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Scheuermann's Disease: A Narrative Review of Treatment Standards

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ABSTRACT

Background: Scheuermann's disease is a structural spinal deformity characterised by thoracic or thoracolumbar hyperkyphosis, defined by anterior wedging of ≥5° across three or more contiguous vertebrae, Schmorl's nodes, and endplate irregularities. Incidence ranges from 0.4% to 10% in adolescents. The atypical form shows higher prevalence among young athletes.

Aim: The purpose of this article is to evaluate and summarise the current state of knowledge regarding Scheuermann's disease.

Material and methods: A narrative literature review was conducted using Google Scholar, PubMed, Springer Link, and Scopus, with keywords related to Scheuermann's disease. English-language articles from September 2015 to January 2026 were included, with exceptions for historical sources.

Results: The natural course is mostly benign. Conservative treatment, comprising of physiotherapy, bracing, and analgesia, aims to halt progression, reduce pain, and improve posture, with bracing achieving approximately 50% correction and major pain improvement. Surgical treatment, standardised as a posterior approach, offers adequate correction with fewer complications than anterior-posterior approach. The key complication is junctional kyphosis. Sports participation is permitted post-treatment, as tolerated.

Conclusions: Scheuermann's disease is an important cause of juvenile thoracic hyperkyphosis, with persisting gaps in etiology, diagnostics, and management. Most patients lead normal lives. Conservative treatment is sufficient in most cases, with surgery reserved for patients that didn't respond to initial measures. Deformity progression is reported in long-term observations, regardless of treatment.

Keywords: Scheuermann's disease, Scheuermann's kyphosis, juvenile kyphosis, brace, hyperkyphosis, surgery

1. Introduction

Scheuermann's disease, also known as Scheuermann's kyphosis or juvenile kyphosis is a structural spinal deformity of the thoracic or thoracolumbar spine. Kyphosis is a physiological curve of the spine in the sagittal plane, with a normal range between 20 to 40 degrees, while hyperkyphosis exceeds 45 degrees[1,2]. This deformity is classified as either structural or non-structural. One of the most common types of structural hyperkyphosis is Scheuermann's disease[2]. It's the second most common deformity of the growing spine after scoliosis[3]. The condition was first described by a Danish surgeon, Holger Werfel Scheuermann in 1920[4]. This deformity of kyphosis consists of anterior wedging of at least 5 degrees of three or more contiguous vertebrae, Schmorl's nodes and end plate irregularities. Incidence of juvenile kyphosis ranges from 0,4% to 10% in adolescent patients. Most cases are diagnosed in adolescents aged 12 to 17 years, with males being more affected than females[5]. Scheuermann's disease is classified as either typical or atypical presentation based on location; thoracic kyphosis is the typical form, while involvement of lumbar spine is the atypical form[6]. Atypical form is also known as 'apprentice kyphosis'; it is more prevalent in the athletic population, for example heavy lifters. Atypical form is also more likely to progress than the typical one[7]. Etiology of this disease remains unclear with multiple theories proposed. Some authors propose genetic predisposition or hormone abnormalities[8].

The purpose of this article is to evaluate and summarize the current state of knowledge regarding Scheuermann's disease.

2. Literature Search Strategy

This comprehensive narrative literature review was conducted to identify relevant sources of information about Scheuermann's disease. Google Scholar search engine as well as PubMed, Springer Link, and Scopus electronic databases were used using the following keywords: "Scheuermann's disease", "Scheuermann disease", "Juvenile kyphosis", "Hyperkyphosis", "Adolescent kyphosis", "Thoracic kyphosis", "Thoracolumbar kyphosis". The review focused predominantly on scientific literature, systematic reviews, meta-analyses, and case reports. Articles written in languages other than English were excluded from the scope of the search. The timeframe for included sources was restricted from September 2015 to January 2026 with an exception for historical background.

2.1 AI

AI was utilized for two specific purposes in this research. Text analysis of clinical reasoning narratives to identify linguistic patterns associated with specific logical fallacies. Assistance in refining the academic English language of the manuscript, ensuring clarity, consistency, and adherence to scientific writing standards. **AI** were used for additional linguistic refinement of the research manuscript, ensuring proper English grammar, style, and clarity in the presentation of results. It is important to emphasize that all AI tools were used strictly as assistive instruments under human supervision. The final interpretation of results, classification of errors, and conclusions were determined by human experts in clinical medicine and formal logic. The AI tools served primarily to enhance efficiency in data processing, pattern recognition, and linguistic refinement, rather than replacing human judgment in the analytical process.

3. Research Results

3.1 Epidemiology and Natural History

Scheuermann's disease is diagnosed in minors from age 10 to 17[2,5]. The occurrence of this deformity is dependent on the examined population, mostly ranging from 0,4% to 10% in The United States of America and 2% to 8% in European studies[1,2,9]. Most authors report bigger prevalence in males, but some of more recent studies report similar prevalence in both genders[8,10]. Thoracic deformity is thought to be the most common form of juvenile kyphosis[6]. Some studies report that up to 20% of youth seeking medical advice due to back pain are diagnosed with Scheuermann's kyphosis[9]. Some sources state a higher chance of occurrence in taller patients[11,12].

The natural course of Scheuermann's disease is generally considered to be benign with most of the patients' lives unaffected by the deformity. This population has kyphosis of up to 60 degrees. Only a small fraction of patients report significant increase in their spinal curvature and deterioration of their well-being. An atypical presentation is more likely to be symptomatic after reaching a skeletal maturity than the typical presentation[8]. Mean progression of the thoracic kyphosis ranges from 10 to 15 degrees over thirty to forty-six years of observation[13]. This increase doesn't correlate with worsening of the previously reported symptoms and doesn't deteriorate quality of life of the affected population. Adult patients diagnosed with juvenile kyphosis report persistent back pain, fatigue, and tightness of postural muscles in later life. In the most severe cases, with kyphosis exceeding 100 degrees, decreased respiratory function and restrictive lung disease may be present. Pain is more common in this population than in the general public, with severity being mostly mild to moderate[14].

3.2 Etiology and Pathogenesis

There are several ongoing and historical theories explaining possible causes of Scheuermann's disease. The most broadly described theory is the biomechanical one. The deformity may be caused by altered biomechanics of the intricate structure of the spine and its surrounding muscles and ligaments. Biomechanical stressors modify the remodelling response in the vertebrae, compressive loading and downward forces affect vertebral bodies unevenly, with more pressure on the anterior part. This impairs growth and in effect causes classic wedge-shaped vertebrae characteristic for Scheuermann's kyphosis. Subsequent factors are smaller sternum causing increased pressure in the anterior parts of the vertebrae and tight hamstrings causing increased anterior pelvic tilt[2,7,15].

Another theory explores hereditary and genetic causes. Scheuermann's disease is thought to be hereditary in an autosomal dominant pattern. Penetrance is reported to be about 74%. Monozygotic twins also display higher rates of occurrence than dizygotic twins which strengthens this claim. Genetic mutation is found mostly in one of IHH, PAX 1, SOX 9 genes[5,7,15].

Less significant factors include transient osteoporosis with mean bone density being abnormally lower in affected patients in comparison to the control, abnormal collagen to proteoglycan ratios, defective collagen formation, dural cysts, and growth hormone hypersecretion[5,7,15].

Main historic theories were of Scheuermann, who proposed osteonecrosis of the vertebral ring resulting in an impairment of growth in the anterior part of the vertebrae, leading to the wedged shape of the vertebral body[4]; Schmorl believed that the cause for longitudinal growth arrest was the herniation of the discs with resulting loss of disk height, followed by closing of the anterior intervertebral spaces and formation of nodes[16].

The association with sports and resistance strength exercises is worth exploring. Athletes are more likely to suffer from lower back pain than the general population[11]. Several sources report higher prevalence of atypical Scheuermann's kyphosis among adolescent athletes. Activities most frequently associated with the disease are heavy weightlifting and repeated cycles of spinal flexion and extension typically observed in gymnastics. Other sports reported in literature include wrestling, football, tennis and bicycle racing[1,9,12]. Conversely, researchers don't report correlation between typical form of Scheuermann's kyphosis and physical activity[13].A study from 2019 reports juvenile patients with Scheuermann's disease have reduced aerobic capacity and worse exercise tolerance, especially those with kyphosis of over 75 degrees. There was also noted inverse correlation between increase in kyphosis and declined aerobic capacity. This

study established an important observation of impaired athletic activity in Scheuermann's disease[17].

3.3 Clinical presentation

There are two major reasons for patients with Scheuermann's kyphosis to seek medical advice, back pain and the postural deformity which has cosmetic effects on the appearance and self-esteem. Pain is the driving factor for seeking medical help by teenagers. It is most intense at the apex of the kyphosis, usually subacute, may be intermittent or chronic. It worsens with flexion, after exercises and in the evenings. Resting mitigates the pain[5,7,18]. The cosmetic aspect is the most common cause for concern for patients that first report to the doctor in adulthood. Most patients are diagnosed in their adolescence[5]. Impairment of respiratory function happens in population with kyphotic curvature of over 100°. Patients with Scheuermann's disease are at a bigger risk of ossification of thoracic disk herniation and ossification of the ligamentum flavum than the general population. Some sources suggest that over 90% of thoracic disk herniations are associated with Scheuermann's disease[7].

Scheuermann's kyphosis also alters morphology of the rib cage. Diagnosed patients have longer and flatter ribs, with increase of anterioposterior diameter relative to the transverse diameter. These changes may be another reason for respiratory complications[19]. Initial signs are discovered by patients themselves, their parents or during the school screenings. Patients don't report any particular incident or trauma that causes the deformity[5].

Body image and subject of mental health is another significant factor in the broad picture of Scheuermann's kyphosis. Most patients are diagnosed around the time of puberty, which is a time of fragile self-image. Perceived looks and body image play a major role in the self-image. Patients suffering from Scheuermann's disease score worse on the SRS-22 questionnaire than the general population[20].

The differential diagnosis must include other important causes for structural kyphosis, which include infections, tumour and compression fractures.

Physical examination should begin with inspection of the body, most patients present with thoracic hyperkyphosis with compensation by hyperlordosis of lumbar and cervical spine, and goose-neck deformity, which is a forward protrusion of the head and neck. Common signs also include pigmentation of the skin over the spinous processes of the vertebrae, mild scoliosis, tightness of hamstrings, iliopsoas, and pectoral muscles. Visual inspection should be followed by assessment of the flexibility. Forced flexion and extension is performed. This step provides important information that allows us to differentiate between rigid and postural kyphosis.

Kyphosis in Scheuermann's disease is rigid, accentuated by forward flexion and cannot be corrected by extensions of the spine or lying on a flat surface[2,5,7].

Compensatory hyperlordosis of the lumbar spine serves to maintain sagittal balance. However once the limit of compensation is reached, while deformity further progresses, positive sagittal balance may occur[2,20].

This development is associated with worse health-related quality of life in adults and may accelerate degenerative disease in the lumbar spine[21,22].

The last step of the physical examination typical for Scheuermann's disease focuses on neurovascular examination to discover any neurological impairment and abnormal reflexes. Neurological abnormalities are rare, but their presence impacts future treatment possibilities[23].

3.5 Diagnostic Imaging and Classification Criteria

Diagnostic imaging and classification criteria go hand in hand in Scheuermann's disease. Current diagnostic criteria were proposed by Sørensen in 1964. This condition is defined by:

- thoracic spine kyphosis of over 40°
- occurrence of at least 3 adjacent vertebrae, each wedged by at least 5°[2,8]

Modifications by Ali et al. in 1987 state that minimum of two adjacent apical vertebrae were enough for the diagnosis. Modifications by Sachs et al. in 1987 define this condition as a presence of at least one wedged vertebra of ≥5°, in combination with thoracic kyphosis exceeding 45°[20]. Wedged vertebrae may be accompanied by several findings: Schmorl's nodes, decreased intervertebral disc spaces, irregular vertebral apophyseal lines with flattening and wedging of the apophysis, increased anteroposterior diameter of affected vertebral bodies, and irregular endplates. Schmorl's nodes are herniations of nucleus pulposus through the endplates into the vertebral body. These appear in up to 70% of examined patients with Scheuermann's kyphosis, although these are not pathognomonic[20,24]. These findings are more common for the typical form of Scheuermann's disease. A rare sign should also be mentioned, Edgren–Vaino sign. It is a bone proliferation opposite Schmorl's node, it is said to be pathognomonic[24]. Apex of the deformity is typically located at the T7-T9 level for the thoracic kyphosis, and at T10-T12 level for the thoracolumbar kyphosis[25].

Imaging options include conventional radiographs of the spine, computed tomography, magnetic resonance imaging and rasterstereography.

Conventional radiographs are a golden standard for diagnosing Scheuermann's kyphosis. Radiographs are taken in anterior-posterior and lateral views in standing position and a lateral view with the patient performing a forced hyperextension. These projections allow to differentiate between flexible and rigid postural hyperkyphosis, measure Cobb angle and diagnose Scheuermann's kyphosis. Cobb angle is measured in lateral view projection by drawing the lines along the endplates and measuring the angle at the intersection of the lines[26]. Computed tomography is useful in preparation for surgery. It allows to precisely measure the angles of the kyphosis and to measure the affected vertebral bodies.

Magnetic resonance imaging is used to examine patients with atypical history and any possible neurological deficits discovered in the physical examination. Lonner et al. in their study propose screening MRI imaging in operative patients to reduce risk of neural axis complications. They reported that 5% of reviewed cases had altered operative plans due to MRI findings, while the rate of neurological complications remained unchanged despite the adjustment of operative plans[27].

Furthermore there is another way of imaging that is safer to use. Rasterstereography is a non-invasive, radiation free imaging technique that creates 3D surface topography of the back. It works by projecting a grid of horizontal lines, measuring the distortion of these lines over the kyphosis and possible scoliosis and calculating curvatures with more precision than measurements based on X-rays. It is the most useful in monitoring the development of the disease over a longer period of time[28,29].

3.6 Conservative Treatment

Scheuermann's disease can be managed by conservative treatment. Its aim is to stop the progression of the kyphosis, mitigate pain, and improve posture. Conservative approach consists of strengthening and stretching of postural muscles, bracing, pain killers and avoidance of triggering factors. Patients with skeletal immaturity, maximum kyphosis up to 60°, without major pain, and without signs of worsening of the deformity can only be periodically observed up to full skeletal development by a clinician with use of imaging studies and physical examination[23].

Indications for non-invasive treatment include:

- thoracic kyphosis of 45° to 80°,
- thoracic kyphosis with presence of radiographic signs, namely Schmorl's nodes and wedged vertebrae,

- cosmetic complain and lowered self-esteem,
- persistent pain[2,8,12]

Physiotherapy puts an emphasis on strengthening of thoracic extensor muscles to improve function of patients. Developing strength and stretching of pectoralis muscles, hamstrings and abdominal muscles improves posture and relieves contractures. Contractures are a compensatory mechanism of increased lordosis initially caused by the kyphosis. Physiotherapy on its own cannot fully stop the progression of the deformity, as it is more useful in flexible deformities. The goal of physiotherapy is to alleviate and manage pain[2,23]. Young patients without full skeletal maturity require additional orthosis, and earlier treatment provides better long-term results. Physical exercises should be a part of the treatment, regardless of the choice of surgical or non-surgical approach. Apart from pain relief it also improves respiratory capabilities in patients suffering from restrictive lung disorders caused by spine deformity[23].
Young athletes with kyphosis lesser than 50°, who have successfully completed a physiotherapy course may return to full physical activity without restrictions. Athletes during bracing treatment may participate in physical activity with the brace off for the duration of the practice or the game if they started the physiotherapy and are free of the pain. Pain may be recurrent, in spite of the treatment, although overall outcomes are very good[1].

3.6.1 Orthotics

Bracing is often used for treatment of mild to moderate presentations of Scheuermann's disease in skeletal immature patients. Bracing's aim is to improve thoracic kyphosis by facilitating vertebral remodelling. Remodelling happens by stopping the progression of the deformity and aligning the spine into proper position. It also has a secondary effect, bracing also aligns lumbar lordosis to its proper location. The most apparent drawback of this method is the compliance, which is of utmost importance. Orthotics should be worn for the most of the day, with minimum being 16 hours a day, up to 23 hours a day[12,23]. Braces are used up to the point of full skeletal development or for a minimum of 18 months if full development is reached before. Brace should be put aside slowly, in another 18 months that follow this step. Prognostic factors for adequate response are kyphosis fewer than 65°, skeletal immaturity and flexible deformity[23]Błąd! Nie zdefiniowano zakładki.. There are several types of braces available on the market, as to find the best fit for individual cases.
Milwaukee brace is a cervico-thoraco-lumbo-sacral brace, which extends from the neck down to the pelvis. It provides three points of pressure on the body. It's built of a pelvic girdle, one

anterior bar and two posterior bars. It's the biggest orthotic used. Its goal is keeping the head centred relative to the pelvis while extending the spine. The Milwaukee brace is the most reliable one to choose according to the studies[23,30].

Boston brace, also known as Thoraco-Lumbosacral Orthosis, is a low profile brace, positioned around the trunk and under armpits, with no support for the upper part of the thoracic kyphosis. It has three points of pressure. It is smaller in size than the Milwaukee brace. Results of this orthosis aren't as good as a Milwaukee brace, but thanks to the smaller footprint it's better tolerated by patients[23,31]. Another type of brace is the Maria Adelaide brace. It was created in Turin, its main goal was to increase compliance while trying to preserve the effects of the Milwaukee brace. It reaches from the sternum to the buttocks. Compliance in this method is substantial, 84,9% of the patients used the brace according to the received schedule. 60,4% achieved reduction of the curve, while 29,7% achieved stabilisation of the deformity[32].

The effect of the treatment is significant. Some studies report averaging of 50% correction at the end of bracing and major pain improvement. Some of the correction is lost after termination of the treatment[8].

3.7 Surgical Treatment

Indications for surgical treatment:

- Kyphotic curve exceeding 70°,
- Severe persistent pain,
- Unsuccessful conservative treatment,
- Neurological deficits or cardiopulmonary complications,
- Progression of the deformity[1,21]

Older patients are more likely to suffer from larger deformity that can only be corrected by surgical procedure. Older patients also typically have less flexible kyphosis and have reached skeletal maturity. These patients are less likely to respond to conservative treatment. On the contrary, younger patients may not fully respond to the surgical treatment considering they may not have reached full skeletal maturity[33].

3.7.1 Pre-operative procedure

Some studies suggest MRI imaging before the operation as stated before. Possible findings include low-lying conus, posterior disc herniations, syrinx, spondylosis. Estimated risk of damaging the spinal cord during surgical procedures has been cited at approximately 3.2%[27].

3.7.2 Approaches

There are two approaches possible to choose from, anterior-posterior approach and posterior approach. Anterior-posterior approach was the standard, especially for more rigid deformities found in adult patients. It was found, in initial studies, to provide greater correction rate, more gain in spinal height, and lower risk of development of junctional failure[24]. Recent studies report more complications in AP approach, with most being approach related, e.g. pneumothorax and pulmonary effusion. Posterior-only approach is the modern standard, it provides adequate correction with reduced morbidity, less blood loss and shorter procedure duration. These changes were possible thanks to the improvement in instrumentation and advancements in multi-level corrective osteotomies[6,8].

Ponte osteotomy is a multi-level posterior column osteotomy. It allows to reduce the height of the vertebrae in the posterior segment by resecting laminae and facet joints of vertebrae at the apex of the kyphosis and resecting whole ligamentum flavum. This method is used across the apex of the deformity and it provides 5°-10° of correction per vertebra. Ponte osteotomy shortens the posterior part of the spine and effectively reduces the kyphosis. The anterior column of the spine is untouched by this procedure, the previously closed anterior parts of the disc spaces open up in the consequence of the procedure. This outcome allows to preserve the long-term load bearing capacity of the spine and stability of the correction. Ponte osteotomy is capable of producing noticeable flexibility in extension, flexion and rotation as the result of the procedure[34,35].

Correction is commonly improved and secured with a cantilever technique, using a pre-bent rod. It is secured to pedicle screws proximal to the apex after performing the multilevel osteotomies. Sequentially the metal rod is fastened to the screws distal to the apex. This allows the already connected part to act as a cantilever and pull the upper segment of the deformity posteriorly, further correcting the kyphosis[2]. Sardar et al. recommend using cobalt, chromium or stainless steel rods, at least 6 mm in diameter. Authors report less risk of loose correction over time thanks to these adjustments. Sardar et al. also recommended usage of transition rods as it may transmit stress more gradually between fused and unfused segments[8].

Surgical goal is a correction of around 50° or 50% of the kyphosis prior to the surgery. This goal should be personalized to suit individual patients' anatomy and biomechanics and to restore spinal balance. Caution against overcorrection is strongly advised, as it may cause acute neurological symptoms or junctional pathology[2,33].

3.7.3 Choosing the proper fusion levels

Selection of the fusion level is an important determinant of long term surgical success. Including the whole deformity, defined by the Cobb vertebrae is the minimum requirement to ensure proper fusion. Cobb vertebrae are the highest and lowest vertebrae of the kyphosis and used to calculate the Cobb angle. Upper instrumented vertebra and lower instrumented vertebra are the first and last vertebrae that are included in the fusion construct. They serve as anchors for the fusion. Special attention is paid to the choice of the proximal level of the fusion as this choice affects the risk of post-operative complications the most. Surgeons choose either the uppermost kyphotic vertebra or the neutral vertebra directly above as the upper instrumented vertebra. Preoperative degree of kyphosis is directly correlated with proximal junctional kyphosis[8,35]. This may urge the surgeon to extend the scope of the surgery to the first neutral vertebra. Yuan et al. recommend the fusion start at T2 vertebra or higher as to reduce the risk of proximal junctional kyphosis[36]. It's important to save the interspinous ligament connecting fused and unfused vertebrae to further mitigate risk of complications[8].

In the past, lower instrumented vertebra was the first lordotic disc. Proper identification of this disc may be challenging due to compensatory lumbar hyperlordosis, with risk of the true first lordotic disc not being included in the fusion. This omission increases the risk of developing distal junctional kyphosis[7,37]. Currently the sagittal stable vertebra is used to identify the lowest vertebra that should be included in the fusion. It is the most proximal vertebra touched by the posterior sacral vertical line and is usually lower than the first lordotic disc. Fusions ending at the sagittal stable vertebra are nowadays accepted as the desirable level, allowing minimisation of the complications[8,37].

Surgeons should aim to create a "soft landing" at the ends of the fusion. Biomechanical studies report the benefits of the gradual transition from the immobility of the fused vertebrae to the normal motion of the unfused vertebrae. This goal can be achieved by the use of hooks, wires and ligament augmentation while creating the fusion[2,38].

3.7.4. Complications

A retrospective study cited by Kaspiris et al. stated that overall complications rate was 14% without distinction of the approach type, with adult patients more likely to suffer from complications[35]. Possible complications of the surgery include junctional kyphosis adjacent to the fusion, infection of the wounds, fusion complications, hardware failure and neurological complications, sciatica and cervical pain. Recurrence of the deformity in the vertebra proximal to the highest fused segment is called Proximal Junctional Kyphosis, recurrence distal to the

lowest vertebra is the Distal Junctional Kyphosis. Risk factors for junctional kyphosis include large curve of the kyphosis prior to the surgery, too short fusion, overcorrection, sagittal disbalance and disruption of ligamentum flavum. It does not cause additional pain for the affected patients, although secondary deformity of over 20° is a reason for lower self-image scores on the Scoliosis Research Society (SRS) instrument[35,36]. To limit the incidence of the acute neurological complications use of intraoperative neuromonitoring is recommended[2].

3.7.5 Results

Both approaches provide similar stabilisation and radiographic correction, resulting in pain relief, symptomatic improvement and improved cosmetics[37]. Posterior-only approach is the preferred technique due to shorter duration of the surgery, decreased morbidity, less complications, and less blood loss while providing similar results[39]. The number of patients treated surgically varies widely between studies with up to 60% of patients receiving surgical treatment in some studies. This number may be overestimated for the whole population as it is based on self-reporting patients and suffering from larger kyphosis with more present complications of it. Many patients with lesser curvature and less significant complications may not seek professional help, thus being not reported for treatment in specialised centres[40,41].

4. Results

4.1.Long-Term Outcomes

Most patients have an overall good prognosis of long-term outcomes, especially those with kyphosis of less than 60° This population is usually treated with conservative measures. Pain in the region of the kyphosis subsides after treatment and after fulfilling skeletal growth potential, although patients with the disease are at greater risk of chronic back pain in later life[5]. The American College of Sports Medicine permits involvement in sports, as tolerated, as symptoms diminish in time. Restriction of activity is not recommended unless patients experience severe symptoms[17].

4.2 Curve Progression

Scheuermann's disease shows a tendency for slow, continuous progression over time[42].

In a 39-year follow-up study, by Ragborg et al. progression average of 20° of Cobb angle was reported. Most of this cohort has fulfilled their skeletal growth potential at the final outpatient visit in adolescence, nevertheless significant progression of the deformity was discovered at the follow-up[43].

In a 46-year follow-up study of 19 untreated patients by Ristolainen et al. mean kyphosis increased from 46° to 60° and mean wedge angle developed from 8.8° to 9.9° at the follow-up. While progress of the deformity was apparent, no significant correlation between progression of kyphosis and patients everyday function[13]. Kyphosis larger than 65° may be susceptible to further development even after skeletal maturity and affecting general health of patients[44].

4.3 Quality of Life

Quality of life is judged using SRS-22 and ODI. SRS-22 is a questionnaire specific to Scheuermann's disease. It focuses mostly on assessment of mental health and self-image by posing questions about pain, perceived looks, perspective on future life with the disease, satisfaction with treatment and fulfilling daily tasks[45]. The Oswestry Disability Index (ODI) provides information about daily tasks and how back pain affects them[46]. Patients with Scheuermann's disease score worse on SRS-22 in long term follow-ups, are more susceptible to moderate back pain and may have lower self-esteem than control population[13,43]. In spite of these outcomes, most patients essentially lead normal life with physical activity mildly impacted, only the most severe cases show notably inferior physical function[42,44].

Pulmonary function was impaired in the form of restrictive lung disease only in most severe cases with curvatures of about 100° and more. Neurological complications are scarce, progression of the deformity does not influence the nervous system[12,42].

Untreated patients also score worse on SRS-22 and ODI questionnaires, with progression of about 0,45° per year with worse function than general population[18].

4.4 Long-term outcomes after conservative treatment

In a cohort study of 158 patients treated with braces the mean Cobb angle was 57.6°±6.3° at beginning of the treatment, 43.3°±7.8° at the end of conservative intervention, and 44.49°±7.4° at the ten-year follow-up. The wedge angle was 14.43°±2.535° at the beginning of the treatment, 8.571°±3.589° at the end of conservative intervention, and 8.654°±3.57° at ten years of follow-up. The difference between end of treatment and follow-up was not significant[44].

4.5 Surgical long-term outcomes

A retrospective cohort of 51 patients who underwent surgical correction, with mean follow-up of 14 years reports the mean pre-treatment curvature corrected from 84.4°±5.7° to 44.0°±3.9° after intervention, with a final follow-up value of 46.5°±4.2°. The mean pre-treatment ODI fell from 31.4±12 to 7.1±5.6 at two years post-operatively. The final SRS-22 values in the posterior-

only approach and combined anterior-posterior approach were 4.1±0.4 and 4.0±0.35 respectively, with no significant difference between the approaches. 28 out of 30 patients were satisfied with cosmetic results post-operatively.

No difference was observed in stability of correction between posterior-only and combined anterior-posterior approaches[37].

5. Conclusions and Future Directions

Scheuermann's disease is one of the most widespread causes of hyperkyphosis of the thoracic or thoracolumbar spine in the juvenile population, nevertheless there are still some scientific gaps left to explore. Etiology, prevalence and gender ratio remain inconclusive, with recent research providing new outlooks on the state of knowledge about Scheuermann's kyphosis. Diagnostic criteria remain an area of dispute despite a century of research. Most widely used radiologic criteria were formed in 1964, and are still present with small modifications nowadays. This literature review sought to present a current state of knowledge based on the most recent scientific evidence.

The natural course of Scheuermann's disease is usually benign, adolescent patients typically suffer from moderate back pain and a cosmetic deformity. Deformity slowly progresses over time and doesn't impact daily life. Only a small part of the patients experience severe symptoms and require surgical interventions. Young athletes, such as lifters and gymnasts, are at greater risk of developing Scheuermann's disease due to excessive forces affecting their bodies and more strain put on the developing body. Aims of the conservative treatment are mitigating pain, stopping progression of the kyphosis and improving posture over time. These goals are reached by means of physiotherapy, painkillers and bracing in larger deformities. This treatment is adequate for most of the cases as its success is evidence based. Surgical treatment is useful for patients that didn't respond to initial conservative measures. Deformities are corrected by about 50%, with major improvement in symptoms. The posterior-only approach is the modern standard of surgical intervention, with sufficient corrections, while being quicker, safer and causing less complications for patients. Most important complications are proximal junctional kyphosis and distal junctional kyphosis, which can be avoided by extending the scope of the fusion. In long-term follow-ups progression of the deformity is reported, no matter the type of treatment patients received, and bigger risk of chronic back pain. In spite of the progression, most patients live essentially normal lives, and function very similarly to the general population. Whilst recent studies provide progress in diagnostics and treatment, uncertainties still remain.

There is no consensus on definitive pathophysiology, with a plethora of considered causes such as uneven distribution of compression on the vertebrae, hereditary likeliness and possible gene mutations carrying higher risk of the deformity explored. Diagnostic criteria differ between sources, with a need for unified criteria ideally based on more than solely x-ray imaging. Conservative treatment remains the first choice of action, with physiotherapy recommended for the majority of patients. Despite the ubiquity of physiotherapy, there's a need for development of standardised programs of rehabilitation or major research about efficacy of it. Future research should also investigate the most optimal type of brace, with the possibility of reducing the time that patients use braces per day. This may increase the compliance of patients, which is the most important for success of bracing.

Further researches of surgical treatment should focus on refining criteria for the choice of the upper instrumented vertebra and lower instrumented vertebra, as to limit rate of junctional kyphosis as well as implementation of robotics for improving the treatment. In general, the latest research concerning Scheuermann's disease is mostly concluded on smaller cohorts, which may skew the results and don't represent the whole population of patients suffering from the disease. These cohorts predominantly consist of patients who seek help in specialised centres, with larger curvatures and more prominent symptoms. Scheuermann's disease requires future research conducted on bigger cohorts, to provide more accurate information, as well as incorporation of new technologies such as robotics and 3D printing to provide more personalised surgical treatment.

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