26 Diagnosis, Classification and General Treatment Options for Hyperkyphosis

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The physiological sagittal shape of the spine consists of kyphosis of thoracic spine and lordosis of cervical and lumbar spine. Normal range of thoracic kyphosis and lumbar lordosis are 20–45° and 40–60°, respectively [1]. The sum of these curvatures aims to keep the spine in sagittal balance, a condition with lowest energy consumption during standing position. The sagittal balance is characterized by the plump line, which is drawn vertically from the center of the C7 vertebral body down to the sacrum. In normal condition, the plump line bisects the sacral endplate. A variety of conditions may lead to increasing segmental (angular) or regional (arcuar) kyphosis. Compensatory mechanisms exist to counteract the shift of the trunk to the forward as hyperlordosis of cervical and lumbar spine, reclination of pelvis and flexion of knees. Exhaustion of these compensatory mechanism result in the shift of the plump line anterior to the femoral head axis and sagittal imbalance of the spine. Table 26.1 illustrates etiologic conditions that result in kyphotic deformities.

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26.1 Patient Evaluation

Patients should be examined in standing position with knees as straight as possible. Patients with imbalanced spine try to compensate with knee flexion and backward rotation of the pelvis. The grade of knee flexion should be taken into account, when analyzing spine parameters on lateral view x-ray. Hip flexion contraction may limit the compensatory mechanism of the pelvis. The effect of hip and knee on spine posture can be removed by sitting position. If an imbalanced spine improves in sitting position, the cause may lie in hip flexion contraction, which can be proved by Thomas maneuver. Examination in supine position may reveal the flexibility of the deformity, which can be illustrated with lateral view x-ray with a bolster underneath the apex of the deformity. Attention should be paid on myelopathy signs as gait pattern and pathologic reflexes.

26.2 Radiologic Evaluation

X-ray images in lateral and ap view of the whole spine from occiput to the end of sacrum with femoral heads should be performed. The sagittal balance is evaluated by the plump line, which is drawn vertically from the center of C7 vertebral body down. With a balanced spine, the plump line falls on the anterior edge of S1 endplate. The spine is significantly imbalanced if plump line falls

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Table 26.1 Pathologic conditions that result in kyphotic deformity of Spine

Degenerative process	Trauma	Inflammation	Growth	Neuromuscular
Loss of disc space height Osteoporosis	Posttraumatic Postoperative Tumor Osteoporosis	Infection Ankylosing spondylitis	Scheuermann Congenital Postural	M. Parkinson

anterior to the femoral head axis. On the frontal plane, the spine is balanced if the vertical line dropped from C7 spine process falls on the sacrum midline. For the evaluation of the spine flexibility, x-ray in lateral view is performed in supine position with a bolster underneath the apex of the deformity to prove any opening of the disc spaces.

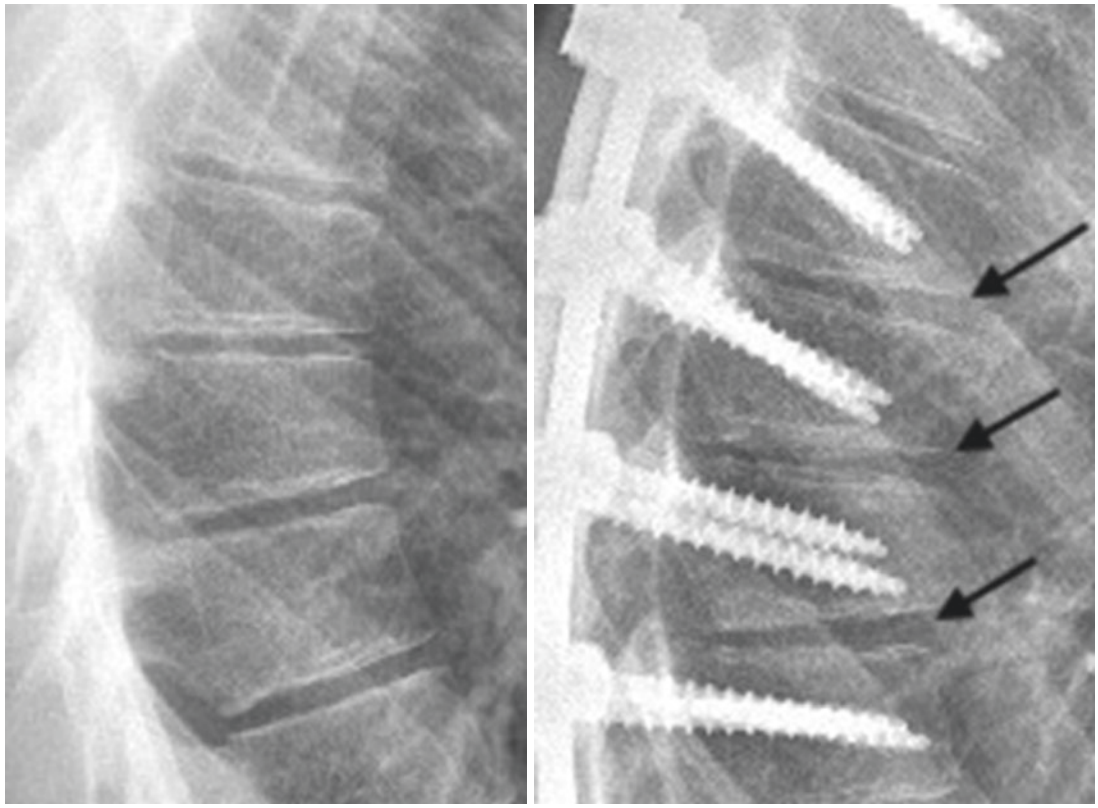
Any neurologic abnormality, angular kyphosis or any other irregular deformity of the spine without obvious underlying cause, require MR-imaging of the whole spine. CT scanning is helpful in cases of complex deformities for structural illustration of the spine.

26.3 Treatment Options

Surgical treatment options for correction of spine deformities involve dorsal instrumentation combined with varying osteotomy techniques. The spectrum of osteotomies ranges from partial removing of interlaminar bone, which represents the least invasive technique, to resection of one or more vertebral bodies as the most invasive technique. With increasing degree of osteotomy, the potential for correction of the deformity as well as the risks of the operation increase. The type of osteotomy selected, depends on the degree of the deformity and on the flexibility of the spine. The first osteotomy of the spine was described by Smith-Petersen (SPO) to treat the hyperkyphosis of ankylosing spondylitis by opening up the anterior column through dissection of anterior disc space and anterior longitudinal ligament and simultaneous closing the posterior wedge after resection of posterior elements in lumbar spine [2]. With the classic SPO a maximum correction of 30° is possible. The center of rotation through this osteotomy is in the posterior anulus of the disc. Thus, the correction maneuver results in lengthening of the spine anteriorly. This may lead to the rupture of great vessels running anterior to the spine, a very serious complication that was reported in numerous studies [3]. Older patients were more frequent involved in this complication due to the atherosclerotic changes and consequently loss of the flexibility of vessels in elderly people. Wilson reported few years later a modification of SPO which was limited to only posterior osteotomy without anterior opening [4]. Aim of this technique was to avoid anterior lengthening of the spine and subsequent rupture risk of the anterior vessels. Today, a wedge osteotomy of posterior column without opening of anterior disc space is commonly referred to SPO. This technique requires some mobility of the disc space anteriorly. Without opening of the anterior column, a maximum correction of 10° in each segment is possible.

Ponte described 1984 multisegment closing wedge osteotomy of thoracic spine to treat scheuermann kyphosis by a Λ shape interlaminar osteotomy with resection of flavum ligament and osteoclasia of adjacent laminae as well as facet joints [5]. With Ponte-procedure the anterior column of spine is preserved and the correction is achieved by the forceful compression through segmental pedicle screws. The center of rotation is at the posterior disc anulus as with SPO. This results in slight opening of anterior disc space with a maximum of 10° correction of each segment (Figs. 26.1 and 26.2).

With pedicle-subtraction osteotomy (PSO) the correction is completely achieved by closing of the resected wedge without lengthening of the anterior column. Thomasen described this method to avoid anterior lengthening and to save the anterior vessels [6]. Technically, PSO is performed following instrumentation of the spine. After resection of the lamina and facet joint, the pedicles are removed completely, vertebral body is decancellated through the base of the pedicles and the lateral cortical wall of the vertebral body is removed in a posteriorly based wedge manner.



Figs. 26.1 and 26.2 Pre- and postoperative x-ray in lateral view of thoracic spine with scheuermann kyphosis. Correction was achieved with multiple Ponte osteotomies. Arrows indicate anterior opening of disc spaces

The anterior cortex and longitudinal ligament are preserved. The correction is achieved by closing the gap through compression of adjacent pedicle screws (Figs. 26.3 and 26.4). Attention should be paid to remove sufficient amount of the lamina to avoid compression to the neural structures by closing the wedge. Compared to SPO, PSO is associated with more blood loss during the vertebral resection. With PSO a correction up to 30° can be achieved in the osteotomized vertebral body. PSO is the procedure of choice in fixed kyphotic deformities of all etiologies. Despite the rule that the correction should be performed where the deformity is located, PSO is usually performed at L2 or L3, for example in case of fixed global imbalance of the spine or ankylosing spondylitis. These levels offer some advantages as this area distal to the conus is less risky with regard to neurologic complication by manipulation of dural sac. Further, the more distally the osteotomy the more correction can be achieved

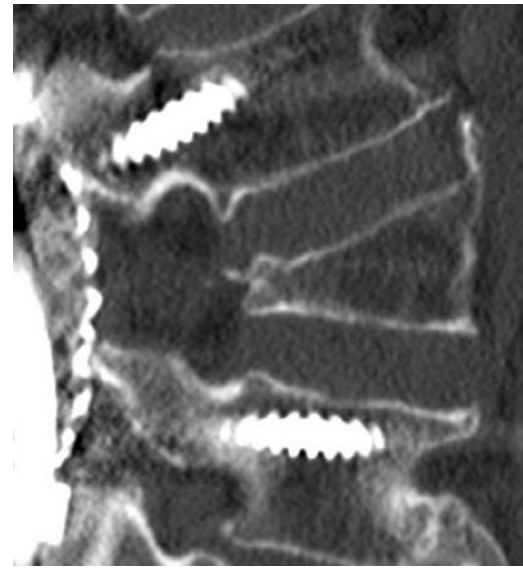


Fig. 26.3 Postoperative CT scan of pedicle subtraction osteotomy of L2. Shape of vertebral body after posterior based wedge resection

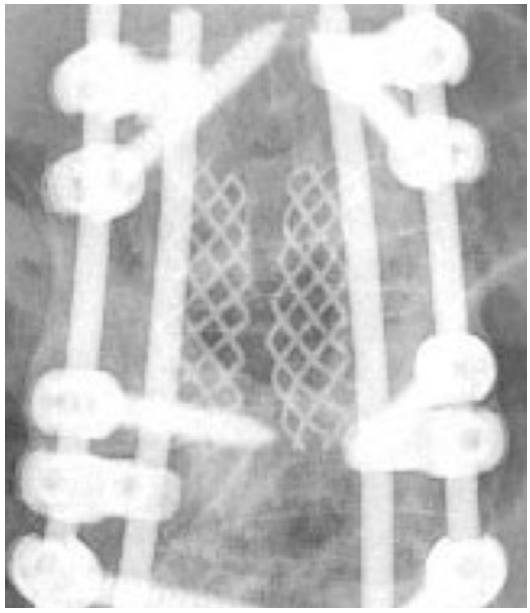
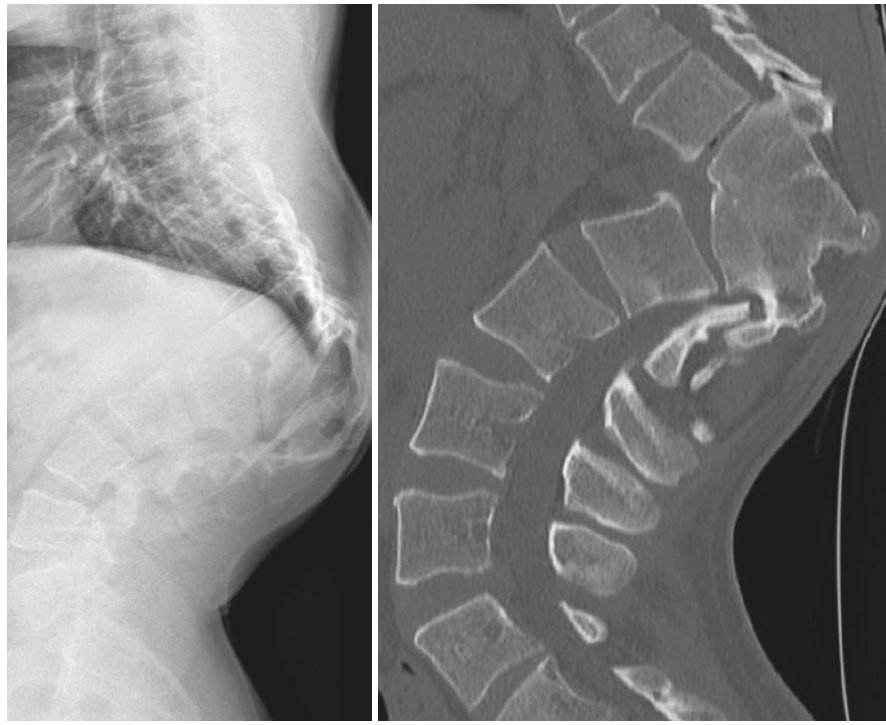


Fig. 26.4 Postoperative x-ray in ap view demonstrate the double rod technique and the use of a titanium mesh to bridge the posterior bone gap for deposition of bone graft to achieve more stable instrumentation and bony fusion of the osteotomy

due to the long lever arm. Recent studies support to perform PSO at more distal levels, even at L5, to achieve the main lordotic curve at lumbosacral junction [7]. However, if the deformity is in cervicothoracic spine, as with ankylosing spondylitis, PSO can be performed in the upper thoracic spine below C7 where vertebral arteries run outside the vertebra. Simultaneous deformity in frontal plane can be addressed by asymmetric wedge resection of the PSO. Long term complication of PSO is failure of instrumentation as break of rods. This may occur when posterior bony fusion does not take place due to the wide posterior osteotomy and open disc space anteriorly. This complication can be avoided either by bridging the posterior gap with bone graft or by selection of the vertebra for PSO where adjacent disc spaces are fused anteriorly. Some authors recommend dorsal instrumentation with double rod each side to achieve a more stable situation.

For correction of severe deformities in frontal and sagittal plane, vertebral column resection (VCR) is a powerful technique (Figs. 26.5, 26.6, and 26.7). With this technique, a complete cross-



Figs. 26.5 and 26.6 Preoperative x-ray and CT scan of severe posttraumatic rigid kyphosis. Vertebral column resection was selected to correct the kyphosis

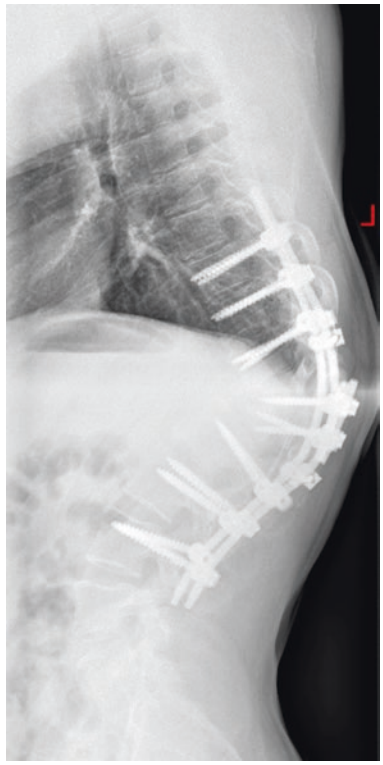


Fig. 26.7 Postoperative x-ray after vertebral column resection. A correction of 50% was achieved. Due to intraoperative loss of neural function that was detected by neuromonitoring, the correction was performed partially

sectional resection of bony and ligamentous tissue of spine is carried out, which enables multiplanar correction of the deformity. Preoperative planning of resection area is crucial for a sufficient correction of the deformity that ranges from one to more vertebral bodies. Appropriate indication for VCR are rigid angular kyphoscoliosis or congenital scoliosis due to hemivertebral formation. Sometimes implantation of a cage anteriorly is necessary to bridge the gap after vertebral resection. However, this technique is very challenging, requires experienced surgical team and is associated with high rate of neurological complication. Neurological complication results from either direct injury to neural structures or disturbances of blood supply. Neuromonitoring with SSEP and MEP is routinely recommended during surgery to control neural function.

26.4 Take Home Message

Several pathologic conditions may lead to a short or large curve hyperkyphosis of spine. The spine and the adjacent joints are able to compensate the hyperkyphosis to some extent. A symptomatic sagittal imbalance of spine emerges, when these compensatory mechanisms fail.

A thorough clinical and radiological evaluation is crucial to detect the location, the extent and the mobility of the deformity as well as the compensatory mechanisms of organism to counteract the deformity.

Several osteotomy techniques are available for correction of hyperkyphosis. They range from partial posterior osteotomy to complex multilevel vertebral body resection. With increasing degree of osteotomy, the potential for correction as well as the risks of operation increase.

Pearls

- Hip and knee joints compensate for spine deformities. They have to be considered and examined to evaluate the full extent of the spine balance
- Flexible and regional deformities can be addressed by one-column osteotomy technique as Ponte-osteotomy, whereas rigid deformities require three-column osteotomy techniques as PSO or VCR
- Wide decompression of spinal canal is needed for PSO and VCR to avoid stenosis after correction
- Use temporary rods for controlled and stepwise correction maneuver to avoid dislocation of screws

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