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REVIEW

Optimal management of idiopathic scoliosis in adolescence

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Abstract: Idiopathic scoliosis is a three-dimensional deformity of the growing spine, affecting 2%–3% of adolescents. Although benign in the majority of patients, the natural course of the disease may result in significant disturbance of body morphology, reduced thoracic volume, impaired respiration, increased rates of back pain, and serious esthetic concerns. Risk of deterioration is highest during the pubertal growth spurt and increases the risk of pathologic spinal curvature, increasing angular value, trunk imbalance, and thoracic deformity. Early clinical detection of scoliosis relies on careful examination of trunk shape and is subject to screening programs in some regions. Treatment options are physiotherapy, corrective bracing, or surgery for mild, moderate, or severe scoliosis, respectively, with both the actual degree of deformity and prognosis being taken into account. Physiotherapy used in mild idiopathic scoliosis comprises general training of the trunk musculature and physical capacity, while specific physiotherapeutic techniques aim to address the spinal curvature itself, attempting to achieve self-correction with active trunk movements developed in a three-dimensional space by an instructed adolescent under visual and proprioceptive control. Moderate but progressive idiopathic scoliosis in skeletally immature adolescents can be successfully halted using a corrective brace which has to be worn full time for several months or until skeletal maturity, and is able to prevent more severe deformity and avoid the need for surgical treatment. Surgery is the treatment of choice for severe idiopathic scoliosis which is rapidly progressive, with early onset, late diagnosis, and neglected or failed conservative treatment. The psychologic impact of idiopathic scoliosis, a chronic disease occurring in the psychologically fragile period of adolescence, is important because of its body distorting character and the onerous treatment required, either conservative or surgical. Optimal management of idiopathic scoliosis requires cooperation within a professional team which includes the entire therapeutic spectrum, extending from simple watchful observation of nonprogressive mild deformities through to early surgery for rapidly deteriorating curvature. Probably most demanding is adequate management with regard to the individual course of the disease in a given patient, while avoiding overtreatment or undertreatment.

Keywords: management, idiopathic scoliosis, adolescence

Detection and screening of idiopathic scoliosis

In patients with idiopathic scoliosis, skeletal deformity results in visible external abnormalities, including lateral deviation of the spinous processes, asymmetry of the shoulders, scapulae, waistline, and/or hips, lateral imbalance of the trunk, humps in the rib cage or lumbar region, and disturbances in physiologic kyphosis and lordosis.[1,2] These signs are very likely to go unnoticed at the early stage of idiopathic scoliosis[3–5] (Figure 1).

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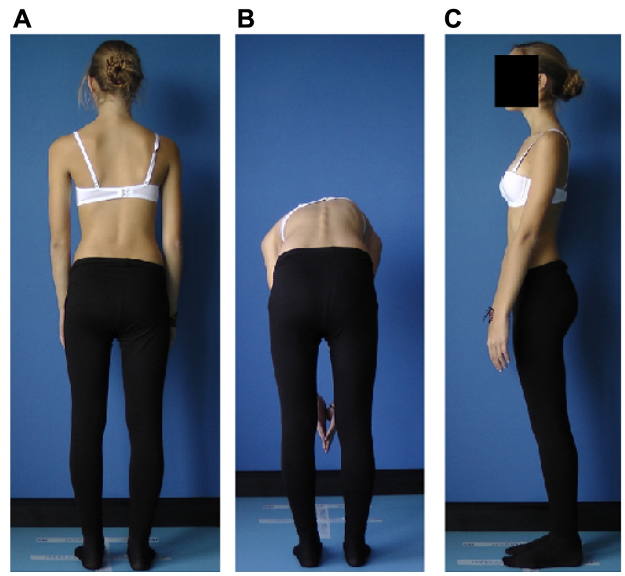

Figure 1 Clinical signs of idiopathic scoliosis. (**A**) Trunk asymmetry and lateral deviation of the spine in the frontal plane, (**B**) trunk rotation in the horizontal plane, and (**C**) disturbances in physiological curvature in the sagittal plane (kyphosis flattening).

School-based screening for scoliosis is performed primarily for the purpose of early detection of spinal deformity, which enables implementation of early conservative treatment that can reduce the risk of curve progression.[3,6–14] The screening test should have high sensitivity and specificity, although it is not intended to be diagnostic.[15,16] Suspicion of idiopathic scoliosis in adolescence is based on detection of three-dimensional deformity of the spine and trunk occurring for unknown reasons in a healthy adolescent between the age of 10 years and skeletal maturity.[1,12] Confirmation of the diagnosis is based on radiographic examination of the spine revealing its deformity, where the magnitude of curvature in the frontal plane has a Cobb angle greater than 10°. Although X-ray is the gold standard for diagnosis of idiopathic scoliosis, it is not used as a screening method because of the risks associated with radiation exposure.[1,2]

Prediction of the course of infantile scoliosis is done based on Mehta's rib-vertebra relationship as studied on the anteroposterior radiogram.[17] Increased downward obliquity of the ribs on the convex side, an apical rib shadow overlapping the corresponding vertebral body, or a rib-vertebra angle difference of ≥20° indicate progressive scoliosis.[17,18] Recent studies have shown that measurement of the rib-vertebra angle difference can also be used as a prognostic factor in juvenile scoliosis.[18,19] Magnetic resonance imaging is indicated in the presence of unusual findings (eg, an uncommon curvature pattern, pain, trunk stiffness) to search for other conditions, such as spondylolisthesis, tumors, tethered spinal cord, or syringomyelia.[1] Generally, idiopathic scoliosis is not associated with neurologic deficits nor pain.

To be effective, a scoliosis screening program should meet the following requirements: it should rely on noninvasive tests that can detect early changes; be acceptable to the population; be simple, rapid, and inexpensive to perform; and the cost of case finding should be economically balanced in relation to total medical care expenditure. Moreover, it requires evidence of effective intervention and availability of facilities for diagnosis and treatment.[15,16]

Several techniques have been developed for early detection of scoliosis. Basic visual postural assessment can be performed in 30 seconds.[5,20] This is based on inspection of the trunk from the front, side, and back while the child is standing in a natural position and in the forward-bending position (Adams test) in order to identify the presence of a rib hump.[5,20] According to the World Health Organization, two factors contribute to the reliability of a screening test, ie, variation of the method and variation of the observer.[15] Accuracy of visual assessment depends on the experience and skills of the screener.[21] Côté et al[22] reported that the Adams forward-bending test is 92% sensitive and 60% specific in detection of thoracic curves with a Cobb angle ≥20°. For detection of lumbar curves, the Adams test is 73% sensitive and 68% specific. Côté et al also reported an interexaminer reliability coefficient of 0.61 for detection of thoracic rotational prominence and 0.29 for lumbar prominence.

The Bunnell scoliometer, a specially designed inclinometer, was introduced in 1984 to limit the subjectivity of the forward-bending test.[23] It is used for fast and easy quantitative determination of the degree of trunk rotation.[3,6,23] The angle of trunk rotation should be measured at three levels of the spine, ie, proximal thoracic, main thoracic, and thoracolumbar or lumbar.[23] Measurement of the angle of trunk rotation by scoliometer is reported to have interobserver and intraobserver reliability of ±2.0° to ±4.0°.[24,25]

In response to criticism by the US Preventive Services Task Force, Bunnell went to a minimum 7° angle of trunk rotation as a criterion for referral, from a previously recommended angle of 5°, to decrease the number of false positives.[23,26] This increased criterion results in a referral rate of about 3%, corresponding to the prevalence of scoliosis in the general population.[1,26–32] According to Bunnell, 95% of curvatures ≥30° would be detected, while 12% of 20° curvatures would be missed. However, it is also recommended that children with a lower degree of trunk deformity (4°–6° trunk rotation), which can indicate the presence of mild scoliosis, should be rescreened in 4–12 months.[23,24] Ashworth et al[33] report that the cutoff value for an angle of trunk rotation ≥7° is characterized by high sensitivity (83.3%) and high specificity (86.8%). Rotational deformity of the thorax can also be measured using other devices, eg, a spirit level or ruler,[23] the spinal rotation meter introduced by Pruijs,[24,34] or a regular smartphone with an acrylic sleeve.[35]

Axial rotation of the vertebrae is only one aspect of the three-dimensional nature of scoliotic deformity. Amendt et al[36] correlated two radiographic parameters, ie, pedicle rotation and Cobb angle, and obtained coefficients ranging from 0.48 to 0.70. These investigators also assessed agreement between the angle of trunk rotation on the scoliometer and radiographic pedicle rotation measurements, and found a poor correlation of 0.32–0.46.[36] The relationship between spinal curvature (radiographic Cobb angle) and the surface (angle of trunk rotation) shows a significant correlation of 0.46–0.89, but the standard deviation is high.[3,23,30,36] Bunnell[23] states that it is not possible to predict the degree of curvature from surface topography reliably in any given patient or by any given technique. Visible surface asymmetry involves many structures, including the spine, rib cage, muscles, viscera, fat, and skin, that are unique to each patient and change over time with progression of deformity. Grivas et al[37] showed that the correlation between surface and radiologic deformity is weak in younger children (aged 7–13 years) but becomes stronger in older children (aged 14–18 years).

Surface topography is another method which is popular for both screening and follow-up.[3,38–40] Surface topography is based on evaluation of external body contour and can be performed using several techniques. Moire topography was the first photogrammetric method, introduced in 1970 by Takasaki.[41,42] Nowadays, raster stereography and light beam body scanning are the most commonly used.[39,40,43] While surface topography methods enable accurate, noninvasive, three-dimensional assessment of trunk shape, the time and expense required to perform these studies make them impractical for mass screening.[3,23,40] Surface topography equipment requires delivery, adaptation to space and access to a computer. Surface topography examination is more complex than inclinometry and requires longer training of personnel. Using surface topography, there is a need to uncover the whole surface of the back, which prolongs the preparation time and can be problematic for adolescent girls in a school environment. Further, more research on surface topography is needed because of the lack of specific referral criteria regarding parameters and cutoff values.[40]

Despite the often voiced concern about excessive costs and over-referral, screening programs have been shown to be cost-effective when screeners are well trained and appropriate referrals are made to minimize the lack of specificity.[3,6,11] It has been suggested that its effectiveness may be further improved by targeted screening of high-risk groups according to age and gender.[3,4] The ratio of girls to boys with small curves is similar, but scoliosis in girls tends to progress more often.[1,24,32] The Scoliosis Research Society, American Academy of Orthopedic Surgeons, Pediatric Orthopedic Society of North America, and American Academy of Pediatrics statements recommend that school-based programs screen girls for scoliosis twice at ages 10 and 12 years and boys once at age 13 or 14 years.[2]

Grivas et al[44] showed that geographical latitude has an influence on the prevalence of idiopathic scoliosis and age at menarche in girls. Because future growth potential and magnitude of the curve at the time of diagnosis are important determinants of progression of idiopathic scoliosis, it is considered that girls who live in countries further north than 25 degrees should be screened at an older age than those living south of this latitude.[3,44]

Suggestions for more efficient screening also consider the use of a sitting forward-bending position which provides more stable posture and shows the real trunk asymmetry, that is revealed due to leveling of the pelvis and elimination of any effect of unequal leg length on shape of the back.[3,24,45] Grivas et al[24] and Chowanska et al[46] report that the sitting position demonstrates a better surface-spinal deformity correlation than the standing position.

In order to achieve reasonable direct and indirect cost-effectiveness of screening programs, overexposure to X-rays and overtreatment must be avoided.[3] Not all children referred because of a positive screening result require radiography and treatment. Moreover, children with equivocal findings should remain under the observation of a school nurse, and only those with more severe findings should be referred to a physician.[3,5,16,23] The National Scoliosis Foundation[5,20] recommends two-stage screening to increase the efficiency and effectiveness of detection. The first stage is focused on getting the true negative cases back to their classes and the second stage concentrates on confirming the true positive cases.

Role of physiotherapy

General considerations

Physiotherapy is one of the components of conservative treatment in children with idiopathic scoliosis.[12,47,48] It can be applied in the form of exercises or sometimes as physical therapy involving electrostimulation of the paravertebral muscles.[12,47,48] Opinions as to the efficacy of physiotherapy for idiopathic scoliosis differ.[48–50] On the one hand, there is a lack of adequate scientific data confirming the effectiveness of physiotherapy in reducing the risk of progression of scoliosis;[48,49] on the other, a number of publications indicate the positive influence of exercises on the course of scoliosis.[12,48,49,50] Unfortunately, the majority of reviews show that the studies reported have an insufficient level of evidence,[48–50] and the objective difficulties in organizing and conducting studies to obtain appropriate scientific evidence need to be borne in mind.[48,50]

Exercises for idiopathic scoliosis are based on various strategies of therapeutic management, and differ in terms of methodologic assumptions, duration of performance, the number of days a week they are done, and the way they are performed, ie, with a physiotherapist or individually.[12,51–58]

Specific physiotherapeutic exercises

To systematize exercises for idiopathic scoliosis, the Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) drew up a consensus document on physiotherapeutic management.[12] The term "specific physiotherapeutic exercises" was defined according to evidence-based medicine guidelines. In order to recognize a particular physiotherapeutic method as being specific for idiopathic scoliosis, it has to demonstrate usefulness in treating children, adolescents, and adults with the condition, ie, an influence on the curvature angle, improvement in cardiorespiratory parameters, reduction or abolition of pain, and improvement in body esthetics and quality of life.[12,47] Moreover, each method should comprise: three-dimensional correction of deformity with the focus on restoration of spinal curvature in the sagittal plane; stabilization of actively corrected body posture; and training of adolescents in how to maintain the corrected body posture while performing activities of daily living.[12,47]

Education of children and parents involves explanation of the nature of the disease, together with its possible course and potential consequences, realistic therapeutic objectives, rules while performing physical (including home-based) exercises, and cooperation with the physiotherapist and physician supervising the treatment.

Specific physiotherapeutic exercises should be conducted by a trained and certified physiotherapist operating within a therapeutic team including a psychologist, orthotist, orthopedist, and a medical rehabilitation specialist. Cooperation with a school nurse, physical education teacher, and corrective gymnastics instructor is also needed. Specific physiotherapeutic exercise has to be adapted to the individual curvature pattern of the child and the treatment phase. Individually tailored therapy should be revised regularly and systematically. Objective documentation and verification of the results are crucial.[12,47,59] There are several methods that can be used for specific physiotherapeutic exercises which meet the abovementioned criteria,[12,60] ie, the Barcelona School,[61] DoboMed,[62] Functional Individual Therapy for Scoliosis,[13] Lyon,[63] Schroth,[64] Scientific Exercises Approach To Scoliosis,[65] and Side Shift[66] techniques.

Patients should meet with the physiotherapist on 2–4 occasions each month, with exercises completed at home on an outpatient basis. The nearest medical center leading in a given method is usually consulted every 3–4 months to verify the quality of exercises and set new therapeutic objectives.[12,47]

It is worth emphasizing that specific physiotherapy can be helpful in supporting brace treatment and preparing the child for surgery.[12,47,67] Physiotherapy can be modified and adapted to specific objectives, including: preparation for brace treatment by increasing spinal mobility and mobilizing soft tissues;[12,52] increasing stability of the corrected body posture to reduce loss of correction after completion of brace treatment;[12,68,78] increasing patient compliance with brace treatment;[69] and reducing the pain and functional limitations associated with surgical fusion of the spine.[70] Because idiopathic scoliosis is associated with various respiratory and physical capacity impairments,[71–74] physiotherapy plays a vital role in improving cardiovascular parameters via symmetrical and asymmetrical breathing exercises.[12,75–77]

Another physiotherapeutic technique, ie, inpatient rehabilitation, is practiced in selected European countries on an inpatient basis. It is started at the beginning of treatment to help educate the child and parents, usually lasts 3–4 weeks, and can be repeated at 6–12-month intervals. It is essential to supplement specific inpatient rehabilitation with outpatient therapy.[12,47] Its effectiveness depends on the child's willingness to cooperate and parental involvement, as well as on the model of physiotherapeutic management selected.[12,47]

Effectiveness of physiotherapy

Studies of the usefulness of exercises[48,50] indicate potential advantages resulting from therapy, including: reduction in Cobb angle,[51,52,55,78,79] reduction in risk of progression in comparison with the natural history of idiopathic scoliosis,[54,64,80] improvement in clinical parameters, ie, lateral deviation, surface rotation,[81] and angle of trunk rotation,[55,72] improved body esthetics,[55] fewer patients requiring brace treatment,[55,78] and fewer patients requiring surgical treatment.[82]

Mordecai and Dabke[48] analyzed 155 publications on the effectiveness of exercise. Only 12 of these papers met their inclusion criteria, ie, treatment involving only exercise, at least level IV evidence,[48,83] at least one month of follow-up, and a minimum of one defined outcome measure. Nine of the 12 papers were identified as prospective cohort studies, of which three were controlled and only one had observer blinding. The authors indicated that the inclusion criteria, recommendations, and contraindications to exercise were not clearly determined in any of these papers. Cobb angle was the basic parameter taken into consideration,[51,52,66,78,82,84] and any changes in its magnitude were usually statistically significant. However, the size of these changes was small,[85,86] often within the range of measurement error for Cobb angle (1.7°–6.5°). Negrini et al[78] found that the Cobb angle decreased by 0.67° in 35 patients treated with Scientific Exercises Approach To Scoliosis physiotherapy, in contrast with an increase of 1.38° in the group treated with nonspecific physiotherapy. Otman et al[51] observed a reduction in mean Cobb angle from 26.1° to 17.8° in a group of 50 patients performing exercises five days a week, four hours a day, for six weeks under therapist supervision and followed with exercises performed at home for a year. Weiss et al[84] noted an increase in mean Cobb angle from 27° to 29° after 33 months in 181 patients treated with the Schroth method. An increase in Cobb angle of ≥6° was observed in 25% of patients and a decrease of ≥6° in 18% of patients. The authors concluded that there was a positive outcome when compared with the natural history of scoliosis, which has a natural progression rate of 62%.

Scoliosis and sport

Physiotherapy for scoliosis encompassing sporting activity has a significant influence on enhancing physical fitness, increasing body awareness, and improving self-esteem and quality of life.[12,76,77,87] Children with idiopathic scoliosis may participate actively in physical education classes. After surgical treatment, a gradual return to sport activity takes up to one year with possible exclusion of sports requiring full flexibility of the spine. The patients return to noncontact sports six months after surgery, while contact sports are usually allowed one year after surgery.[88]

Conservative treatment with corrective bracing

The aims of conservative treatment of idiopathic scoliosis according to the SOSORT 2011 consensus document are to stop curve progression, to prevent respiratory dysfunction, to prevent or treat back pain, and to improve esthetics.[12]

Indication for bracing

Brace treatment is recommended for skeletally immature adolescents with idiopathic scoliosis and a Cobb angle of 25°–40°. Nevertheless, each clinical situation should be evaluated, and for each patient, a maximum and minimum treatment can be assessed according to the practical approach recommended in the 2011 SOSORT consensus document (Table 1).[12] Therapeutic decisions beyond the maximum or minimum indicate overtreatment (too much burden on the patient) or undertreatment (not enough efficacy), respectively.[12]

When using the practical approach, it is helpful to consider prognostic factors in order to chose an optimal option between maximum and minimum treatment.[12] Bunnell reported that the risk of progression at the onset of puberty is 20% in 10° scoliosis and 90% in 30° scoliosis, and decreases during the final stage of puberty to 2% in 10° scoliosis, 20% in 20° scoliosis, and 30% in 30° scoliosis.[89] The prognostic formula proposed by Lonstein and Carlson takes into account chronological age, Cobb angle, and the Risser sign.[90] The following factors have been suggested as possible determinants of an increased risk for progression of scoliosis: positive family history, laxity of skin and joints (connective tissue defect), flattening of thoracic kyphosis,[91] angle of trunk rotation exceeding 10°, and growth spurt.[89] Other factors associated with a higher risk of curve progression are trunk imbalance and a short curve. The esthetic impact is also important in making a decision about brace treatment.[12,92]

The potential genetic contribution to idiopathic scoliosis has been studied in over 60 publications, with over 30 candidate genes and 18 unique loci suggested.[93] A genetic prognostic test has recently been proposed, based on the presence of 53 single nucleotide polymorphisms.[94] Although initial results have been promising, further research seems necessary.[12] Genetic assessment of the risk of progression in young patients with newly diagnosed idiopathic scoliosis can potentially reveal cases with a poor prognosis. On the other hand, it could help in avoiding overtreatment in cases of nonprogressive scoliosis.

Main types of braces

Braces can be classified according to construction (rigid brace or soft brace), wearing time (full-time 100%, part-time 50%, night-time 30%) as well as suitability to location of the main scoliotic curvature (cervical, thoracic, lumbar, sacral).[95] The success of brace treatment in progressive idiopathic scoliosis is usually defined as the rate of patients with progression not exceeding 6° of Cobb angle.

The Cheneau brace is a rigid polyethylene orthotic device invented by Jacques Cheneau in 1972. It is a TLSO (thoraco-lumbo-sacral orthosis) type of brace designed mainly for thoracic, low thoracic, thoracolumbar, or lumbar scoliosis. Double-curve and triple-curve scoliosis can also be treated well using this brace, but not cervicothoracic scoliosis. The Cheneau brace acts by a combination of passive and active mechanisms of correction. The passive mechanisms comprise three-dimensional tissue transfer, an elongation effect, derotation of the rib cage, and bending. The active mechanisms comprise guidance of vertebral growth, asymmetrically guided respiratory movements, repositioning of the arrangement of trunk muscles, and an antigravitational effect.[96] The success of treatment (progression below 6°) is achieved in 48.1%–85.7% of patients.[97,98] Boston, Gensingen, Lapadula, Lyonese, Progressive Action Short Brace, Sforzesco, Sibilla are other examples of rigid TLSOs.[99–102]

The SpineCor is a soft brace devised in the 1990s by Rivard and Coillard. It comprises a pelvic unit and a system of elastic bands which wrap around the body in a specific pattern adapted to the curvature pattern. The idea of the SpineCor is to introduce specific corrective movement dependent on the type of the curve. It is postulated that full-time corrective movement helps to achieve neuromuscular integration and avoid loss of correction after weaning from the brace. A success rate of 59.4%–68.0% has been reported.[103–105] The TriaC, Olympe, Spinealite, and St Etienne are other examples of soft braces.[106,107]

Night-time rigid braces are being worn during sleep (6–10 hours per day). The Charleston brace is a plastic orthotic device developed by Reed and Hooper in 1978, which keeps the spine in overcorrection by application of direct, lateral, and rotational forces on the trunk to move the spine toward the midline or beyond the midline.[99,108] The success rate using this treatment is reported in the range of 12%–66%.[109,110] The Providence brace is another example of a night-time rigid brace.[99]

The Milwaukee brace is a CTLSO (cervico-thoraco-lumbo-sacral orthosis) orthotic device was constructed by Blount and Moe in 1945 and is still in use. The brace consist of a pelvic girdle and a neck ring connected with two posterior and one anterior metal rods.[99,111] It works by applying longitudinal forces completed with lateral forces. Some correction by active autoelongation is also observed. The brace can be used to correct single, double, and triple curves variously situated, including in the cervicothoracic location.[112] The results are reported to have a success rate of 52.0%–77.0% for avoiding progression of the curve.[113,114]

Table 1 Practical approach for adolescent idiopathic scoliosis according to the Society on Scoliosis Orthopaedic and Rehabilitation Treatment 2011 consensus document

	Cobb angle									
	0–10° + hump	11°–15°	16°–20°	21°–25°	26°–30°	31°–35°	36°–40°	41°–45°	46°–50°	>50°
Risser 0										
Min	Ob 6	Ob 6	Ob 3	PSE	PSE	SSB	PTRB	PTRB	PTRB	FTRB
Max	Ob 3	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
Risser 1										
Min	Ob 6	Ob 6	Ob 3	PSE	PSE	SSB	PTRB	PTRB	PTRB	FTRB
Max	Ob 3	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
Risser 2										
Min	Ob 8	Ob 6	Ob 3	PSE	PSE	SSB	SSB	SSB	SSB	FTRB
Max	Ob 6	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
Risser 3										
Min	Ob 12	Ob 6	Ob 6	Ob 6	PSE	SSB	SSB	SSB	SSB	FTRB
Max	Ob 6	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
Risser 4										
Min	No	Ob 6	Ob 6	Ob 6	Ob 6	Ob 6	Ob 6	Ob 6	SSB	FTRB
Max	Ob 12	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
Risser 4–5										
Min	No	Ob 6	Ob 6	Ob 6	Ob 6	Ob 6	Ob 6	Ob 6	SSB	FTRB
Max	Ob 12	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su

Note: Adapted from Negrini S, Aulisa AG, Aulisa L, et al. 2011 SOSORT guidelines: Orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. Scoliosis. 2012;7:3.[12]

Abbreviations: Ob, observation every 12/8/6/4 months; PSE, specific physiotherapeutic exercises; SSB, soft bracing; PTRB, part-time rigid bracing (12–20 hours); FTRB, full-time rigid bracing (20–24 hours) or cast; Su, surgery; Min, minimum; Max, maximum.

It should be emphasized that direct comparison of the reported results of treatment is difficult because of the divergent methodology used for assessment. The TLSO is more comfortable for the patient to wear and easier to hide under the clothes than the CTLSO. However, only the CTLSO can be used for high thoracic and cervicothoracic scoliosis.[99] Generally, soft braces are claimed to be more comfortable to wear than rigid braces, but a study by Wong et al [105] and our clinical experience do not confirm this suggestion.

Effectiveness of brace treatment

Evidence for the effectiveness of bracing for idiopathic scoliosis in most studies is of very low quality, and the methods used for evaluation are not consistent. Studies of brace treatment are difficult to compare, and many additional factors could have influenced on their results. It is not possible at this time to state with any certainty which brace is more effective than another.[12]

Negrini et al have published a Cochrane review on brace treatment for idiopathic scoliosis. Their criteria were randomized controlled trials and prospective cohort studies comparing braces with no treatment, other treatment, surgery, and different types of braces. They identified 1285 titles, from which 128 full texts were reviewed.[115] Only two studies met their inclusion criteria, ie, one by Wong et al in 2008[105] and the other by Nachemson et al in 1995.[116] The conclusions of the reviewers were that there is very limited quality evidence that braces are more effective than observation or electrical stimulation, and there is low-quality evidence that rigid braces are more effective than soft braces.[115]

Wong et al performed a randomized controlled trial comparing the effectiveness of treatment and patient acceptance of the SpineCor soft brace (n = 22) versus a rigid brace (n = 21) in skeletally immature patients with idiopathic scoliosis and a Cobb angle of 20°–30°. They reported a success rate of 68% for patients in the soft brace group and 95% in the rigid brace group. There was no significant difference between the groups in subjective perception of daily difficulties associated with wearing the brace.[105]

Nachemson et al performed a prospective international multicenter study in 240 girls with scoliosis of 20°–35°. In total, 111 girls were treated with a rigid brace for at least 16 hours per day, 129 were observed, and 46 underwent night-time electrical surface stimulation of paravertebral muscles. The reported success of the treatment (curve progression $<6°$) was 74% for rigid braces versus 34% for observation versus 33% for electrical stimulation.[116]

Rowe et al performed a meta-analysis comparing the success rate of different methods of treatment. The best results were achieved for braces worn for 23 hours daily. The most effective brace system was the Milwaukee brace. The Charleston brace was the least successful, but was still better than observation.[117]

Brace treatment should be performed by an experienced therapeutic team, including a physician, physiotherapist, orthotist, and psychologist. Support groups and Internet forums are helpful.[69] It is important that both the patient and the caregivers participate actively in the course of treatment. Education, psychotherapy, systematic monitoring of outcome, assessment of patient cooperation and compliance, verification and modification of methods in the course of the therapy, and proper brace fit are crucial elements of successful treatment.[69]

Place of surgery

The main goals of operative treatment for progressive idiopathic scoliosis in the adolescent age group are to halt progression of deformity, to achieve three-dimensional correction of pathologic spinal curvature, to balance the trunk, to reduce the hump, to maintain permanent correction at long-term follow-up, and finally, to perform the demanding surgical procedure in the most safe conditions for the patient.[119] However, surgery for idiopathic scoliosis does not restore the normal spine. Correction of scoliosis using spinal implants is completed systematically, with spinal fusion covering all the instrumented levels.[118] Surgery for idiopathic scoliosis is advised if the Cobb angle exceeds a threshold of 50° at completion of growth and even more when a risk of progression remains.[12,118] Loss of physiologic sagittal curvatures may be an additional argument in favor of surgery because a harmonious spinal profile is considered one of the important determinants of being free of back pain in adulthood.[118,119] The esthetic aspect is of great importance. The final decision regarding operative treatment for idiopathic scoliosis should be an intentional choice made by the patient and parents supplied with adequate information about the surgery itself and the postsurgical course. For example, limitation in sport and physical activities is related to extension of spinal fusion, but for a typical single thoracic curvature, this is barely noticeable by the patient.

The rate of surgery after brace treatment has been reported to range from 11% to 42.5%.[120,121] For children previously managed conservatively, need for surgery may be perceived as failure rather than continuation of treatment. On the other hand, many adolescents refuse conservative treatment from the outset and readily accept the surgical option. Still others will need psychologic support to accept surgery and improve motivation.

Preparing the patient for surgery requires a thorough clinical and radiologic evaluation. Measurements of Cobb angle for the major and minor curves are taken from a standing frontal long-cassette radiograph.[122,123] The tilt of the inferior limit vertebrae and of the stable vertebrae measured to the horizontal line, apical vertebra translation to the central sacral vertical line, as well as global coronal balance by relating C7 to the central sacral vertical line are assessed. Vertebral rotation is measured using the Perdriolle or Nash-Moe method.[124,125] Curve flexibility is determined on supine bending X-rays and traction film. Global sagittal balance is assessed on the lateral standing projection considering the distance from the C7 plumb line to the first sacral vertebral body, and thoracic kyphosis and lumbar lordosis are evaluated.[126]

On the basis of radiologic measurement, the curves are classified using the method described by Lenke et al.[127] The type of curve implies extent of instrumentation, ie, indicates structural curves requiring fusion, whereas nonstructural regions will not be fused.[128,129] Sparing spinal levels from surgical fusion is always one of the goals of preoperative planning, especially at the lumbar spine. The recommendations made by Lenke et al for fusion are described in Table 2.[128]

In recent years, there has been significant progress in the surgical treatment of scoliosis, in terms of progress in construction of spinal implants and instruments, and in safety of the procedures by use of blood salvage techniques and intraoperative neurophysiologic monitoring of the spinal cord.[118]

Posterior spinal instrumentation is the most widely used technique in the surgical treatment of idiopathic scoliosis (Figure 2). Milestones in this approach are represented by the techniques devised by Harrington in 1962 and Cotrel-Dubousset in 1984.[130,131] Posterior instrumentation provides good curve correction in three dimensions, reduces rib prominence, tends to reduce the number of fused vertebral levels, and avoids the need for a postoperative brace. Curve correction is achieved using screws, hooks, or wires carefully implanted in previously exposed posterior elements of the vertebrae and connected with rods and transverse devices to form a stable framework.[118] Corrective maneuvers for realignment of segmental vertebrae using a variety of techniques such as rod rotation, apex translation, distraction, and direct vertebral derotation, can be implemented.[126] Solid bony fusion is achieved by meticulous posterior decortication and bone autograft (local, iliac, or costal) or by biological bone substitutes.[118] Posterior spinal instrumentation is implanted through a vertical posterior midline skin incision.

Anterior instrumentation is an alternative to the posterior approach, using vertebral bodies to insert anchors and interbody fusion for stable correction. Anterior instrumentation is recommended mainly for single thoracolumbar and lumbar curves, providing good three-dimensional correction with a reduced number of fused levels.[118,132] Anterior spinal instrumentation is implanted through an oblique lateral skin incision on the flank, leaving no scar on the back.

A number of studies have been published comparing different variants of instrumentation. Yilmaz et al reviewed 105 patients and showed that pedicle screws and hybrid (screw and hook) instrumentation give better correction of deformity, maintain this correction in the coronal and sagittal planes, and provide better patient satisfaction compared with hook-only constructs.[126] Lilienquist et al came to similar conclusions based on an analysis of 95 patients.[133] Kim et al reported on 58 patients and noted that pedicle screw instrumentation achieved significantly improved correction of deformity and better postoperative pulmonary function than hybrid constructs. Both instrumentation methods provided similar junctional change, reduction in the number of fused levels, and decreased operative time.[134,135] Cheng et al reported that use of apical sublaminar wires and pedicle screw instrumentation provided similar correction of deformity and comparable fusion lengths without neurologic problems.[136] Cheng et al reported pedicle screws to be more expensive, but were associated with less blood loss than sublaminar wire constructs.[136] The reported disadvantages of pedicle screws are its increased cost, steep learning curve, and safety concerns.[118] Generally, it appears that any type of modern segmental spinal instrumentation offers similar correction capabilities. It seems justified to leave the choice of implant system to the surgeon who will rightly propose the system

Table 2 Treatment options implied by curve type according to the Lenke classification

Curve type	Structural regions recommended for fusion	Approach
Main thoracic	MT	PSF or ASF
Double thoracic	PT, MT	PSF
Double major	MT–TL/L	PSF
Triple major	PT, MT, TL/L	PSF
Thoracolumbar/lumbar	TL/L	ASF or PSF
Thoracolumbar/lumbar, main thoracic	TL/L, MT	PSF

Abbreviations: ASF, anterior spinal fusion; PSF, posterior spinal fusion; PT, proximal thoracic; MT, main thoracic; TL/L, thoracolumbar/lumbar.

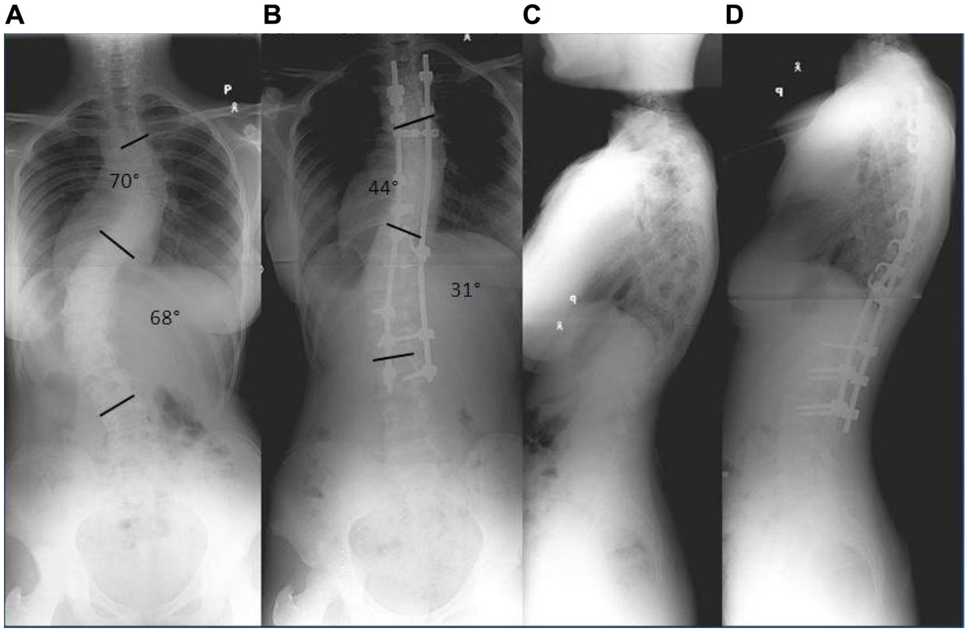

Figure 2 Surgical treatment of idiopathic scoliosis using posterior instrumentation. (**A** and **C**) Preoperative anteroposterior and lateral standing radiographs of an adolescent girl with progressive idiopathic scoliosis Lenke type 6CN. (**B** and **D**) Postoperative standing radiograph of the patient after hybrid-type posterior instrumentation. Satisfactory correction, increased trunk height, and a well balanced spine are seen in both the sagittal and coronal planes.

he or she is most familiar with. Modern instrumentation techniques no longer require postoperative cast or brace immobilization.

Rib hump is a cosmetic concern and one of the most frequent complaints reported by patients with idiopathic scoliosis. Application of new techniques and instrumentation systems has reduced the need for thoracoplasty.[137] This procedure consists of resection of the ribs on the convex side or rib osteotomies on the concave side.[138] Chen et al reported that thoracoplasty combined with posterior instrumentation resulted in a temporary decrease in vital capacity, which returned to preoperative values by one-year follow-up.[139]

Psychologic aspects

Quality of life in adolescents with idiopathic scoliosis is being increasingly recognized by physicians, physiotherapists, and other specialists, including psychologists and nurses. Analysis of the goals of treatment outlined in the SOSORT consensus document highlights the importance of patient quality of life, esthetics, psychologic well-being, and disability.[60]

The Scoliosis Research Society questionnaire, a specific health-related quality of life instrument, is used before and after corrective surgery for scoliosis. This questionnaire, introduced in 1999 as the SRS-24,[140] consists of 24 items divided into two sections, with the first section containing the domains of pain, general self-image, general function, and function-activity,[141] and the second section, appropriate only for postsurgical patients, measuring postoperative self-image, function after surgery, and satisfaction with surgery. The SRS-24 was modified to the SRS-23,[142] then to the SRS-22,[143] and finally to the SRS-22 refined (SRS-22r).[144] The aim of these modifications was to improve its psychometric properties, thereby increasing the precision by which health-related quality of life can be assessed in patients with scoliosis or related spinal deformity from the age of 10 years through to adulthood.[145] The SRS-22 has 22 items, canvassing function, pain, self-image, and mental health domains, and a subtotal score.[146] The SRS-22 is more versatile than the SRS-24 because patients with nonoperative and operative scoliosis and healthy control groups can complete all sections.[147] The original version of the SRS-22 has undergone many transcultural adaptations, including Spanish,[148,149] Japanese,[150,151] Italian,[152] Chinese,[153] Dutch,[154] Korean,[155] Turkish,[156] Polish,[157] Norwegian,[158] Swedish,[159] and French Canadian versions.[160] The SRS-22r, which is the most thoroughly validated version, has been translated into Greek,[161] Japanese,[162] Persian,[163] Brazilian,[164] Spanish,[165] Italian,[166] and Swedish.[145] Ranging from two to seven questions in each domain of the SRS-24, in the SRS-22r there are five each in the function, pain, self-image, and mental-health domains, and two questions about satisfaction/dissatisfaction with management. The number of responses possible for each question has been standardized to five. Scores vary from 1 to 5, with 5 being the best health condition. The maximum score for a five-question domain is 25, and the minimum is 5. For a two-question domain, the totals are 10 and 2, respectively.[146]

Studies comparing adolescents with idiopathic scoliosis and healthy controls have shown that the SRS patient questionnaires are able to discriminate between patients from healthy controls,[140,150] varying curvature severity,[140,151] and satisfaction levels in patients who are treated surgically.[146] In the past few years, an increasing number of questionnaires assessing quality of life in nonsurgically treated patients have been devised, including the Scoliosis Quality of Life Index,[167] a simplified version of the SRS-22 known as the Quality of Life Profile for Spinal Deformities,[168] the Pediatric Outcomes Data Collection Instrument,[168] the Child Health Questionnaire,[169] the Berner Questionnaire for Well Being,[170] and the Brace Questionnaire.[171]

The Brace Questionnaire is an instrument for measuring quality of life in adolescents with scoliosis who are being treated conservatively with a corrective brace. The Brace Questionnaire consists of 34 Likert-scale items associated with eight domains, ie, general health perception, physical functioning, emotional functioning, self-esteem and aesthetics, vitality, school activity, bodily pain, and social functioning. This questionnaire is designed to be self-administered and to be developmentally appropriate for patients aged 9–18 years. The minimum score on this questionnaire is 20 and the maximum is 100. Higher scores indicate better quality of life. A subscale score can be calculated for each of the eight domains by dividing the total score of each dimension by the number of its items.[171] The Brace Questionnaire has recently been validated in Polish.[172]

Two questionnaires can estimate the stress induced by deformity, ie, the Bad Sobernheim Stress Questionnaire-Deformity, and that induced by treatment with a brace, ie, the Bad Sobernheim Stress Questionnaire-Brace.[173]

The Trunk Appearance Perception Scale and Spinal Appearance Questionnaire were created to assess the self-image of patients with scoliosis.[174,175] The Spinal Appearance Questionnaire was designed to measure patient perception of several aspects of the appearance a spinal deformity.[174]

Studies comparing assessment by adolescents with those by their parents[176] reported that parents gave better scores than those given by the adolescents themselves.[177] Further studies investigating reliability and validity with regard to transcultural adaptations of these questionnaires for patients not treated with surgery and differences in quality of life according to gender are needed. Further research is also needed with larger sample sizes, taking into account gender and control groups. Psychologic aspects of care in adolescents with idiopathic scoliosis cannot be overestimated.

Summary

Idiopathic scoliosis has traditionally been considered to be a dangerous and life-threatening condition. It is no more, at least in developed countries, considering the whole therapeutic spectrum available. Most of the cases that are detected early appear to be benign, moderate cases benefit from conservative management, and severe cases can be treated successfully with surgery.

Medicine is increasingly turning towards prevention rather than treatment of disease. In the absence of ability to prevent occurrence of scoliosis, the focus should be on early detection to prevent possible progression.[3,6] For Bunnell, scoliosis screening is "vitally important, but we don't want to screen out a whole bunch of people who don't need medical attention because it's very costly. We're not looking for the cheapest way to screen – we're looking for a better quality outcome for our patients".[3]

Optimal management of idiopathic scoliosis requires that the professional team covers the whole therapeutic spectrum, extending from simple watchful observation for mild nonprogressive deformities, using all nonsurgical options for moderate cases, through to early surgery for dangerous, rapidly progressive curvatures. Adequate management tailored to the individual course of the disease in a given patient is probably the most demanding aspect of the management of adolescents with idiopathic scoliosis.

Disclosure

The authors report no conflicts of interest in this work.

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