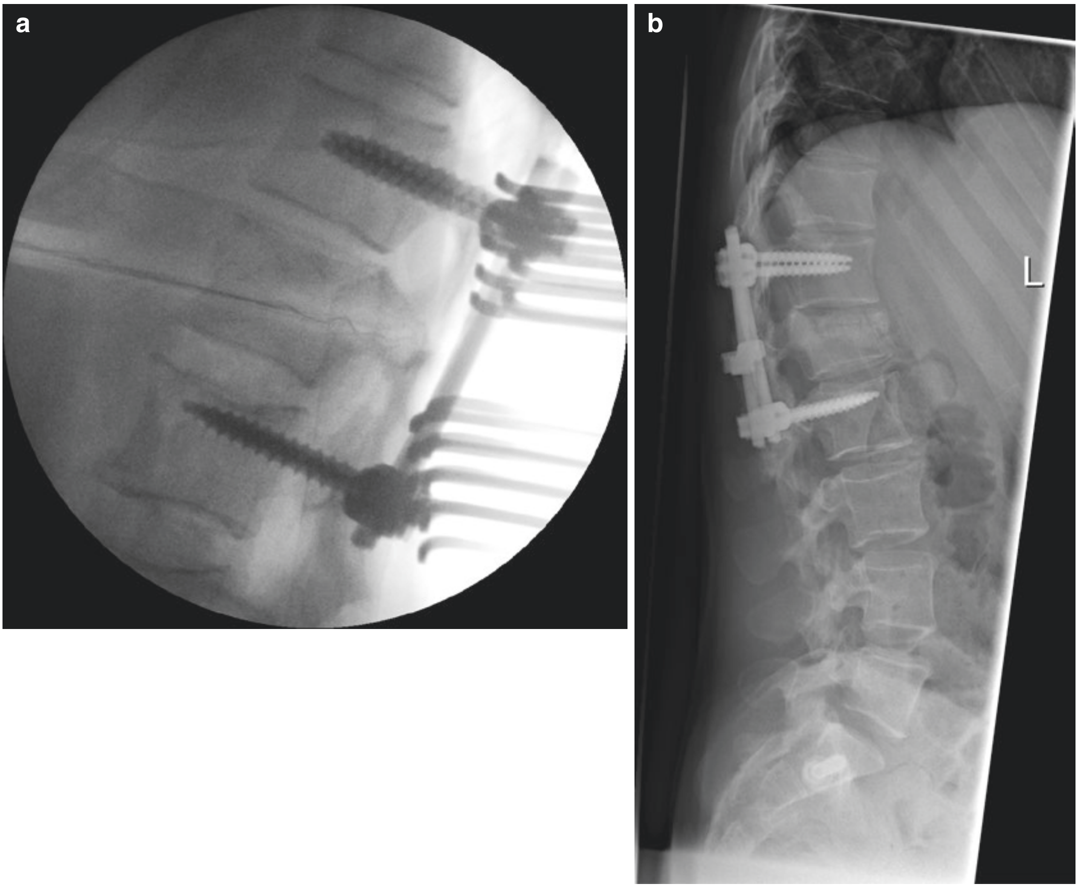

Fig. 2.14 (**a**, **b**) Images showing loss of kyphosis when fracture stabilised using polyaxial pedicle screws

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.

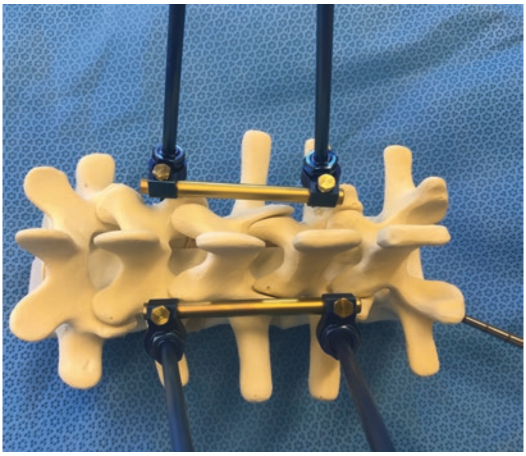

Fig. 2.16 The AO fracture set demonstrated on a dry bone model. Note long Schanz screws, longitudinal rods and the complex and mobile rod/screw connector

Most injuries will not require any intervention. If the vertebral body is badly comminuted, then this damage may not heal completely. If the vertebral body fracture fails to heal completely, there is a risk of failure of the anterior support and potential loosening and failure of the posterior stabilising construct.

To help with the decision about the need for anterior surgery, the McCormack-Gaines load-sharing classification was published [7]. This assesses the degree of angular kyphosis, the proportion of the vertebral body that is comminuted and how far apart the fracture fragments are placed. From this, a score is calculated, and those scores which suggest the fracture is more angulated, large degree of comminution with fracture fragments widely displaced should have anterior stabilisation.

A lateral approach is made to the anterior spine. This can be performed by traditional open approaches or by more minimally invasive approaches. The object is to remove the fractured vertebral body fragments and the intervertebral discs on either side of the damaged vertebral body. The space thus created can be filled with a bony strut graft or a cage (Fig. 2.17). If posterior stabilisation has been performed, the graft/cage inserted may not need any further instrumentation. If the fracture is being treated by anterior surgery alone, the strut/cage must be supported by a plate or screw and rod system to provide stability (Fig. 2.17).

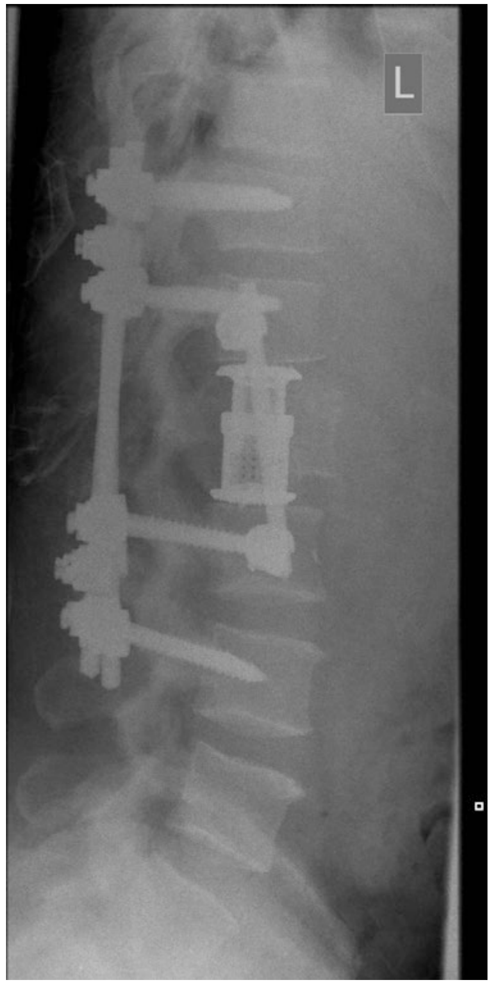

Fig. 2.17 X-ray showing use of expandable cages to create anterior support for spine after excision of comminuted vertebral body

Open Reduction Manoeuvres and Fixation

A-Type Fractures

Many A-type fractures can be treated by nonoperative measures. However, when surgery is required, a posterior stabilisation is usually sufficient. The main fracture in these injuries is to the vertebral body. The object of the operation is to stabilise the vertebra in the position the bone is in to allow vertebral body fracture healing or to achieve this stability but also to correct any kyphosis that the fracture has created in the vertebral body.

The author's preferred tool for correction of A-type fractures is the AO fracture set (Fig. 2.16). In this technique, the pedicle screws are replaced by Schanz screws (Fig. 2.18). Four Schanz screws are inserted as shown in the model (Fig. 2.19). The longitudinal rods attach to the Schanz screw using a mobile connector. The rods and screws are connected tightly at the bone adjacent to the uninjured endplate of the fractured vertebra. The screws in the bone next to the fractured endplate can then be compressed down towards the locked screws (Figs. 2.18, 2.20, 2.21, and 2.22). This will correct the kyphosis by indirect means. The connecting bolt is then locked onto the Schanz screw. The longitudinal rod is then locked onto the connecting bolt of the Schanz screw.

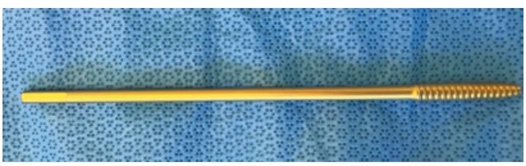

Fig. 2.18 A 7 mm Schanz screw

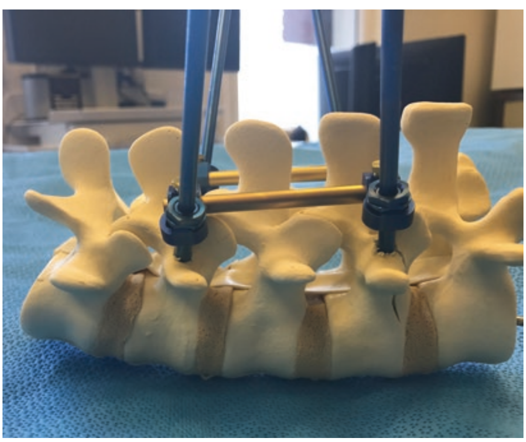

Fig. 2.19 Dry bone model showing construct position before attempted reduction and recreation of lordosis

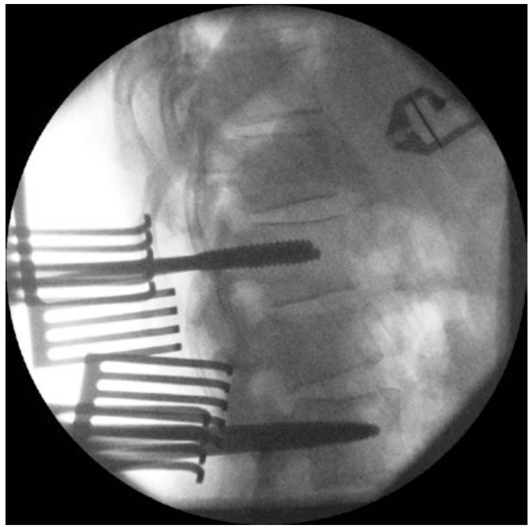

Fig. 2.20 Intraoperative image intensifier view of kyphosed fractured vertebra before reduction

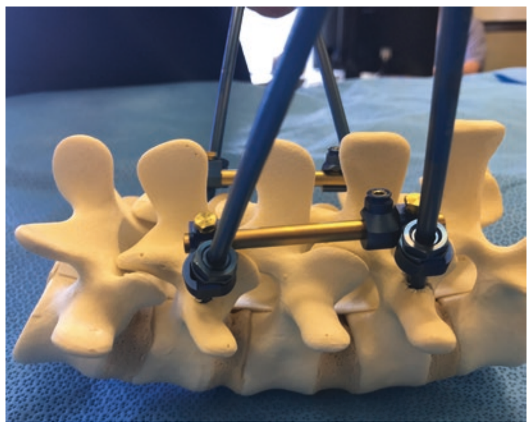

Fig. 2.21 Dry bone model showing compression of Schanz screws

The above technique can only be used if the posterior vertebral body wall of the fractured vertebra is intact. If the posterior vertebral body wall is fractured (burst fracture), following the above protocol will force bone fragments from the fractured posterior vertebral body wall into the spinal canal. This may cause cord/nerve compression. To avoid this complication, a "C clamp" (Fig. 2.23) can be attached to the longitudinal rods just below the rod connector. This C clamp then becomes the fulcrum about which the lordosing forces act, and thus canal compromise is prevented (Fig. 2.22).

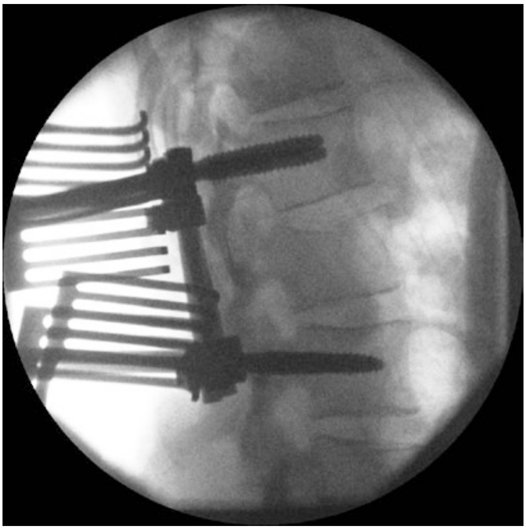

Fig. 2.22 Intraoperative image intensifier view showing correction of kyphosis after reduction manoeuvre

Fig. 2.23 The C clamp used to allow screw compression in the presence of a posterior vertebral body wall fracture. This needs to be applied within 2 mm of the Schanz screw

B-Type Fractures

The objective of operating on these fractures is to close down the distraction of the posterior ligamentous/bony complex and to re-establish the posterior tension band in the spine at the zone of injury. The posterior elements of the vertebra on either side of the area of injury have to be exposed.

It should be remembered that the injury may pass through the interspinous ligament and supraspinous ligament of adjacent vertebrae. Thus, pedicle screws may be inserted into adjacent bones.

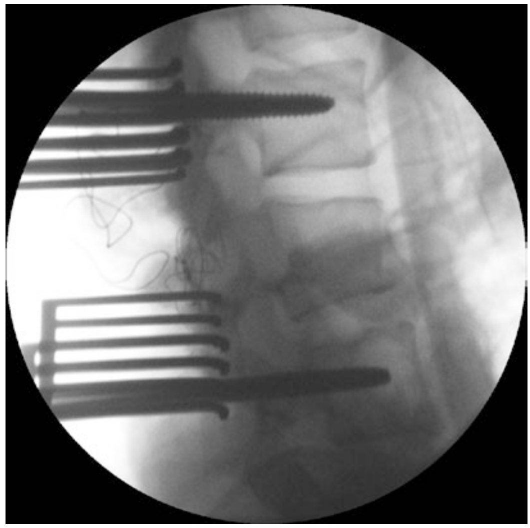

Fig. 2.24 Intraoperative image intensifier view of a bony Chance fracture before closure manoeuvre to approximate posterior bony elements

The posterior osteo-ligamentous injury is often associated with an A-type compression injury of the vertebral body anterior to the posterior tension band injury. This bony injury will frequently prevent the use of this injured bone for pedicle screw insertion. If this is the case the intact bones on either side of the injured bone should be used for screw insertion (Fig. 2.24).

Pedicle screws are inserted into the relevant bone by the surgeon's normal technique. Longitudinal rods are attached on either side to the pedicle screws. One set of screws are locked tightly (at either the proximal or distal end). The compression device for the pedicle screw set can then be used to pull the two sets of screws together (Fig. 2.25). This action will close the posterior gap.

The posterior injury is often associated with an axial split in the lamina and/or spinous process or is associated with a transverse tear of the ligamentum flavum. Before compressing the screws to close the posterior gap, the surgeon must ensure that all soft tissues are excised in these areas. Failure to excise these damaged soft tissues could result in the tissue being forced anteriorly into the spinal canal and thus risk spinal cord or nerve damage.

Fig. 2.25 X-ray showing the final healed position of the Chance fracture treated in Fig. 2.23

Fig. 2.26 Sagittal trauma CT showing fracture-dislocation at the T11/12 level

C-Type Fractures

C-type fractures are generally always unstable. These will generally always require surgical stabilisation. Relatively few patients with C-type injuries will not have operations. Therefore, when moving patients with these injuries, full log-rolling precautions should be observed. There is usually a translational and rotational injury pattern with these injuries (Fig. 2.26). This will usually compromise the spinal canal size, and neurologically, injury is frequently associated with this injury pattern. This neurological damage can range from mild paraesthesia in the lower limbs to complete paraplegia.

It is important to have performed a complete neurological assessment of the patient once they are stable haemodynamically. The clinician should look for signs such as priapism which would indicate spinal cord injury. The neurological examination should be repeated regularly to determine if the neurological status remains as it was on presentation and is improving or deteriorating. If the neurological status is deteriorating, all imaging (X-ray, CT, MRI) should be performed urgently to allow urgent surgical intervention. If the neurological status remains unchanged or shows signs of improvement, surgery can be planned with less urgency but should be performed at the earliest opportunity. This will allow early mobilisation of the patient and help with early rehabilitation.

Patients with C-type injuries should be moved onto the operating table with full log-rolling precautions.

Preoperative planning should always involve actively determining if any intervertebral disc fragments have migrated posteriorly as a result of the injury. If this has occurred, the operative plan must include a step to remove this disc fragment at an early stage of the operation. This will minimise the time the spinal cord or cauda equina is compressed by this disc material. This will minimise the risk or neurological problems from the compression this disc material causes.

The surgeon should also be prepared for possible traumatic laceration of the dura mater and the presence of CSF leakage. The degree of damage to the dural sac will determine which operative repair is chosen.

Often when the patient is positioned onto the operating table, the fracture displacement will reduce spontaneously (Fig. 2.27). If this occurs, the surgical approach is performed as usual. The surgeon needs to remember that the exposure needs to be longer as more pedicle screws are required to produce the final stability in these very unstable injuries. As there is often a rotational instability associated with these injuries, cross-links are often inserted to the final implant construct to provide further rotational stability (Fig. 2.28).

Frequently, the fracture dislocation in the spine does not reduce spontaneously when the patient is rolled onto the operating table. If this occurs, the surgical exposure should be performed in the normal fashion. The surgeon will frequently see that the factor preventing reduction is the dislocation of the inferior facet of the proximal vertebra over the superior facet of the inferior vertebra at the injury site (Fig. 2.29). When this occurs, the first step is to excise the superior articular processes of the inferior vertebrae. This may allow the superior vertebra to reduce posteriorly into a more anatomical posi-

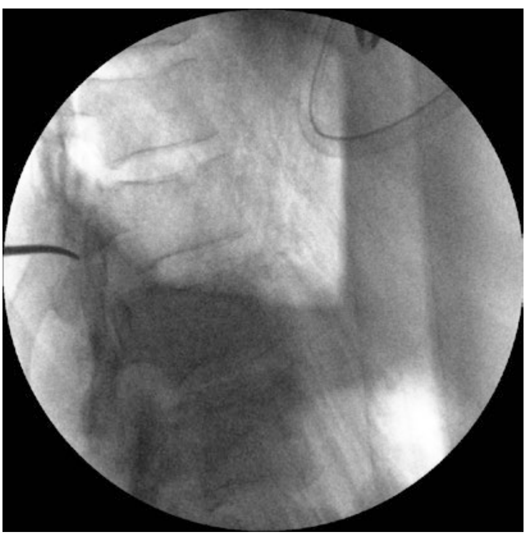

Fig. 2.27 Intraoperative image intensifier view showing spontaneous reduction of fracture-dislocation. Reduction achieved when patient positioned prone on Wilson frame

Fig. 2.28 X-ray of final construct required to achieve translational and rotational stability in fracture-dislocation shown in Fig. 2.26

Fig. 2.29 Parasagittal trauma CT showing locked facets at T11/12

tion. If this manoeuvre fails to achieve reduction, the next stage is to excise the inferior articular processes of the superior vertebra. This will mean that the vertebra should be free and reduce with more ease. Perfect alignment is not necessary but alignment should be as close to anatomical normality as possible (Fig. 2.30). Once this procedure is completed, the surgeon will find that the dural sac is widely exposed, and this allows access into the vertebral bodies and disc space anteriorly via a posterolateral approach. This can be useful if bone grafting is required in the disc space.

There are occasions when all the manoeuvres above fail to provide adequate reduction. If this occurs, the instrumentation used to stabilise the fracture can be used to achieve reduction. Most modern pedicle screw systems have access to long tab screws (Fig. 2.31). These screws can be inserted into the vertebra immediately above the area of subluxation (Fig. 2.32). As the locking nut is applied and tightened in this screw head, this action will draw the subluxed spinal fragments back towards the remainder of the spine (Fig. 2.33).

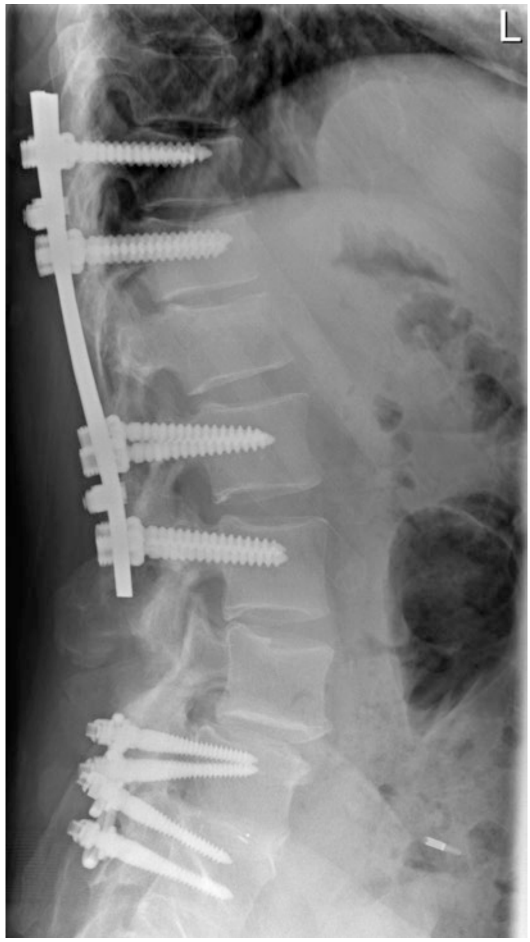

Fig. 2.30 X-ray showing final reduction achieved with fracture dislocation

Once reduction is achieved, longitudinal rods are applied (or have been inserted to help to reduce the fracture). The construct is locked. Bone graft is applied along the length of the construct. After grafting, cross-links are applied for rotational stability.

Summary of Tips and Tricks-Pitfalls

1. All spinal fractures should be assessed, and the fracture pattern determined as being A-, B- or C-type injuries.
2. A full radiological assessment including MRI scan is required to properly assess the degree of bony and ligamentous injury.

Fig. 2.31 A "long tab" screw

Fig. 2.32 Intraoperative image intensifier view of a fracture dislocation which failed to reduce after excision of both inferior and superior articular processes

3. Most spinal injuries can be stabilised from posterior approaches
4. Anterior surgery may be required to support posterior constructs.
5. Most reductions in spinal fractures can be achieved indirectly by either patient positioning or use of the spinal instrumentation.
6. Infrequently does the fracture have to be directly manipulated to achieve reduction.
7. Urgent neurological deterioration necessitates urgent investigation and surgery.

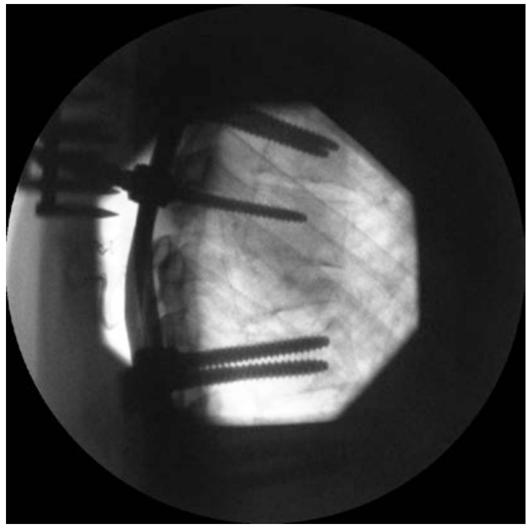

Fig. 2.33 Intraoperative image intensifier view showing use of longitudinal rods and screws to draw subluxed spine back to more anatomical position

References

1. Holdsworth FW. Fractures, dislocations, and fracture dislocations of the spine. J Bone Joint Surg Br. 1963;45:6–20.
2. Chance QC. Note on a type of flexion fracture of the spine. Br J Radiol. 1948;21:452–3.
3. Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine. 1983;8:817–31.
4. Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S. A comprehensive classification of thoracic and lumbar injuries. Eur Spine J. 1994;3(4):184–201.
5. 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;30:2325–33.
6. Vaccaro, et al. AO Spine thoracolumbar spine injury classification system: fracture description, neurological status, and key modifiers. Spine. 2013;38(23):2028–37.
7. McCormack T, Karaikovic E, Gaines RW. The load-sharing classification of spine fractures. Spine. 1994;19:1741–4.