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Reviews

Scheuermann Kyphosis for dummies

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Abstract: Scheuermann kyphosis debuts in young adolescents and it is defined as a fixed hy perkyphosis >40º Cobb, with associated anterior wedging of vertebral endplates of >5º in three or more adjacent vertebrae. It is thought to be caused by mechanical stress on structurally deficient vertebral endplates. For its diagnosis, clinical history and plain radiographs are used, but also MRI when there is neurological affection. Treatment depends on the severity of the curve: those <60º can be treated orthopedically with Milwaukee bracing in combination with rehabilitation treatment (stretching or muscle strengthening) and postural hygiene. If >70º, surgical treatment is indicated using a posterior-only approach, as it reduces the appearance of complications when compared with anterior and combined approach. Vertebral osteotomies will be made depending on the DAR. We will use pedicular screws and bars, and transverse hooks to end instrumentation, as we attach dis tally the SSV and proximally the first kyphotic vertebra, to avoid revision surgery. Among the complications (14%) we find surgical site infection (up to 10%), neurological injury (8%), or pulmonary complications derived from anterior approach (20%). Therefore, a global balance of the patient and his sagittal balance will have to be made to guarantee an optimal result.

Keywords: kyphosis; Scheuermann's disease; surgery

Abstract: Scheuermann's kyphosis appears in young adolescents and is defined as a structural rigid hyper kyphosis >40º Cobb, with the presence of anterior wedging of the endplates >5º, in three or more contiguous vertebrae. It is thought to be caused by mechanical stress on a vertebra whose end plate is structurally weakened. For the diagnosis, in addition to the clinic, we use plain X-rays and MRI when neurological symptoms are associated. Its treatment depends on the degree of kyphosis, I feel those <60º treated only if they are symptomatic or progress, using Milwaukee-type orthoses in combination with stretching/muscular strengthening and postural hygiene. If it is >70º, surgical treatment would be indicated, opting for a solely posterior approach since it reduces the appearance of complications compared to the anterior or combined approach. We will perform vertebral osteotomies based on your DAR. For the fixation of the column, we will use pedicle screws and bars, as well as nails at the ends of the instrumentation.
We will fix distally based on the SSV and proximally we will include the most cranial vertebra included in the kyphosis, which will avoid revision surgeries. Among the complications (14%), we find infection of the surgical wound (up to 10%), neurological injuries (8%), or pulmonary complications in the anterior approach (20%). A holistic approach must be made, focusing on sagittal balance, in order to obtain the best results for the patient.

Keywords: kyphosis; Scheuermann's disease; surgery

1. Introduction

Scheuermann's Kyphosis is a pathology that appears predominantly in young patients (12-17 years old), but almost never before 10 years of age, with a prevalence of 1-8% according to series, without discrimination by sex, and that mainly affects the thoracic spine (but not only). [1] It is also a pathology with a significant potential for comorbidity if left untreated. For all these reasons, in the following sections, we will begin to understand this disease, and what we should do if we find ourselves with a patient in whom we suspect it. Before beginning, and for didactic purposes, it should be noted that the disease is characterized by the following [2]:

1. "Rigid" thoracic hyperkyphosis: it is a thoracic kyphosis with a Cobb angle >40º (which for the dorsal region is formed by a line parallel to the upper vertebral endplate of T4 and the lower one of T12). It will be a rigid kyphosis because it does not completely correct when we ask the patient to stand "straight", that is, to be as upright as possible.
2. Anterior vertebral wedging >5º: we will measure this angle on the lateral X-ray (just like the previous one) by drawing two lines parallel to the plates of the vertebra in question.
3. Wedging present in at least 3 or more contiguous vertebrae.

1.1 History

As a curiosity, this disease takes its name from the first person who described it, Holger Werfel Scheuermann in 1920 [3] who thought it was an osteochondral vertebral lesion that caused wedging. However, it was later, in 1964, when Sorensen [2] described the diagnostic radiographic findings of Scheu ermann and that we have already described at the beginning of the introduction.

1.2 Etiopathogenesis and pathophysiology

There are many theories in this regard, however, the one that is currently most accepted is that of traumatic stress on a weak vertebra due to alteration of its vertebral endplate [4]. But before we talk about the disease, what is the endplate and why is it important? It is an area composed of cartilage and spongy bone that is in close contact with the intervertebral disc. It is an intrinsically weak area that is exposed to the transmission of axial and rotational forces that affect the spine. (Figure 1) It is also a passage area for blood vessels towards the intervertebral disc (of an avascular nature), therefore, if its growth is interrupted, or its morphology is altered, we can say that the disc will also suffer the consequences of earlier degeneration. [5] (Figure 2)

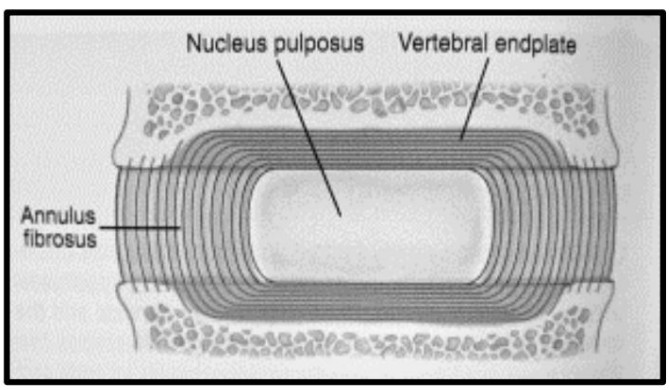


Figure 1. Diagram of the vertebral plateau, as an osteochondral component of the vertebra in close contact with the disc. Image taken from Neumann's book 2009 (page 330). [6]

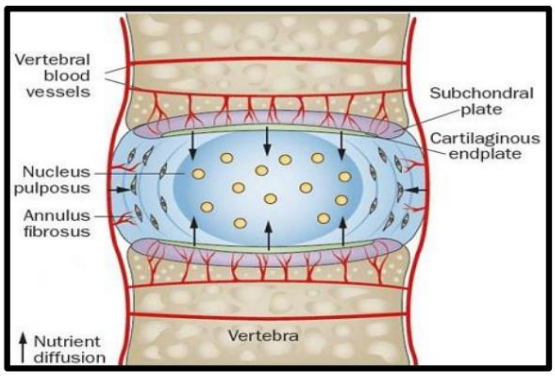


Figure 2. Scheme showing the close nutritional relationship of the endplate with the intervertebral disc. Image obtained from the work of Ruiz Willis, C. [7]

It is known that there is a genetic component, due to the concordance between homozygous twins of incidence of the disease, however, it has only been postulated, without confirming, a theory of autosomal dominant inheritance, in which the collagen 1A1 and collagen genes would be involved. 1A2. [8] What has been found at the end of the end plate in Scheuermann's disease? [9]

- Irregular mineralization due to disorganized endochondral ossification. • Abnormal cartilage with an altered collagen:proteoglycan ratio. The amount of proteoglycans in the biopsy of this growth plate is increased.

All of this will give rise to a deficient growth of the vertebral growth plate during adolescence and that will end up modifying the vertebral morphology towards a wedge-shaped one.

By way of summary, it could be said that osteonecrosis of the growth plate occurs in the anterior portion of the vertebrae of patients affected by this disease. We have the factors that predispose to having a weak vertebra, but now, is there something that can cause its morphology to be altered? [10]

- Strenuous sports activities (weightlifting, artistic/rhythmic gymnastics, rugby…)
- Manual workers (trunk flexion position). • Obesity and high BMI.

This theory has not been confirmed, but they suggest that he may be involved. [eleven]

2. Materials and Methods

The diagnosis of this pathology is clinical and radiographic, so we must take both aspects into account.

2.1 Clinic and types (5,12)

2.1.1. Classic form/type I: The one described by Scheuermann in which there is only thoracic involvement and its apex will be located at T7-9. It is usually diagnosed from adolescence, with the growth spurt and almost always by family members or in a routine physical examination (such as in physical education classes). These patients should be routinely examined to include:

1. Complete spinal examination, including sagittal/coronal balance to assess scoliosis among other findings that may be present. (Fi gure 3) [13] • Structural
   thoracic hyperkyphosis • Non-
   structural lumbar hyperlordosis • Pelvic
   anteversion • Dropped
   shoulders (scapular abduction) • Scoliosis
   (15-20%) that should have the same apex as the kyphosis [14]

Figure 3. Inspection of the spine in a patient with Scheuermann. Note that hyperkyphosis conditions a hump. Image taken from the work of Sardar, ZM. 2019.

2. Full range of motion, which may be limited in these patients.
3. Complete neurological examination to detect possible alterations. It is rare that they appear in these patients unless they are associated with spondylo listhesis, dural cysts, herniated discs or a very angular kyphosis (that is, having few vertebrae causing the kyphosis). It will almost always appear post-traumatically.
4. Evaluate pulmonary symptoms. In some cases, with very pronounced curves (>100º) that limit their quality of life due to the appearance of a restrictive pulmonary pattern.
5. Plain radiography. We must perform complete spine X-rays (30*90 reconstructions) to assess vertebral alignment in both planes (coronal/ sagittal). For the diagnosis of Scheuermann, the one that gives us the most information is the lateral projection and we can find a multitude of findings. (Figures 4 and 5)

Among the most common findings that can be seen on radiography, we must include others that are better assessed with the use of MRI. They include irregular endplates, Schmorl's nodes (16-35%), disc involvement (50%), spondylosis/spondylolisthesis, bone edema (usually associated with back pain) and/or scoliosis. (Figures 5 and 8)

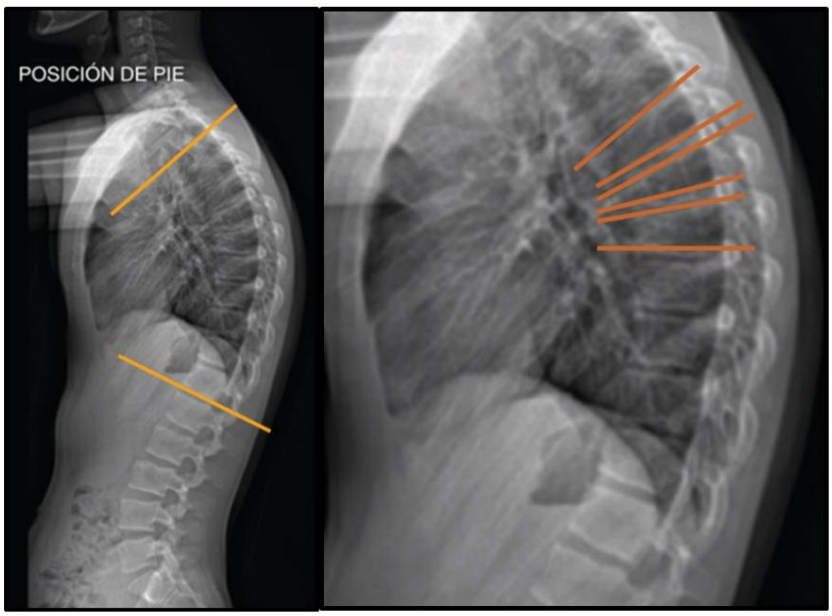


Figure 4. 30*90 X-ray in lateral projection showing a 55º hyperkyphosis with apex in T5 and anterior wedging of three vertebrae.

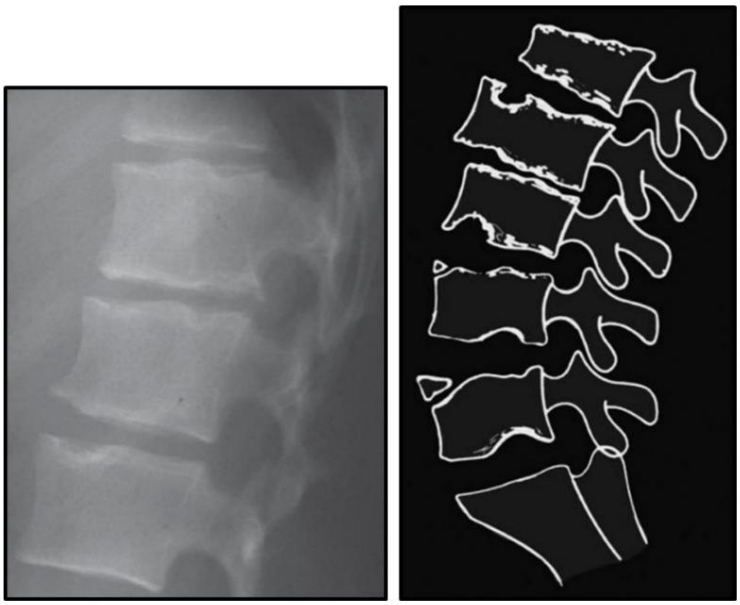


Figure 5. Lateral radiograph magnification with scheme of possible radiographic findings in Scheuermann's disease described in the text. Images taken from Palazzo's work, C. 2014.

Another very important aspect to assess is the sagittal balance on the X-ray, and this is done by calculating the pelvic parameters with a view to preoperative planning (Figure 6). Specifically, the pelvic incidence (PI) is the angle formed by a line perpendicular to the midpoint of the promontory with the midpoint of the line joining the femoral heads. This value is important not only in Scheuermann's kyphosis but also for global sagittal balance and the treatment of many spinal pathologies. [fifteen]

To maintain a good sagittal balance, the PI – LL balance (lumbar lordosis) < 10º must be maintained. However, another formula has been proposed for patients with Scheuermann's Kyphosis that has been validated; however, the fact that these patients have a lower rate of postoperative complications has yet to be discovered. [16] The formula is as follows: ÿ (delta)=(thoracic kyphosis -45)+(thoracolumbar kyphosis-0)+(PI-LL)= ±10º

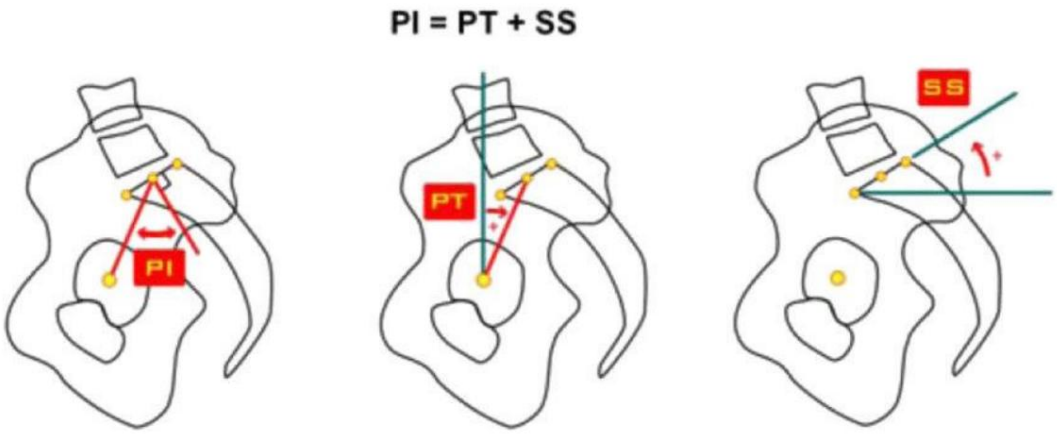


Figure 6. Measurement of pelvic parameters. PI = pelvic incidence, PT = pelvic tilt, SS = sacral slope. Images taken from the work of Le Huec, JC. 2014.

In addition, for pre-surgical planning we will also need to have radiographs of the non-dominant hand (to assess the state of growth) and of the lateral column in correction with a fulcrum in the region of the apex of the curve, to assess its flexibility (correction > fifty%). (Figure 7)

Figure 7. Necessary tests for preoperative planning (Rx non-dominant hand and curve correction).

2.1.2. Thoracolumbar form/type II: In this case, there is involvement of the lumbar spine, with the consequent loss of physiological lordosis. These forms generally present with greater pain, which is almost always located at the apex level. In other cases, it is accompanied by mechanical lower back pain and muscle tension. [17]

The radiographic findings in type II are similar to those found previously.
In addition, it is convenient to talk about Schmorl's nodes [18], they can be central or intraosseous/intraspongeous, but also anterior or posterior retromarginal, and this is due to the fact that during the growth and ossification process of the vertebrae, the ring processes (a secondary ossification nucleus that forms the vertebral end plate), is still formed by cartilage, and can fracture with the consequent herniation of the disc towards those areas.

I want to emphasize that there is no cervical Scheuermann's disease, or at least it has not been documented. It is hypothesized that it could be due to the stability of the uncus (an apophysis of the cervical vertebral bodies) that makes them barely mobile and there is the necessary mechanical stress. Finally, it must be mentioned that this limitation or symptomatology is not related to the magnitude of the curve and that many times the patients are asymptomatic.

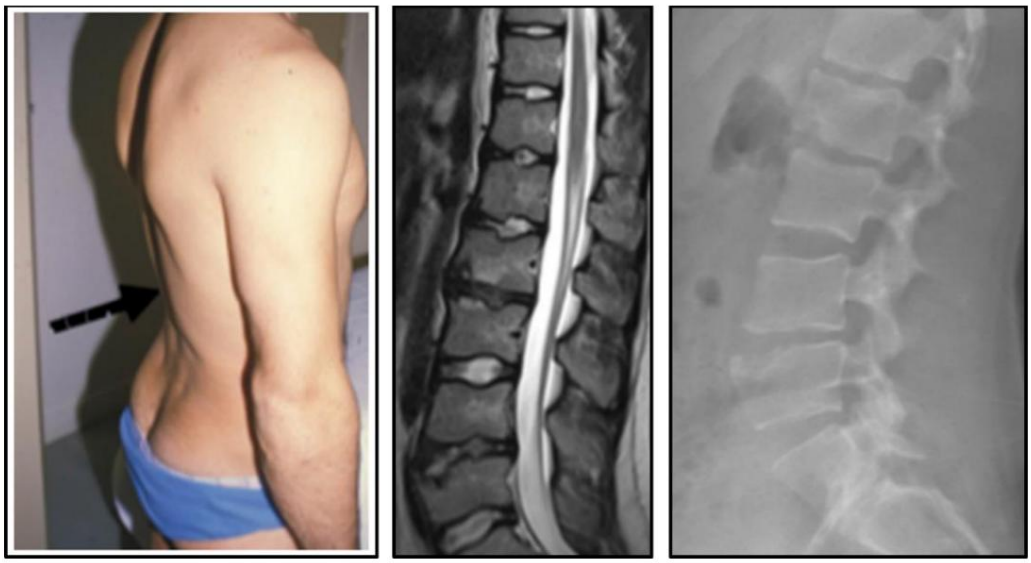


Figure 8. Clinical, MRI and radiographic image of atypical Scheauermann's disease or type II. Images taken from Palazzo's work, C. 2014.

3. Treatment

There is slight disagreement in the literature regarding the limit ranges when treating kyphosis conservatively, orthopedically, or surgically, although there is generally a tendency towards certain values that we will discuss below. Generally, in low-magnitude curves (>60º) we do not usually carry out practically any treatment, observation, advice, and avoiding sports that imply excessive mechanical stress on the vertebrae will suffice (of course, avoiding sports that we have talked about before).).

3.1. Conservative

The vast majority of patients fall into this group of patients in which it is only necessary to observe if the curve progresses. Regarding curves of greater magnitude (50-80º Cobb), with or without symptoms, the following is recommended:

- Postural hygiene •

Pectoral and hamstring stretching / muscular strengthening of trunk erectors. Together with the above, they present demonstrated evidence of pain reduction. [19]

- Psychotherapy in case of psychological affectation by image (not there usually is).
- Orthopedic treatment. Conservative treatment prínceps in our study specialty.
- Physical therapy / manual / osteopathy. No proven evidence.

3.1.1. Corset treatment (Milwaukee, Boston or anti-gravity type): It is based on the reduction of pressure on these vertebral plates in formation. It is the only conservative treatment that has managed to slow or stop the progression of the disease, as well as reduce pain. Although there are a series of requirements to wear these corsets:

1. Being in a period of growth. Skeletal immature patients because they present flexible curves.
2. Time-dependent. It will be necessary from 16-23h/day so that it has some effect.
3. Treatment should be continued up to 1-2 years after the end of growth.

I lie.

Depending on the form of the disease, they will have a series of supports. Posterior at the level of the apex and sacrum (this one only in the classical form) and two anterior ones in the upper part of the trunk and lower to elevate it, compensate the posterior ones, and prevent gravity from exerting a deleterious effect on the curve. [20] It should also be said that, once the corset is removed, there is the possibility that the reduction that was achieved with the curve is lost, that is, that its severity increases. [twenty-one]

3.2. Surgical [22]

Surgical treatment is based on three pillars: release of structures, correction of the deformity, and instrumented arthrodesis. A magnitude greater than 70º is generally accepted as a surgical indication, although in reality it is the patient who usually orders the surgery due to discomfort with the symptoms or the deformity. Some of the most accepted indications are: • Progressive deformity • Refractory chronic low back pain • Progressive neurological deficit • Failure of conservative treatment • "patient-dependent" indication

3.2.1. History: at first, the posterior approach with the Harrington instrumentation or the Cotrel-Dobusset was advocated, but this type of fixation generated too many failures and complications due to the lack of anterior support, they ended up being abandoned individually and began to become fashionable. the double anterior-posterior approaches, which, although not free of complications, achieved greater reductions in kyphosis. [23] They were based on anterior release of vertebral structures by thoracotomy (discectomies + interbody fusion), followed by posterior fusion. Sometimes, halo-traction can be useful to try to make a curve more flexible, which at first seems rigid (Figure 9). Currently, the treatment of choice is the single posterior approach, using pedicle screws and associating osteotomies, with very good results, comparable to those of the double approach (which must be performed in two stages to avoid further complications).

Combined approach (anterior-posterior)	Back-"only"
"Lower correction loss"	less blood loss
"Further Correction"	Less surgical time
	Lower risk of junctional kyphosis

Table 1. Advantages relative to each of the types of approaches. The loss of correction has decreased over the years with the improvement of the surgical technique in both the anterior and posterior approaches. Being now similar to the same in the "posterior-only" also in terms of surgical results. (24)

The main problem is that when we analyze the results, the studies of the combined approach tend to be of low quality, old, and are based on patients with larger and larger curves. This can mean that these supposed advantages of this type of approach are biased (Table 1).

When will the above approach be necessary? Classically it has been used for adult Scheuermann, in type II (because it is necessary to obtain more degrees of correction) or those kyphosis that are rigid in general, due to the limitation or weakness of the anterior noble structures (vascular and nervous). . In any case, both will never be done in the same surgical act, but rather sequentially because it has been studied to reduce complications.

Figure 9. Example of a patient with Scheuermann, and adjuvant treatment with halotraction prior to surgical treatment.

3.2.2. Correction of the deformity: Through osteotomies According to the Schwabb classification [25] we can classify osteotomies into 6 groups: (Figure 10)

1. Aggressive facectomy and/or Smith-Peterson (OS-P). Part of the sheet is resected and the prickly
2. Ponte osteotomy (OP; resection of both facets). In addition, with exeresis of the interspinous ligament and the yellow. In this two we will need the disc to be open in front to be able to correct the deformity (approximately 5-10º per vertebra).
3. Pedicle subtraction osteotomy (OSP; anterior wedge on the vertebral body), with a correction of up to 30º per vertebra.
4. Pedicle subtraction osteotomy + excision of the overlying disc. These last two do not depend on whether or not there is open anterior space, since by itself, it acts on the anterior part of the column.
5. Spine resection (SCR) of one level with excision of adjacent discs.
6. Multilevel spinal resection.

As a summary, it could be said that 3 Smith-Peterson osteotomies would be equivalent in correction to 1 pedicle subtraction osteotomy. [26]

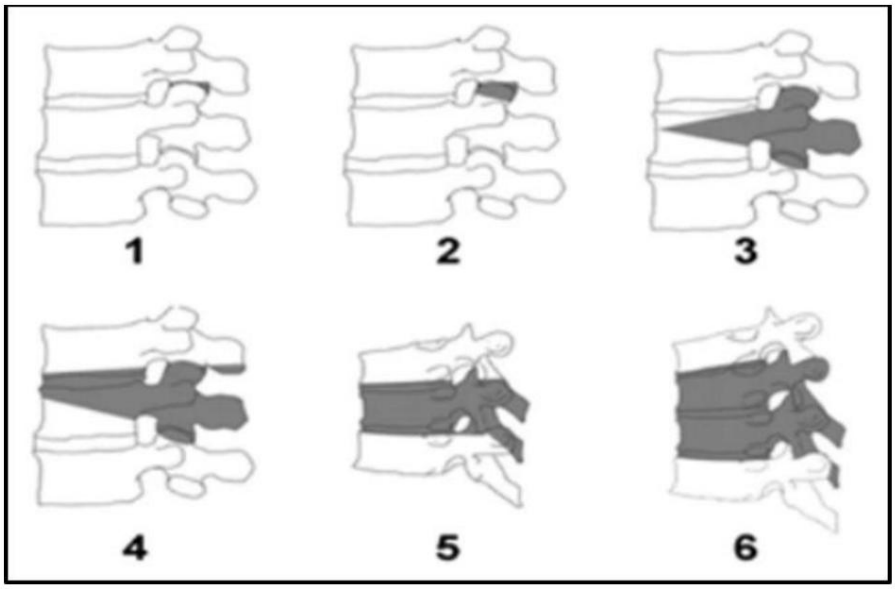


Figure 10. Vertebral osteotomies. Image taken from the work of Schwabb, F. et al.

How many osteotomies do we need? To help answer this question, we can use the value of the DAR (Sagittal Deformity Angular Ratio) = kyphosis angle / number of kyphosis vertebrae. The lower the number, the better, smoother curves and vice versa for more angular curves where we will need a greater number of osteotomies. In addition, a very high DAR has been associated with a greater risk of alerts in neuromonitoring. [We can also calculate it based on the plumb line: if it falls >5cm in front of the lumbosacral disc, we will need at least one OSP.

3.2.3. Transitional or union kyphosis: This complication, frequent in surgical treatment in the past, according to series, has an incidence of 20-40%. It is defined as a Cobb angle >10% between the fused and non-fused segments. [28] More rigid constructs increase the risk of kyphosis of the joint, while those that are more flexible can cause a loss of reduction (we must assess the risk-benefit of each type of instrumentation). (Figure 11)

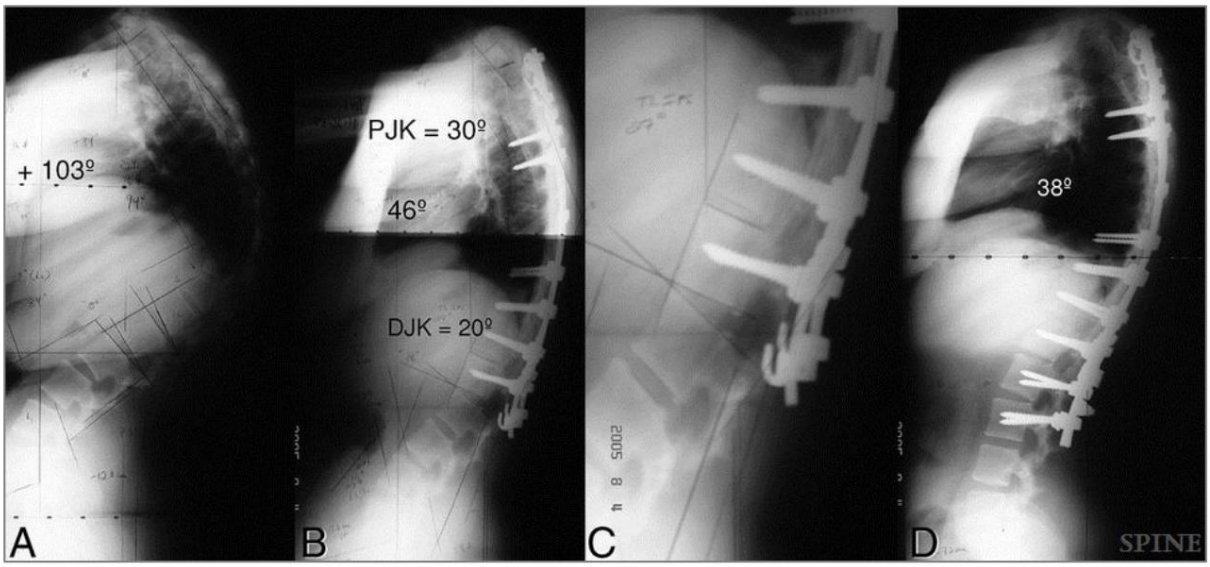


Figure 11. 16-year-old girl with an initial kyphosis of 103º (A), which was treated surgically and in the postoperative period a proximal and distal transitional kyphosis developed (30º and 20º respectively; B and C). For its correction, instrumentation (D) is amplified. Images taken from the work of Looner, BS., et al.

This complication has been associated with a greater pelvic incidence in patients, a lack of fixation of levels that should be included, as well as surgical overcorrection (we will worsen sagittal balance by leaving a small lumbar lordosis that will not be able to compensate for kyphosis). . [29] To avoid this complication, the following options have been evaluated [30]:

- Fusional proximal to the Cobb vertebra. •
- Maintain soft tissues at limit levels. • "Soft-landing"
- or smooth landing of the joint (with hooks, needles or transition bars that change in diameter) for a more gradual transition (already tested in scoliosis with good results).

3.2.4. posterior approach. Selection of the fusion level [31] (Figure 12): previously there was controversy as to what the last distal level should be. Firstly, the FLV (1st lordotic vertebra = first lordotic vertebra) or FLD (disck) was used, which is the most cranial that opened in anterior lordosis ÿ5º. However, it caused many complications because it was difficult to assess in patients with hyperlordosis and ultimately there were very short fusion curves. For the reasons described, the SSV (sagittal stable vertebra) was described and is used today, which is the last one that touches (more proximal) a line perpendicular to the horizontal drawn from the posterior vertex of the body of S1. [32] This new criterion provided a great improvement in the incidence of distal junction kyphosis, as well as greater resistance to screw pull-out, less loss of reduction, and less post-surgical sagittal imbalance. As an appreciation, if the last vertebra touched only slightly, it was convenient to look at the overlying disc, so that if it was in lordosis of ÿ5º, that level of fusion would be considered correct for fixation. At the proximal level, the last vertebra of the Cobb angle (the highest) must be included and it must be taken into account that from the apex of the curve there must be the same number of fixed vertebrae (or even one more proximal vertebra).

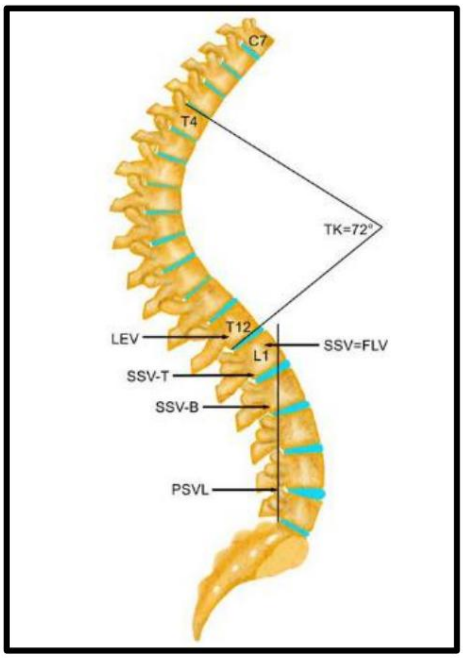


Figure 12. Scheme of useful parameters to select the fixation level of the posterior arthrodesis. PSVL = posterior sacral vertical line. Image taken from the work of Gong, Y., et al.

3.2.5. Surgical complications: Apart from the kyphosis of the union, there are other complications that must be taken into account, with an incidence, according to series, of 14%. [33] They are generally more common in adults and involve surgical wound infection (4-10%), acute neurologic injury (2-8%), or revision surgery (3-14%).

However, there are others that are much more frequent in the anterior approach, such as vascular (6%) or pulmonary (20%; pulmonary embolism, pleural effusion, hemothorax, atelectasis, acute respiratory failure...) complications.

Among the solutions that are proposed, especially when it comes to avoiding neurological damage, it is proposed to improve research in the field of neurophysiological multimodal monitoring. Although scoliosis surgery is not understood or used so far, it is necessary to develop it in this pathology to reduce complications to a minimum. [3. 4]

Finally, it should be noted that a new study has found a correlation between irregularities of the vertebral endplate and vertebral fragility fractures. Therefore, one might think that in Scheuermann's disease there would be a higher risk of fragility fractures, however, the studies do not show clear results. [35]

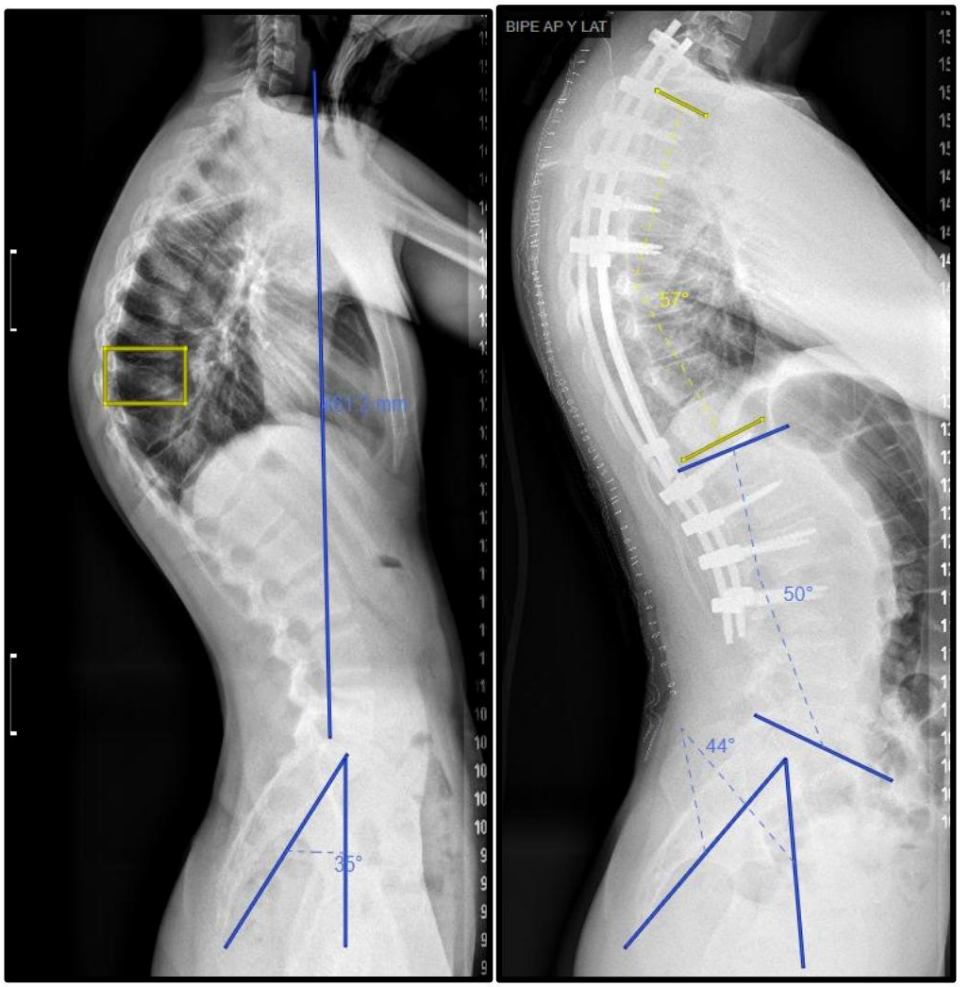
4. Conclusions

To finish, and as concepts that we must be clear about regarding the Kyphosis of Scheuermann, highlight the following points:

- The ethology of this disease is yet to be confirmed and it presents a remainder at the moment.
- The clinic and the simple radiography are enough to give us the diagnosis of this pathology. It is recommended to request an MRI in case of neurological symptoms, since it may be associated with other pathologies such as hernias or spondylolisthesis that will also have to be treated.
- The sooner treatment of the disease is carried out, whenever it is indicated, the better the patient's prognosis will be (regardless of whether it is conservative with orthosis or surgical with arthrodesis).
- Currently, surgical treatment opts more for a single posterior approach in order to avoid complications. However, if the curve is very challenging, experienced surgeons (sometimes in conjunction with thoracic surgery) may perform dual approaches.
- Selecting the correct levels of instrumentation is essential for the prognosis of these patients to be good, and to avoid revision surgeries. We want to remember that they are young patients with time to present complications related to the implant.
- Why do we treat Scheuermann's Kyphosis? It is not merely a surgical indication, as we have already discussed, but clinical, age, magnitude of the curve, complications, patient quality of life, and aesthetics must be taken into account.

Appendix 1. Clinical case (Figures 13 and 14)

A 16-year-old male with 85º kyphosis and 70º lordosis, in addition to a Sanders>V that practically indicates skeletal maturity. In the Rx in correction it barely corrects, so that finally surgical treatment was chosen. Among the preoperative planning are the following values: apex = T9, PI = 35º, SSV = L3, FLL = L3. After surgery, we found the following values: thoracic kyphosis = 57º, lumbar lordosis = 50º, PI = 44º; Therefore, the formula would be as follows: 44-55 = -7º, a value that is considered correct for the global sagittal balance. The technique used was a single posterior approach with instrumentation from T2 (nails) and T3 to L3 with pedicle screws and a double bar (simulating the Dobousset system). In addition, multilevel Ponte osteotomies were performed prior to instrumentation. The multimodal neurophysiological monitoring did not present alterations.



Figures 13 and 14. Clinical case described in the text.

Appendix 2. Adolescent kyphosis management algorithm

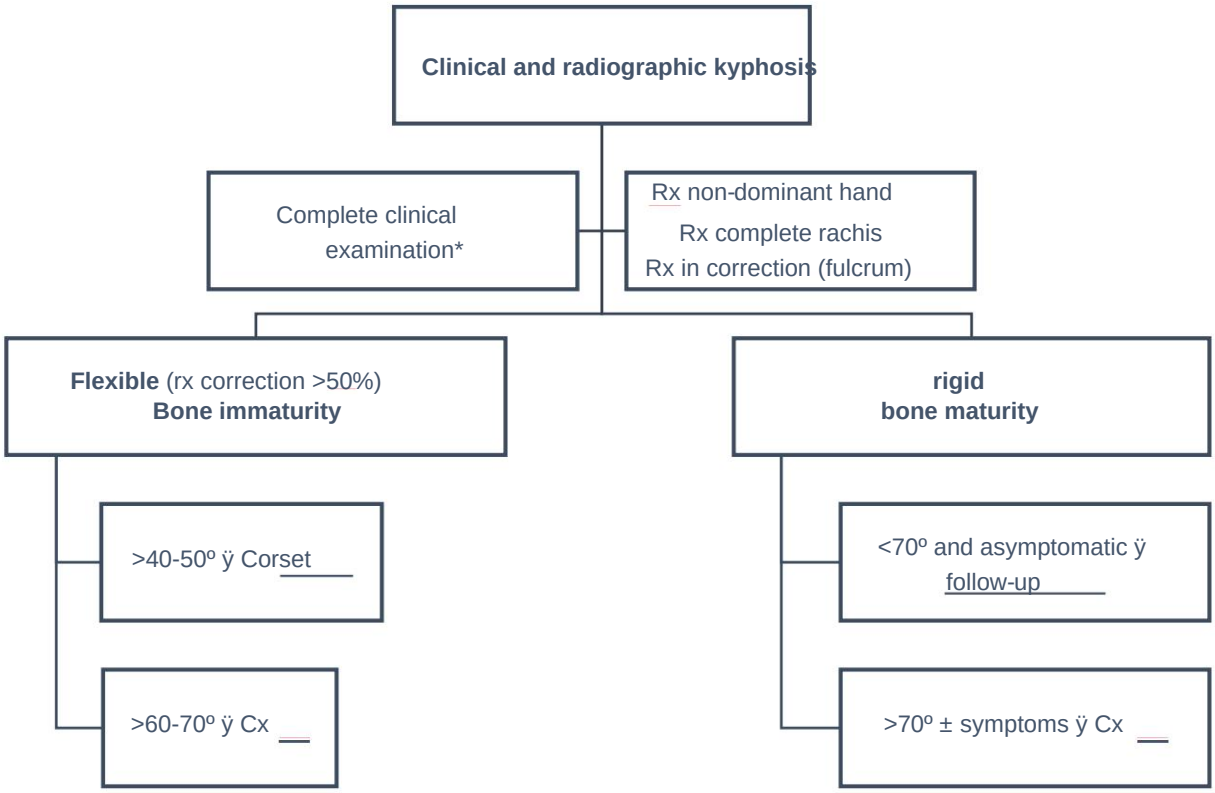


Figure 15. Management algorithm for adolescent kyphosis. We will have to make *differential diagnosis before diagnosing Scheuermann's kyphosis, with postural kyphosis, hyperkyphosis attributable to another pathology, post-surgical kyphosis, ankylosing spondylitis, and scoliosis.

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