

Adolescent Idiopathic Scoliosis: Review and Current Concepts

BRIAN V. REAMY, LT COL, USAF, MC, Malcolm Grow Medical Center, Andrews Air Force Base, Maryland
JOSEPH B. SLAKEY, CDR, MC, USNR, Naval Medical Center, Portsmouth, Virginia

Adolescent idiopathic scoliosis is present in 2 to 4 percent of children between 10 and 16 years of age. It is defined as a lateral curvature of the spine greater than 10 degrees accompanied by vertebral rotation. It is thought to be a multigene dominant condition with variable phenotypic expression. Scoliosis can be identified by the Adam's forward bend test during physical examination. Severe pain, a left thoracic curve or an abnormal neurologic examination are red flags that point to a secondary cause for spinal deformity. Specialty consultation and magnetic resonance imaging are needed if red flags are present. Of adolescents diagnosed with scoliosis, only 10 percent have curves that progress and require medical intervention. The main risk factors for curve progression are a large curve magnitude, skeletal immaturity and female gender. The likelihood of curve progression can be estimated by measuring the curve magnitude using the Cobb method on radiographs and by assessing skeletal growth potential using Tanner staging and Risser grading. (Am Fam Physician 2001;64:111-6.)

Recent research has led to a better understanding of the natural history of scoliosis. However, the optimal strategy for screening, diagnosing and treating this common spinal deformity remains controversial. Of adolescents diagnosed with scoliosis, only 10 percent have curve progression requiring medical intervention.¹ The ability to estimate which curves require therapy has led to more appropriate treatment with observation, bracing or surgery.

Family physicians need to differentiate patients with stable or minimally progressive scoliosis who can be observed from patients with scoliosis that is at high risk for progression. They need to determine the patients they can follow and those who need referral to an orthopedic surgeon. Unnecessary referrals of adolescents with minimal scoliosis who are at low risk for progression can cause marked anxiety and lost time from school and work, and lead to unnecessary radiation exposure.²

Delayed referrals of patients with high-risk curves can lead to increased morbidity. In either situation, the psychological and social

effects of this disease can be profound.² This article describes an approach to diagnosing and treating scoliosis that allows physicians to lessen the adverse psychological, medical and economic effects of over-referral or delayed referral of adolescents to orthopedic subspecialists.

Classification

The Scoliosis Research Society has defined scoliosis as a lateral curvature of the spine greater than 10 degrees as measured using the Cobb method on a standing radiograph.³ Idiopathic scoliosis is a structural curve with no clear underlying cause. Secondary causes for scoliosis can usually be identified by radiography and clinical examination (*Table 1*).

Idiopathic scoliosis is classified based on the age of the patient when it is first identified. Infantile scoliosis has an onset before three years of age. The infantile form accounts for fewer than 1 percent of all cases. Juvenile scoliosis is first detected between three and 10 years of age. The juvenile form occurs in 12 to 21 percent of all patients with idiopathic scoliosis.⁴ Adolescent idiopathic scoliosis is found between age 10 and skeletal maturity.⁴ The adolescent form accounts for the majority of cases of idiopathic scoliosis.

See editorial on page 32.

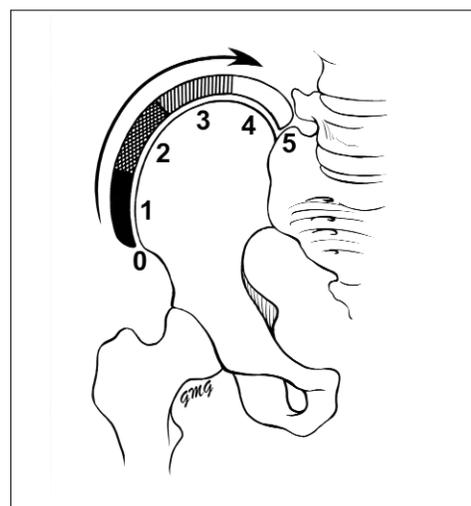
Of adolescents diagnosed with scoliosis, only 10 percent have curve progression requiring medical intervention.

Prevalence

Scoliosis is present in 2 to 4 percent of children between 10 and 16 years of age.⁵ The ratio of girls to boys with small curves of 10 degrees is equal but increases to a ratio of 10 girls for every one boy with curves greater than 30 degrees.⁵ Scoliosis in girls tends to progress more often and, therefore, girls more commonly need treatment than boys.⁵ The prevalence of curves greater than 30 degrees is approximately 0.2 percent, and the prevalence for curves greater than 40 degrees is approximately 0.1 percent.¹ Improved understanding of the natural history and prognosis of this disease can help the physician predict the patients with scoliosis who need treatment.

Natural History/Prognosis

Once a diagnosis of scoliosis has been made, the primary concerns are whether there is an underlying cause and if the curve



ILLUSTRATIONS BY GILBERT M. GARDNER

FIGURE 1. Risser grades zero to 5. Grading is based on the degree of bony fusion of the iliac apophysis, from grade zero (no ossification) to grade 5 (complete bony fusion).

will progress. The three main determinants of progression are patient gender, future growth potential and the curve magnitude at the time of diagnosis.¹ In all cases, females have a risk of curve progression 10 times higher than males.¹ The greater the growth potential and the larger the curve, the greater the likelihood of curve progression.

Evaluation of growth potential is done by assessing the Tanner stage and the Risser grade. Tanner stage 2 to 3 occurs just after the onset of the pubertal growth spurt and is the time of maximum progression of scoliosis.⁶ The Risser grade (zero to 5) gives a useful estimate of how much skeletal growth remains by grading the progress of bony fusion of the iliac apophysis. The iliac apophysis ossifies in a predictable fashion from anterolateral to posteromedial along the iliac crest.

Risser grades are as follows: grade zero signifies no ossification, grade 1 signifies up to 25 percent ossification, grade 2 signifies 26 to 50 percent ossification, grade 3 signifies 51 to 75 percent ossification, grade 4 signifies 76 up to 100 percent ossification and grade 5 signifies complete bony fusion of the apophysis⁷ (Figure 1). In one study,⁸ the Risser grade was directly correlated with the risk of curve progression.

The magnitude of the curve is best determined by measurement of the Cobb angle, which is derived from a standard posteroanterior standing radiograph of the spine. The Cobb angle is the angle formed by a line

TABLE 1

Secondary Causes of Scoliosis

Inherited disorders of connective tissue	Neurologic disorders	Musculoskeletal
Ehlers-Danlos syndrome	Tethered cord syndrome*	Leg length discrepancy
Marfan syndrome	Syringomyelia	Developmental dysplasia of the hip
Homocystinuria	Spinal tumor	Osteogenesis imperfecta
	Neurofibromatosis	Klippel-Feil syndrome
	Muscular dystrophy	
	Cerebral palsy	
	Poliomyelitis	
	Friedreich's ataxia	
	Familial dysautonomia (Riley-Day syndrome)	
	Werdnig-Hoffmann disease	

*—A cord unable to change position in the spinal canal because of growth related to scarring, diastematomyelia or other etiology.



FIGURE 2. The Cobb method of measuring the degree of scoliosis. The physician chooses the most tilted vertebrae above and below the apex of the curve. The angle between intersecting lines drawn perpendicular to the top of the superior vertebrae and the bottom of the inferior vertebrae is the Cobb angle (here, 62 degrees).

drawn perpendicular to the top of the superior vertebrae of the scoliotic curve and a similar perpendicular line drawn along the bottom of the inferior vertebrae (Figure 2).

The risk of curve progression can be estimated by taking into account the patient's sex, time of menarche and growth potential (Tanner stage and Risser grade), and the magnitude of the curve. This is key information to help with decisions about the need for referral to an orthopedic surgeon and, in those who are not referred, about examination frequency for curves at lower risk of progression. It is important to remember that this information does not conclusively determine whether a specific curve will

TABLE 2
Risk of Curve Progression

Curve (degree)	Growth potential (Risser grade)	Risk*
10 to 19	Limited (2 to 4)	Low
10 to 19	High (0 to 1)	Moderate
20 to 29	Limited (2 to 4)	Low/moderate
20 to 29	High (0 to 1)	High
>29	Limited (2 to 4)	High
>29	High (0 to 1)	Very high

*—Low risk = 5 to 15 percent; moderate risk = 15 to 40 percent; high risk = 40 to 70 percent; very high risk = 70 to 90 percent.

Information from references 5 and 8 through 11.

progress, only the general risk of a curve progressing. Table 2 summarizes the results of multiple studies done to assist in predicting the risk of curve progression in adolescents; the table can also assist in patient counseling.^{5,8-11}

The risk that an untreated adolescent with scoliosis will have a curve progress into adulthood has been determined. Curves less than 30 degrees at bone maturity are unlikely to progress, whereas curves measuring from 30 to 50 degrees progress an average of 10 to 15 degrees over a lifetime. Curves greater than 50 degrees at maturity progress steadily at a rate of 1 degree per year.¹ In most patients, life-threatening effects on pulmonary function do not occur until the scoliotic curve is 100 degrees or greater.¹

Of equal significance is the fact that significant psychological illness has been found in up to 19 percent of females who have curves greater than 40 degrees as adults.² Social isolation, limited job opportunities and lower marriage rates are possible consequences.

Pathophysiology

Many studies have attempted to uncover the pathophysiologic process underlying idiopathic scoliosis. Multiple abnormalities have been found, yet none has been conclusively linked to all cases.

Studies of twins¹² have given the firmest indication that the most significant factor is genetic. Indeed, a recent meta-analysis¹³ showed that not only is the risk for scoliosis

Unnecessary referrals of adolescents who have minimal scoliosis and are at low risk for progression can cause marked anxiety and lost time from school or work, and lead to unnecessary radiation exposure.

greater in monozygotic twins than in dizygotic twins, the rate of curve progression is nearly identical among twins subjected to a variety of environmental influences. Current theorists believe that scoliosis is a multigenic dominant condition with variable phenotypic expression.⁵ Therefore, even though scoliosis is typically present in most members of the same family, its severity can vary widely from parent to child and sibling to sibling. When both parents have scoliosis, the risk that their children will require treatment is 50 times that in the general population.⁷

Screening

Screening for scoliosis was common in schools and communities in past years. Over-referral of adolescents with insignificant curves led to a marked decrease in many such programs. Recent studies have demonstrated that over-referral is common even when mul-

iple diagnostic modalities are used.^{14,15} The American Academy of Orthopedic Surgeons recommends screening girls at ages 11 and 13, and screening boys once at age 13 or 14 years of age. The American Academy of Pediatrics has recommended scoliosis screening with the Adam's forward bending test at routine health visits at 10, 12, 14 and 16 years of age, although evidence does not exist to support these recommendations.²

In 1996, the U.S. Preventive Services Task Force released its opinion on screening for adolescent idiopathic scoliosis. The Task Force noted that "there is insufficient evidence for or against routine screening of asymptomatic adolescents for idiopathic scoliosis. Clinicians should remain alert for large spinal curvatures when examining adolescents."²

HISTORY AND PHYSICAL EXAMINATION

Adolescent idiopathic scoliosis is primarily a diagnosis of exclusion. The history and physical examination are intended to exclude secondary causes for the spinal deformity. The patient should be asked about a family history of scoliosis, menstrual onset, and the presence of pain and neurologic changes, including bowel and bladder dysfunction. The presence of severe pain or neurologic symptoms would be atypical for idiopathic scoliosis.

The physical examination should include an assessment of Tanner stage and a complete neurologic examination. Peak curve progression occurs during Tanner stage 2 or 3. Any abnormal neurologic findings should raise concern for spinal cord pathology. Although there is no ideal screening test, the Adam's forward bend test requires no additional equipment (such as a scoliometer or humpometer) and can help to identify scoliosis.⁵ The child bends forward at the waist until the spine becomes parallel to the horizontal plane, while holding palms together with arms extended. The examiner looks along the horizontal plane of the spine from the back and side to detect an asymmetry in the contour of the back known as a "rib hump" (Figure 3). A rib

The Authors

BRIAN V. REAMY, LT COL, USAF, MC, is assistant professor of family medicine at the Uniformed Services University of the Health Sciences F. Edward Hébert School of Medicine, Bethesda, Md., and residency director of the Malcolm Grow Medical Center Family Practice program at Andrews Air Force Base, Md. He received his medical degree from Georgetown University School of Medicine, Washington, D.C., served a residency in family practice at David Grant USAF Medical Center, Calif., and completed a fellowship in faculty development at the University of California, San Francisco, School of Medicine.

JOSEPH B. SLAKEY, CDR, MC, USNR, is vice-chair of the orthopedic surgery department and director of pediatric orthopedics at Naval Medical Center, Portsmouth, Va. He received his medical degree from Georgetown University School of Medicine, served a residency in orthopedic surgery at Naval Medical Center—San Diego and completed a fellowship in pediatric orthopedics at Connecticut Children's Medical Center in Hartford, Conn.

Address correspondence to Brian V. Reamy, LT COL, USAF, MC, 89th Medical Operations Squadron, 1075 West Perimeter Rd., Andrews AFB, MD 20762. Reprints are not available from the authors.

hump is a hallmark of scoliotic curves greater than 10 degrees and should prompt radiographic evaluation.

The direction of curves in adolescent idiopathic scoliosis is remarkably consistent. Ninety percent of thoracic curves are to the right.¹⁶ Therefore, left thoracic curves should raise a red flag and prompt more extensive evaluation.

Additional red flags include markedly painful scoliosis, untoward stiffness, deviation to one side during the forward bend test, sudden rapid progression in a previously stable curve, extensive progression in a patient after skeletal maturity, abnormal neurologic findings and the stigmata of other clinical syndromes associated with spinal curvature.^{5,16,17}

Radiography and Additional Tests

Abnormalities on physical examination require radiographic evaluation with a single standing posteroanterior radiograph to allow measurement of the curve using the Cobb method and Risser grading of the iliac apophysis. Magnetic resonance imaging is indicated whenever there is a left thoracic curve, unusual pain or abnormalities on neurologic examination, or other red flags, to evaluate for spondylolisthesis, tumors or syringomyelia.¹⁸

Referral Guidelines and Treatment

Treatment options for patients with scoliosis range from the unproven or harmful to the beneficial. Physical therapy, chiropractic care, biofeedback and electric stimulation have not been shown to alter the natural history of scoliosis.^{2,7,12} In contrast, bracing and spinal surgery have been proved to alter the natural history of curve progression. Bracing techniques have also improved markedly; braces are more comfortable and better tolerated than in the past, when studies had shown that adolescents wore their braces only 65 percent of the time they were intended to use them.¹⁹

In addition, most modern braces are of the underarm thoracolumbar-sacral orthosis

The Scoliosis Research Society has defined scoliosis as a lateral curvature of the spine greater than 10 degrees as measured using the Cobb method on a standing radiograph.

type, which can be worn under the clothing. A recent study showed that bracing had a 74 percent success rate at halting curve progression.²⁰ It is important to counsel adolescents and their parents that bracing does not correct scoliosis but may prevent significant progression of the spinal curvature. Orthosis use is usually continued until the patient reaches Risser grade 4 or 5.⁵

Spinal surgery with instrumentation corrects a significant part of the deformity and hopefully stops further progression of the scoliotic curve. Current consensus is that surgery should be performed for curves greater than 40 to 45 degrees when there is growth remaining.^{5,21} Many implants are available to provide excellent stability and strong corrective forces to the spinal column.²² Modern surgery is accompanied by spinal cord monitoring using somatosensory and motor-evoked potentials,

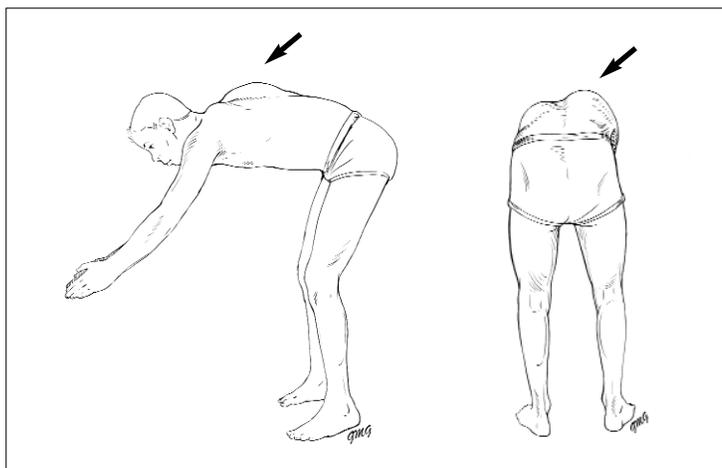


FIGURE 3. Adam's forward bend test. (Left) As the patient bends over, the examiner looks from behind and from the side, horizontally along the contour of the back. (Right) A rotational deformity known as a rib hump (arrow) can be easily identified.

TABLE 3
Treatment and Referral Guidelines for Patients with Scoliosis

Curve (degrees)	Risser grade	X-ray/refer	Treatment
10 to 19	0 to 1	Every 6 months/no	Observe
10 to 19	2 to 4	Every 6 months/no	Observe
20 to 29	0 to 1	Every 6 months/yes	Brace after 25 degrees
20 to 29	2 to 4	Every 6 months/yes	Observe or brace*
29 to 40	0 to 1	Refer	Brace
29 to 40	2 to 4	Refer	Brace
>40	0 to 4	Refer	Surgery†

*— If the patient is Risser grade 4, probably only observation is warranted.

†— If the patient is Risser grade 4, surgery can be delayed.

Information from references 5, 7, 8, 10, 11, 20 and 21.

thereby decreasing the rate of neurologic injury to one in 7,000 procedures.⁵

Adolescent scoliosis can be followed by the family physician if the curve has a low risk of progression and an underlying cause has been excluded. Curves that demonstrate progression in patients with continued growth remaining and curves with a high risk of progression should be referred to an orthopedic subspecialist. Referral is always indicated when red flags are present on physical or radiographic examination. Recommendations for radiograph frequency, treatment and referral are summarized in *Table 3*.^{3,7,8,10,11,20,21}

The opinions and assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the U.S. Air Force or U.S. Navy medical departments or the Air Force or Navy at large.

Figures 1 and 3 were provided by Gilbert M. Gardner, M.A., Medical Visual Information department, David Grant USAF Medical Center, Calif.

The authors indicate that they do not have any conflicts of interest. Sources of funding: none reported.

REFERENCES

1. Miller NH. Cause and natural history of adolescent idiopathic scoliosis. *Orthop Clin North Am* 1999; 30:343-52.

2. Screening for adolescent idiopathic scoliosis. Policy statement. US Preventive Services Task Force. *JAMA* 1993;269:2664-6.
3. Kane WJ. Scoliosis prevalence: a call for a statement of terms. *Clin Orthop* 1997;126:43-6.
4. Dobbs MB, Weinstein SL. Infantile and juvenile scoliosis. *Orthop Clin North Am* 1999;30:331-41.
5. Roach JW. Adolescent idiopathic scoliosis. *Orthop Clin North Am* 1999;30:353-65.
6. Renshaw TS. Idiopathic scoliosis in children. *Curr Opin Pediatr* 1993;5:407-12.
7. Lonstein JE. Adolescent idiopathic scoliosis. *Lancet* 1994;344:1407-12.
8. Lonstein JE, Carlson JM. The prediction of curve progression in untreated idiopathic scoliosis during growth. *J Bone Joint Surg [Am]* 1984;66:1061-71.
9. Lonstein JE. Natural history and school screening for scoliosis. *Orthop Clin North Am* 1988;19:227-37.
10. Bunnell WP. The natural history of idiopathic scoliosis. *Clin Orthop* 1988;229:20-5.
11. Little DG, Song KM, Katz D, Herring JA. Relationship of peak height velocity to other maturity indicators in idiopathic scoliosis in girls. *J Bone Joint Surg [Am]* 2000;82:685-93.
12. Skaggs DL, Bassett GS. Adolescent idiopathic scoliosis: an update. *Am Fam Physician* 1996;53:2327-35.
13. Kesling KL, Reinker KA. Scoliosis in twins. A meta-analysis of the literature and report of six cases. *Spine* 1997;22:2009-14.
14. Yawn BP, Yawn RA, Hodge D, Kurland M, Shaughnessy WJ, Ilstrup D, et al. A population-based study of school scoliosis screening. *JAMA* 1999;282:1427-32.
15. Karachalios T, Sofianos J, Roidis N, Sapkas G, Korres D, Nikolopoulos K. Ten-year follow-up evaluation of a school screening program for scoliosis. Is the forward-bending test an accurate diagnostic criterion for the screening of scoliosis? *Spine* 1999;24:2318-24.
16. Rinsky RA, Gamble JG. Adolescent idiopathic scoliosis. *West J Med* 1988;148:182-91.
17. Sarwark JF, Kramer A. Pediatric spinal deformity. *Curr Opin Pediatr* 1998;10(1):82-6.
18. Oestreich AE, Young LW, Young Poussaint T. Scoliosis circa 2000: radiologic imaging perspective. I. Diagnosis and pretreatment evaluation. *Skeletal Radiol* 1998;27:591-605.
19. DiRaimondo CV, Green NE. Brace-wear compliance in patients with adolescent idiopathic scoliosis. *J Pediatr Orthop* 1988;8:143-6.
20. Nachemson AL, Peterson LE. Effectiveness of treatment with a brace in girls who have adolescent idiopathic scoliosis. A prospective, controlled study based on data from the Brace Study of the Scoliosis Research Society. *J Bone Joint Surg [Am]* 1995; 77:815-22.
21. Pinto WC, Avanzi O, Dezen E. Common sense in the management of adolescent idiopathic scoliosis. *Orthop Clin North Am* 1994;25:215-23.
22. Bridwell KH. Spinal instrumentation in the management of adolescent idiopathic scoliosis. *Clin Orthop* 1997;335:64-72.