28 Surgical Correction and Special Features in Traumatic and Congenital Kyphotic Deformities

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28.1 Introduction

The term kyphosis is derived from Greek and is used to describe a "hump". As the word implies, in spine, it is used for sagittal spinal curves with anterior concavity. The normal spine has two areas physiologically aligned in kyphosis: the thoracic spine and the sacrum. Pathological kyphosis can be found in any part of the spine and can be due to a variety of etiologies including congenital or developmental anomalies, trauma, infection, inflammatory diseases or degenerative disc disease among others. It therefore can affect any age group.

Congenital kyphosis is usually caused by anterior formation defect or segmentation failure. This form of anterior tethering in a growing spine can cause a progressive deformity. Severity of the resultant deformity varies according to type of defect, location and the number of affected vertebrae. Not only the deformity can cause a sagittal malalignment and imbalance, in severe cases it can result in neurological cord compression. Surgical treatment in congenital kyphosis is recommended for significant, progressive and unstable deformities to restore normal sagittal alignment, prevent sagittal imbalance and preserve neurological structures.

Most symptomatic posttraumatic kyphotic deformities occur at the thoracolumbar junction. They are mainly caused by a loss of the anterior vertebral column height or support. Indications for surgical treatment in these cases are correction of the deformity, neurological decompression and stabilization of the injury in acute cases. In installed deformities, the main objective of surgery would be to correct the resulting sagittal malalignment.

In this chapter, we will be presenting a clinical case of each etiology and discuss the rationale for treatment of kyphotic deformity in these scenarios. We will be reviewing the various surgical techniques available for each case, guide the reader through the decision making and discuss other relevant considerations.

28.2 Case Description

28.2.1 Congenital Kyphosis Case

An 18-month child was referred to our clinics with a progressive angular kyphosis in thoracolumbar area. Clinical exam revealed a partially flexible thoracolumbar hump with no associated neurological abnormalities. Full-body standing X-Rays showed a congenital spine dislocation with a segmental kyphosis measuring 52° between

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T10-L2 (Fig. 28.1). CT scan showed an hypoplasia of L1 vertebral body with dysplasia of posterior facets and T10-L2 kyphotic deformity of 38° (Fig. 28.2). Facet joints could be seen clearly dislocated bilaterally. A small rotational component was also present. MRI of the whole spine confirmed an angular kyphosis due to a formation defect of L1 vertebral body (type 1). There was no cord compression or myelopathy nor other associated intracanal abnormalities (Fig. 28.3). We recommended surgery in his case due to the severity of the deformity and the high risk of progression and neurological impairment. The patient was operated on at 20 months of age. Through a midline posterior approach, the spine was subperiosteally exposed and 3.5 mm (cervical) pedicle screws were bilaterally inserted from T11 to L3 while skipping L1. We then proceeded to perform

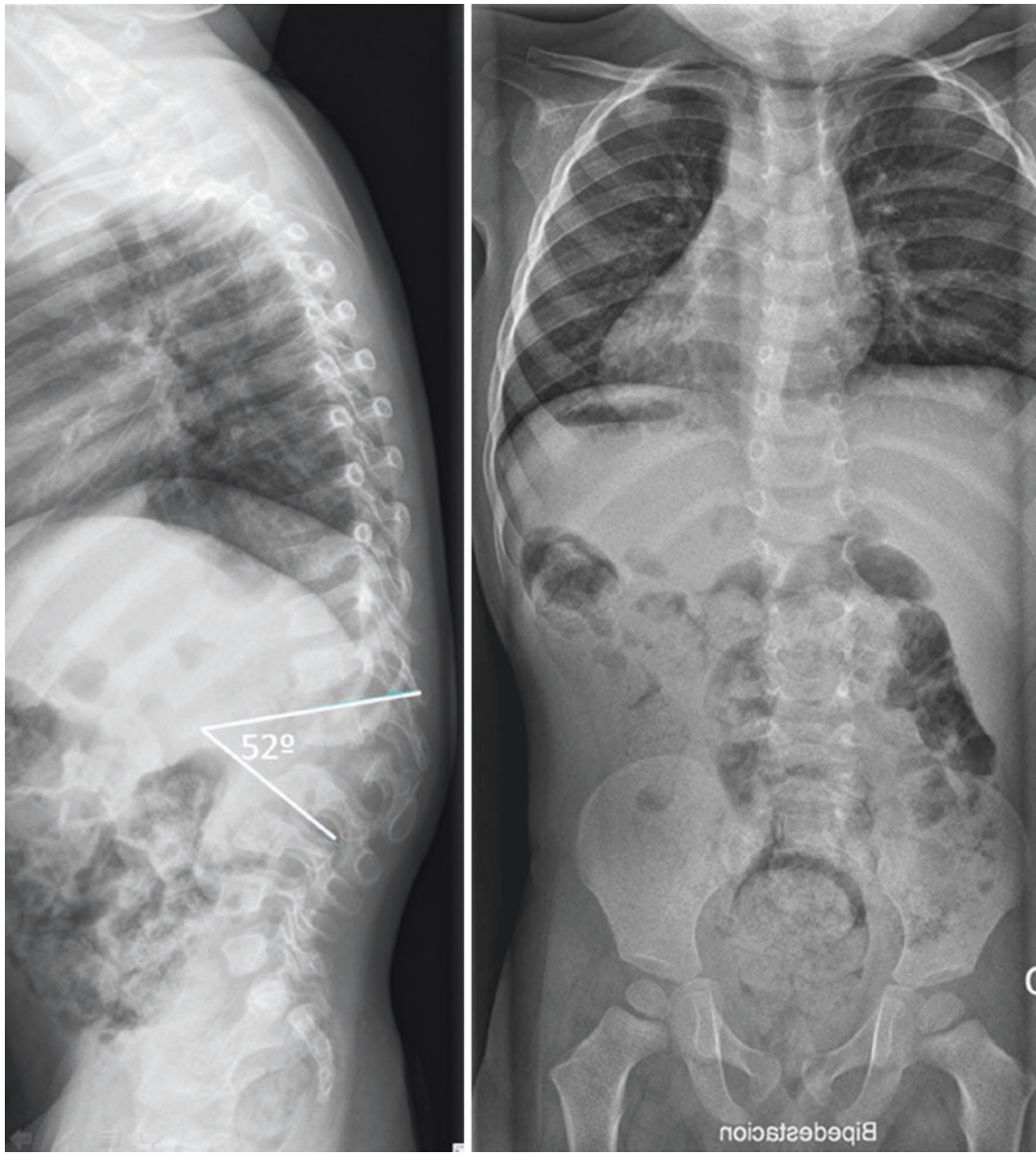

Fig. 28.1 AP and lateral X-rays of a 18 month old toddler with a congenital L1 kyphosis and dislocation. Regional kyphosis measured 52° and the T12-L1 facet joints were clearly dislocated

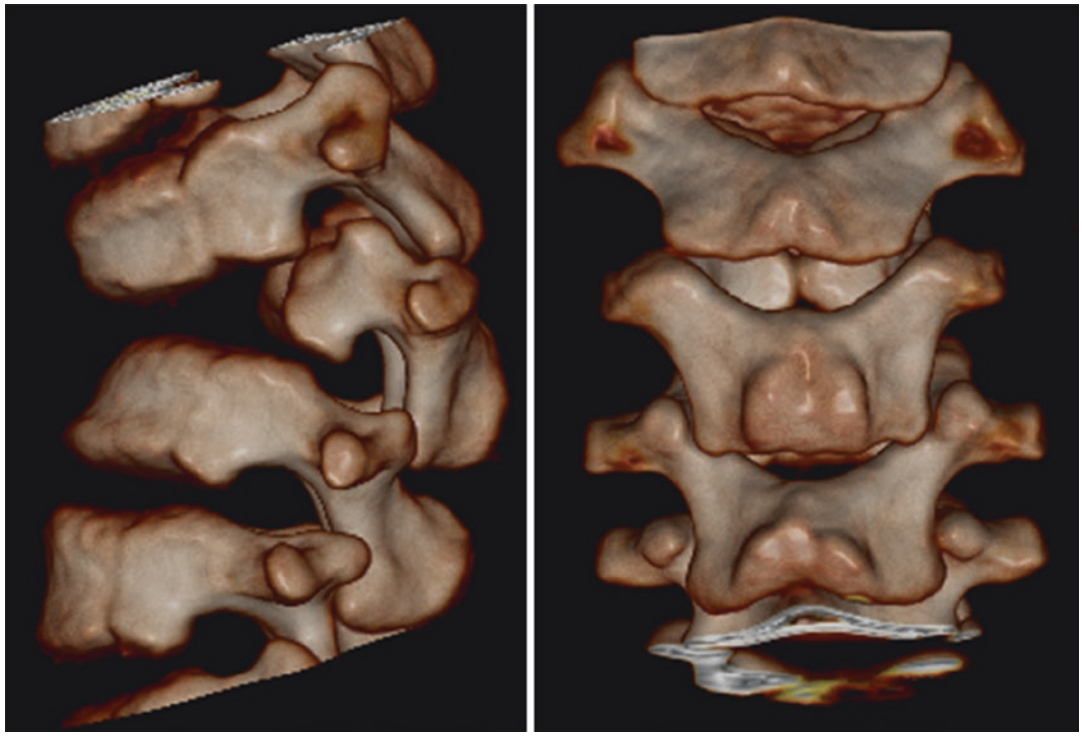

Fig. 28.2 3D reconstruction of the CT scan showing a relatively preserved posterior arch with dysplastic and naked facets and a regional kyphosis of 38°

a posterior vertebral column resection (PVCR) of the L1 including the discs above and below. Progressive stepwise correction of the deformity was performed under neuromonitoring, anterior column reconstruction was done with a mesh cage impacted with local bone graft. Final construct was done with physiologically aligned rods tightened under compression. A rigid thoracolumbar orthosis was prescribed after surgery until fusion was achieved. 2 years after surgery he had a very satisfactory course with complete fusion and no recurrence of the deformity (Fig. 28.4).

28.2.2 Postraumatic Deformity Case

A 61 year-old female was referred to our clinics for surgical assessment. She refers a fall from her own height 8 months prior to presentation when she was diagnosed with an L1 fracture. She was initially treated conservatively with an external rigid brace for 3 months. Unfortunately she progressively developed a disabling severe low back pain that did not respond to conservative treatment. On clinical examination she had a thoracolumbar kyphosis but seemed to conserve a fair sagittal balance. Her deformity was rigid and did not correct on forced extension nor when she laid down. Her neurological assessment was unremarkable.

Whole spine standing films showed a consolidated L1 fracture with a resultant regional kyphosis of 38° (Fig. 28.5). She however could maintain a sacral vertical axis (SVA) of 5.4 cm at the expenses of a hyperextension of the lower lumbar spine (L2-S1 Lordosis 71°, L4-S1 65°). The pelvis was retroverted (PT 20°, SS 31° for PI of 50°, GT 35°). Her GAP score was 9. In summary, the patient presented with a Type II sagittal imbalance due to a fracture in thoracolumbar area. The deformity was fixed and angular over the L1. Surgery was prescribed due to the severity of her symptoms and deformity. Taking into account the fixed and angular nature of the deformity, the thoracolumbar location and the shape of the deformed

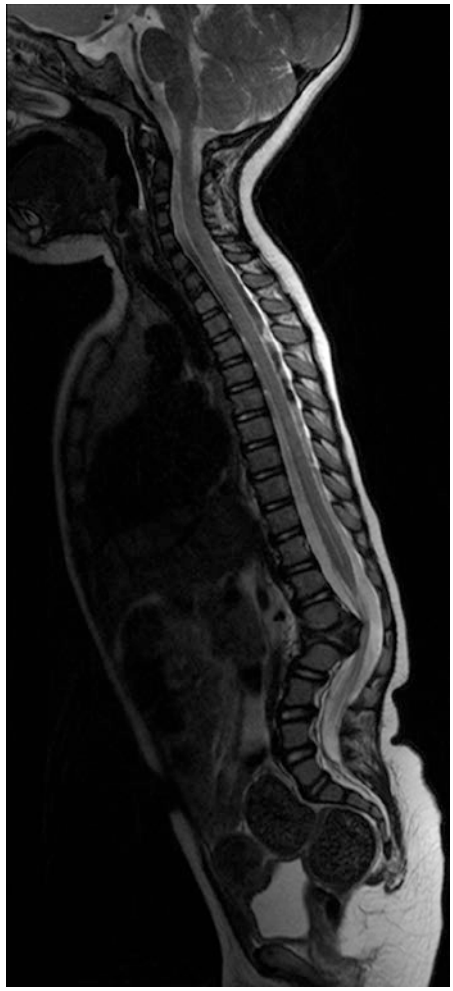

Fig. 28.3 Mid-sagittal cut of a of a T2 weighted whole spine MRI ruling out any neurological compression, myelopathy or intracanal malformation

vertebra with significant loss of anterior vertebral body height, we opted for a PVCR. For this purpose, we resected the wedged L1 vertebral body including the discs above and below to reconstruct segmental morphology, restore anterior column support and enhance fusion. We reconstructed the anterior column using a carbon-fiber cage with local bone graft. Posterior stabilization was achieved with cemented pedicle screws from T5 to L3. By extending to T5 we avoided ending the instrumentation at the thoracic natural apex, therefore, preventing possible Proximal Junctional Kyphosis (PJK). Intraoperative imaging confirmed the appropriate placement of the spinal anchors and adequate sagittal alignment reconstruction of the thoracolumbar junction. Prophylactic vertebroplasty was performed in the first vertebrae above and below the instrumentation to prevent further fractures at these levels. Local and homologous bone grafts were placed over the decorticated posterior elements to further enhance fusion. Intraoperative neuromonitoring was unaltered throughout surgery. The patient did not have any major intraoperative nor perioperative complications. Four years after surgery her pain and disability had improved significantly. She was well aligned, (SVA 2 cm, GT 16°, LL 51°, L4-S1 38°, SS 34°, PT 16°, GAP 1 for age) and the T12-L2 kyphosis measured 1° (Fig. 28.6).

28.3 Discussion of the Cases

The treatment of severe fixed angular kyphotic deformity presents a technical challenge to the spinal surgeon. It requires a proper understanding of the deformity and the resulting compensatory mechanisms as well as mastery of the osteotomy techniques.

Congenital kyphosis is due to defect of formation, of segmentation or both. Segmentation defects involve more than 2 vertebrae and usually result in a regular deformity. It is usually detected in the adolescent age group, has a small progression potential due to its late development and does not cause any direct threat to neurological elements. Defects of formation are more common and usually occur over a single level, although multiple level involvements have been well described. Progression is the rule in these cases and the risk of neurological compromise is of special concern. The congenital dislocated spine has been defined as the potentially most serious form of congenital kyphosis with an abrupt single-level sagittal displacement of the spinal canal [2]. The facet joints are often hypoplastic and/or dislocated. Progression to neurological injury is almost universal. Neurological impairments may rarely be noted at birth or may develop later in about 10–12% of cases of congenital kyphosis, mainly during adolescence [3]. In congenital dislocation, neurological injury occurs much earlier. Consequently, congeni-

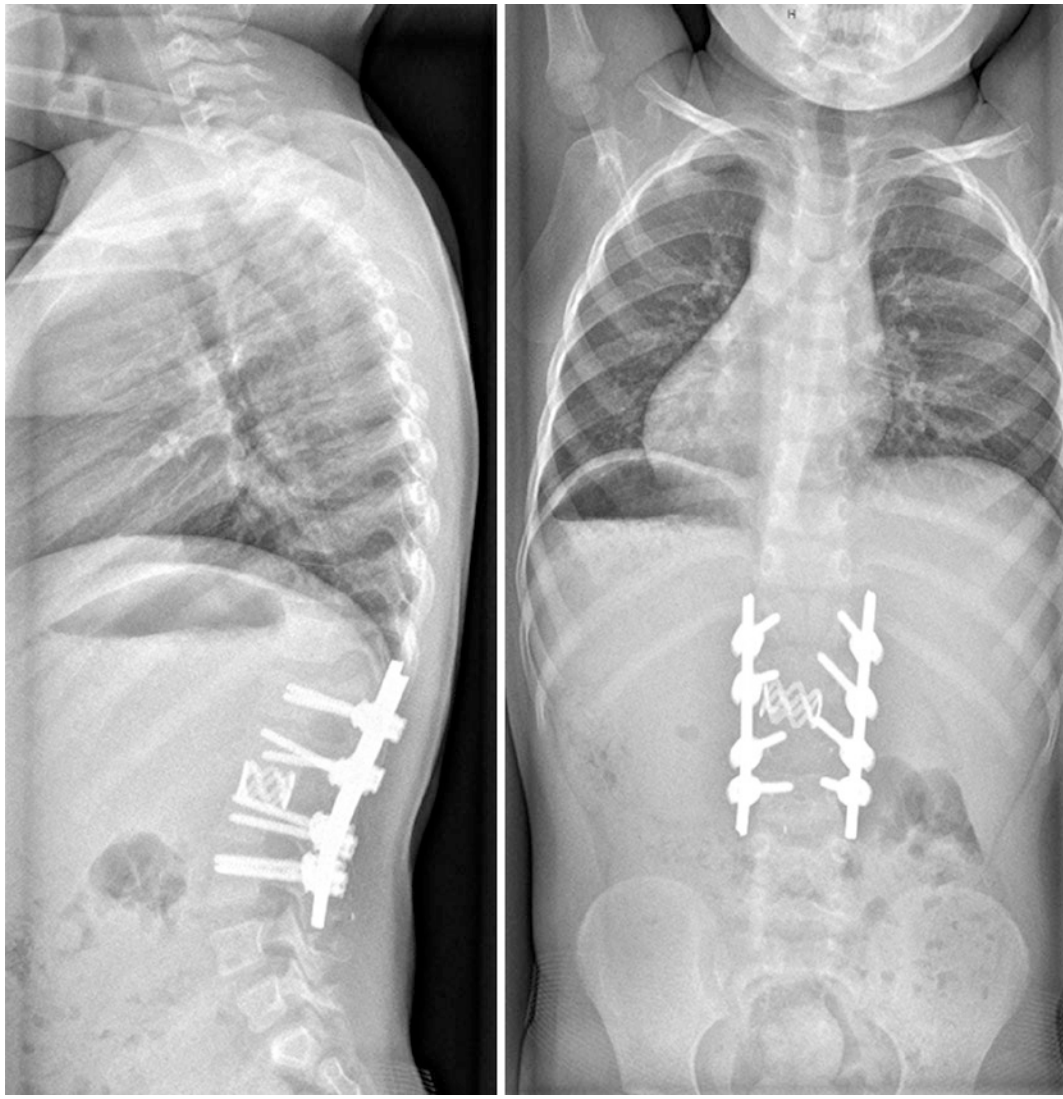

Fig. 28.4 2 year postoperative AP and lateral X-rays showing satisfactory reconstruction of the thoracolumbar junction

tal dislocation is a surgical urgency that requires early stabilization. There is no established age at which it can be approached, and therefore should be treated as early as possible.

Established posttraumatic kyphotic deformities on the other hand do not usually progress overtime. In addition, the neurological injury is sustained with the initial trauma and rarely – if any- develops overtime. A notable exception might be Kummell's pseudoarthrosis where a deficient anterior support can lead to deformity progression, fatigue of the posterior elements, local instability and in extreme cases, neurological compromise.

Surgical indications and goals of treatment vary between both groups. In congenital deformity, the indications are mainly deformity progression and neurological compromise. Therefore the objectives are to halt the progression, restore the physiological alignment and protect neurological structures. These objectives should be achieved with corrections over as few segments as possible to allow for growth. The correction should also be

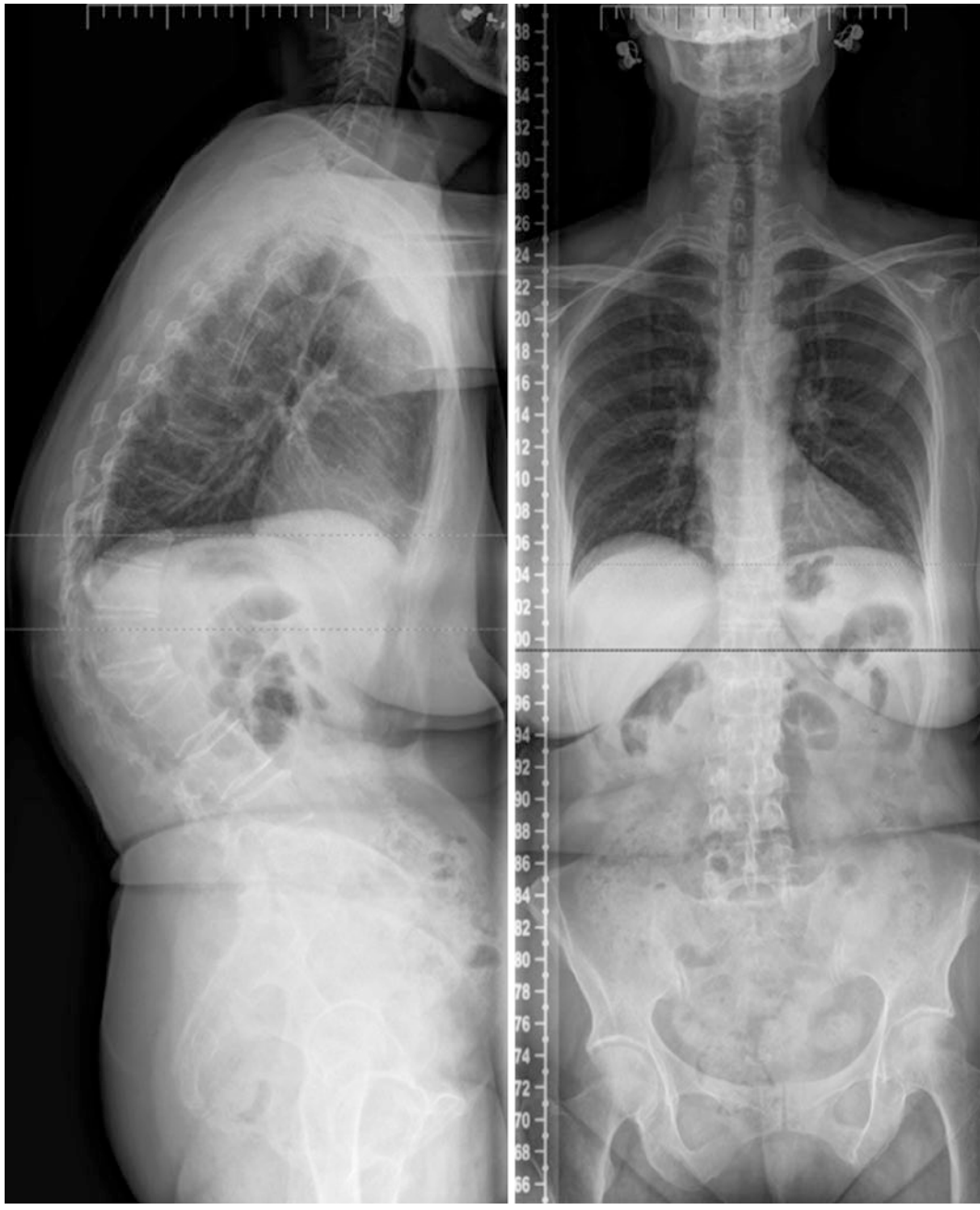

Fig. 28.5 AP and lateral standing whole spine xrays of a 61-year-old lady with sagittal malalignment due to an L1 osteoporotic fracture healed with residual regional kyphosis measuring 41°

maintained throughout growth and patients should graduate in an acceptable state. On the other hand, patients with traumatic kyphosis complain of gross deformity, or from pain and disability secondary to an altered sagittal alignment. Goals of treatment in this group include restoring a balanced and harmonious sagittal alignment by correcting the local kyphosis and eliminating the compensatory curves, achieving solid fusion.

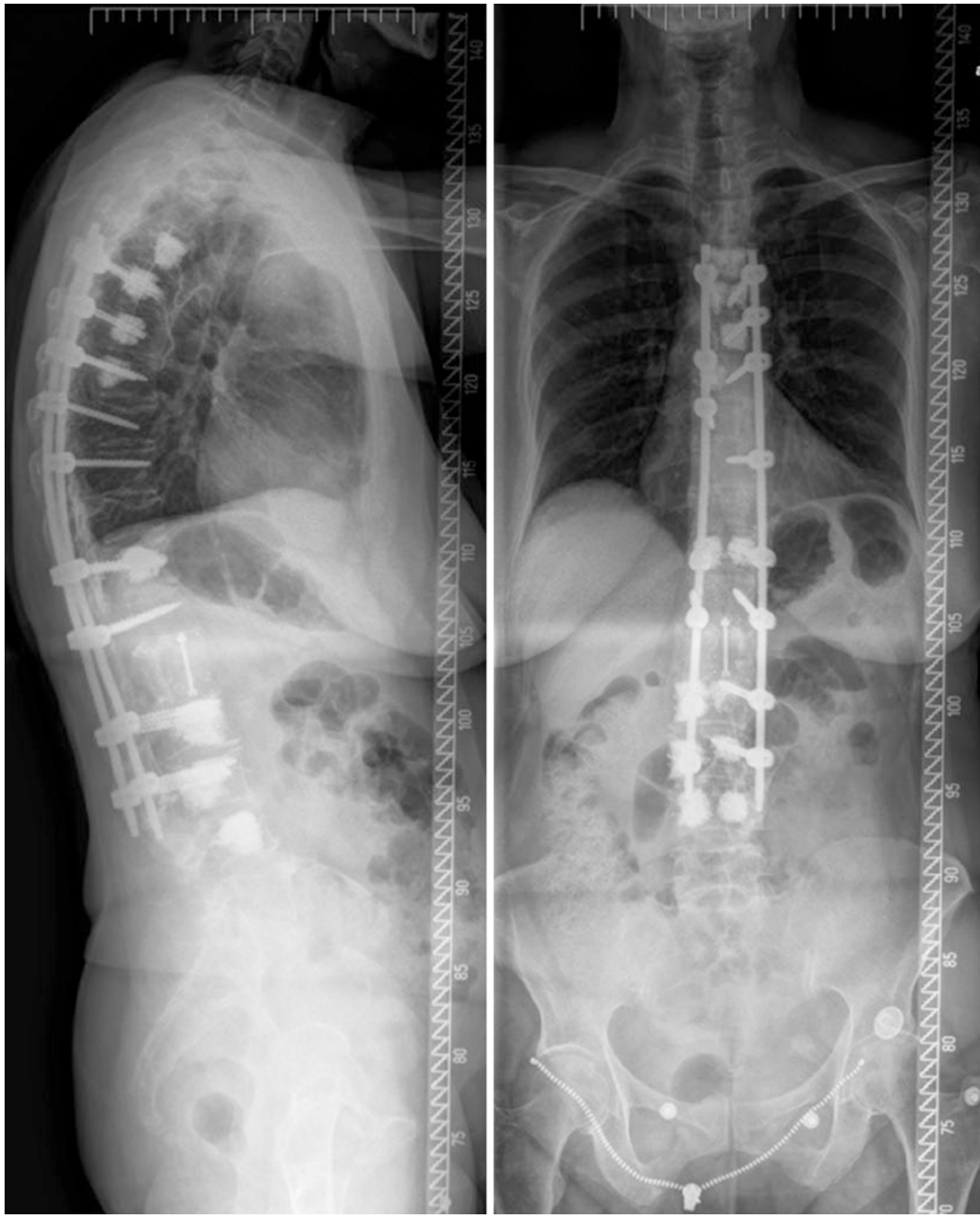

Fig. 28.6 4 years postoperative AP and lateral x-rays. The patient maintained a satisfactory sagittal alignment and had no subsequent junctional failure or new fracture

The initial workup always includes a whole spine standing X-rays to assess global spine sagittal alignment. The main driver is usually the congenital malformation or the traumatic injury. In both groups it is usually angular and can be stiff or fixed. Compensatory mechanisms, generally include recruitment of adjacent segments, mainly flattening the thoracic spine above the kyphosis and/or increasing the lumbar lordosis. When these are not enough, the pelvis is retroverted in an

effort to bring the center of gravity backward towards the sacrum. If these mechanisms fail, the patient then recruits the knees. When all available compensatory mechanisms have been exhausted the patient develops a positive sagittal imbalance [4]. Measuring the SVA or the global tilt can help the surgeon assess the global alignment. Global tilt is independent of patient's position and does not need any calibration of the x-ray [5]. Flexibility can be assessed during clinical encounter or by using a flexion extension xray, or supine xrays over bolsters. Also, comparing standing xrays to supine scans (either MRI or CT) can be helpful. The deformity can be either: (1) totally flexible; (2) partially flexible or (3) fixed [6].

Additional workup includes a CT scan to assess bony anatomy and flexibility. It assists the surgeon in his decision-making and surgical planning. An MRI scan is also in order whenever a neurological injury is suspected or as part of initial workup in patients with congenital deformities. Clinical manifestations of intracanal abnormalities are frequently initially absent and up to 30% of patients with congenital vertebral anomalies have intraspinal malformations detectable by MRI. These include tethered cord, diastematomyelia, diplomyelia, and syringomyelia. Some of these might alter the surgical plan. Finally, an MRI scan also can detect occult concomitant vertebral malformation at other levels.

There is no role for bracing in congenital dislocation and traction has been associated with paraplegia. Segmentation defects can be treated differently depending on the magnitude of the deformity and whether or not correction is desired. In small deformities detected early, a short posterior fusion might suffice. Instrumentation can be avoided especially in younger patients. If the deformity is significant, the surgeon can opt for multiple anterior releases or vertebral column resection, depending on the magnitude of the deformity and the number of involved vertebrae. The use of posterior instrumentation and closing under compression is advised. However, if the patient is too small for instrumentation, a hyperextension cast could be used. Our case shows that instrumented fusion is possible at very early ages using small diameter screws. In defects of formation with kyphosis smaller than 50°, and if the deformity is detected very early, an isolated posterior fusion or tethering can suffice. These deformities are partially flexible and amenable to reduction under compression. Again, fusion can be instrumented or using local grafting techniques and extension bracing. In these cases, a second surgery might be needed to increase fusion rates. Avoiding instrumentation, Winter and Moe reported satisfactory outcomes in 12/17 patients (71%) younger than 5 years [7]. If the deformity is greater than 50° and the vertebral body is very hypoplasic, vertebral resection is recommended. This can be done through a staged anterior/posterior approach or through an all-posterior approach. Authors recommend PCVR as it allows for a better control of the deformity and neurological elements while decreasing surgical and anesthetic times as well as additional morbidities from two surgeries. The anterior column can be reconstructed using a structural graft such as a rib or a fibula, or using a mesh cage.

Whereas a flexible deformity distributed over various segments can be treated with posterior column osteotomies, the mainstay of treatment of severe and rigid angular kyphosis is surgical correction using three column osteotomies. This is specially true in posttraumatic deformities. Several three-column osteotomy techniques have been described, where a circumferential excision of one or more vertebral bodies is performed, through a combined anterior-posterior or a sole posterior approach. As evidence regarding the safety and feasibility of three column spinal osteotomies has increased and instrumentation has become more reliable and powerful (e.g., thoracic pedicle screws vs. hooks or hybrid constructs), more patients have been treated via a single posterior surgical approach aimed at one or more apical kyphotic vertebrae. Despite being circumferential posterior osteotomies, the primary difference of PVCR versus the pedicle subtraction osteotomy (PSO) is that with PVCR both the spinal cord and the impinging wedge fragment are identified under direct vision from the lateral side, thus allowing for confirmation of complete decompression. Therefore, PVCR can be safely performed at the level of the cord and more than one

vertebrae can be excised. This provides the powerful translation and shortening necessary to correct great rigid deformities. Therefore, PVCR can offer better control of angular deformities than PSO [8]. The amount of correction achieved by PSO is limited to anatomical constrains. PSO in lumbar adult spine can achieve a 25–30° [6, 9]. The amount of correction obtained in the pediatric population is much less due to the smaller size of the vertebral body and smaller pedicular wedge. In the thoracic spine PSOs are less frequently indicated [6]. Moreover, authors do not recommend PSOs in the context of a traumatic wedged vertebra. First of all, the amount of correction is less, as the superior cut can only be parallel to the superior endplate and therefore following the wedged angle. In addition it is technically challenging to follow the superior endplate without breaching it or damaging it. Finally, a PSO in the context of a wedged vertebra results in a flattened and shortened vertebral body between two mobile discs, which increases significantly the pseudoarthrosis rate. Although shortening of the cord is considered safe, too much shortening may be dangerous. On the other hand, with PVCR the amount of correction is only limited by the spinal cord and PVCR restores the height of the anterior column.

Up to date, there is no enough literature comparing advantages of PVCR compared with staged anterior-posterior osteotomies (APVCR). Nevertheless, anterior transthoracic procedures have gradually fallen out of favor because of several factors, mainly due to the difficulties in approaching the concavity of the angular kyphosis in deformities greater than 60°. Correction by pure distraction of the anterior column can cause severe stretching of the spinal cord. Irrespective of whether they are staged or performed as a single procedure, combined anterior-posterior procedures are a major surgical undertaking and the associated medical and surgical morbidity can be considerable. Theoretically PVCR has a number of advantages over APVCR: reduction of operative time and blood loss, maintenance of spinal stability and neurological control throughout the whole procedure, more reliable reconstruction of spinal column, less postoperative morbidity and more effective corrections. However, more recent literature did not find any significant differences in blood loss or complication rate between both approaches [9]. Surgical time, surgery through a single approach and anesthestic time as well as full simultaneous control of the deformity and the spinal cord still favor PVCR.

Cancellous bone graft is traditionally used at the site of VCR, anterior column reconstruction may be done with strut grafts or cages. In patients with weak bone, we prefer to reconstruct the anterior column with carbon fiber cages that have big footprint. A larger footprint distributes the load more homogenously, recruits the lateral cortices of the adjacent vertebral bodies and decreases the loading pressure. This would ultimately decrease the rate of subsidence that might be encountered with mesh cages.

During the surgical correction of the deformity, rods are sequentially exchanged after the osteotomy or can be bent in situ. The surgeon should have excellent visual control of the cord during this stage and it is highly advisable to have spinal cord monitoring. These are essential to ensure the safety of the technique. The authors recommend for the routine use of IONM including assessment of both motor and sensory tracts, free-run electromyography and nerve root testing.

Somatosensory evoked potential (SEP) monitoring alone is known to reduce post-operative paraplegia by 50–60% but paraplegia can still occur without SEP warning, most of the times due to anterior spinal artery syndrome, which only affects the vascular territory of the anterolateral column of the spinal cord. Spinal cord perfusion may be compromised even at normal systemic blood pressure when intraoperative mechanical stress is applied to neural tissue. The introduction of motor evoked potentials (MEP) has allowed for monitoring the corticospinal tracts (CT) individually, with changes correlating highly with post-surgical neurological outcomes. Muscle motor evoked potentials triggered by transcranial electrical stimulation (Tc-MEP, mMEP) evaluate the function and the flux of motor outputs from motor cortex, CT, nerve roots, and peripheral nerves. Tc-MEPs have a reported sensitivity of 75–100% and specificity of 84–100% for the detection of iatrogenic motor deficits. Most of the permanent spinal cord injuries are thought to be associated with

changes to the blood supply of the thoracic cord. Excessive traction or shortening of the cord during deformity reduction as well as mechanical impingement can also cause permanent damage if left unrevised. Except for vascular insult, MEPs can point out more precisely the moment that spinal cord is stressed in PVCR and thus allowing for correction to be reversed to the state immediately before any changes in potentials. Transient nerve root injury however remains the most common neurologic complication in PVCR. To avoid neurological complications, common strategies include maintaining blood supply to the spinal cord by preserving the neurovascular bundle on one side and also avoiding hypotensive anesthesia.

Wound infection and/or hematoma after these types of procedure are also a major concern and can affect between 5% and 10% of the cases. They may be prevented with meticulous technique and optimal nutritional status.

28.4 Conclusions and Take Home Message

Including Pearls and Pitfalls

Both of our cases were sharp, angular deformities in thoracolumbar area. In the congenital kyphosis, posterior vertebral column resection and replacement of the insufficiently formed vertebral body was considered the best option to correct the deformity, restore segmental anterior column support and achieve long-lasting circumferential fusion. In the posttraumatic deformity case, we chose PVCR over PSO for two main reasons. Firstly, the magnitude of the correction needed over a single segment could be better achieved with VCR. Secondly, authors prefer VCR to PSO when the vertebral body is significantly wedged and discs above and below are mobile. A PSO in these cases can easily violate the remaining endplates and leave a "floating" osteotomized vertebral body with a high risk of pseudoarthrosis and mechanical failure.

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