

**American College of Radiology
ACR Appropriateness Criteria®
Scoliosis-Child**

Variant 1: Child. Congenital scoliosis. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography complete spine	Usually Appropriate	☼☼☼
MRI complete spine without IV contrast	Usually Appropriate	O
CT spine area of interest without IV contrast	May Be Appropriate (Disagreement)	Varies
MRI complete spine without and with IV contrast	Usually Not Appropriate	O
CT spine area of interest with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without and with IV contrast	Usually Not Appropriate	Varies
Tc-99m bone scan complete spine	Usually Not Appropriate	☼☼☼☼

Variant 2: Child (0 to 9 years of age). Early onset idiopathic scoliosis. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography complete spine	Usually Appropriate	☼☼☼
MRI complete spine without IV contrast	Usually Appropriate	O
MRI complete spine without and with IV contrast	Usually Not Appropriate	O
CT spine area of interest with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without and with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without IV contrast	Usually Not Appropriate	Varies
Tc-99m bone scan complete spine	Usually Not Appropriate	☼☼☼☼

Variant 3: Adolescent (10 to 18 years of age). Adolescent idiopathic scoliosis. No risk factors. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography complete spine	Usually Appropriate	☼☼☼
MRI complete spine without IV contrast	Usually Not Appropriate	O
CT spine area of interest with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without and with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without IV contrast	Usually Not Appropriate	Varies
MRI complete spine without and with IV contrast	Usually Not Appropriate	O
Tc-99m bone scan complete spine	Usually Not Appropriate	☼☼☼☼

Variant 4:**Adolescent (10 to 18 years of age). Adolescent idiopathic scoliosis. Risk factors. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography complete spine	Usually Appropriate	☼☼☼
MRI complete spine without IV contrast	Usually Appropriate	0
MRI complete spine without and with IV contrast	Usually Not Appropriate	0
CT spine area of interest with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without and with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without IV contrast	Usually Not Appropriate	Varies
Tc-99m bone scan complete spine	Usually Not Appropriate	☼☼☼☼

SCOLIOSIS—CHILD

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Summary of Literature Review

Introduction/Background

Scoliosis is an abnormal 3-D curvature of the spine, conventionally defined as a lateral curvature of more than 10° on a standing posteroanterior (PA) radiograph. In the pediatric population, it has a prevalence of about 2%. [1]. Idiopathic scoliosis accounts for at least 75% to 80% of childhood scoliosis, with no underlying structural abnormality or accompanying syndrome identified [1,2]. It is further subdivided into infantile (0–3 years of age), juvenile (4–9 years of age), and adolescent (10–18 years of age) categories depending on the age of presentation, with the adolescent category comprising about 90% [3].

With the widespread use of MRI, it has become apparent that up to 2% to 4% of adolescent idiopathic scoliosis patients in fact do have abnormalities of the neural axis [4,5]. The most common abnormalities revealed by MRI include Chiari I malformation, cord syrinx, cord tethering, and, rarely, intrinsic spinal cord tumor [4,6]. However, there is no consensus on the indications or utility for selective use of MRI. Several risk factors for neural axis abnormalities have been suggested, including left thoracic curve, short segment curve (4–6 levels), absence of apical segment lordosis/kyphosis, long thoracolumbar curve, rapid curve progression (more than 1° per month), functionally disruptive pain, focal neurologic findings, male sex, and pes cavus [3,4,7,8]. Absence of apical segment lordosis/kyphosis is one of the more consistent risk factors [4,6,8]. If detected, the clinical relevance of most of these intraspinal abnormalities, even in the presurgical setting, is unclear. In two studies on consecutive presurgical patients with idiopathic scoliosis and a completely normal neurologic examination demonstrated either a low rate or no change in presurgical management [6,9].

It should be noted that the diagnosis of idiopathic scoliosis is of exclusion. This includes exclusion of a variety of neuromuscular disorders commonly associated with scoliosis, such as cerebral palsy and muscular dystrophy. Intramedullary, extramedullary, and vertebral tumors can be associated with scoliosis, with osteoid osteoma of the posterior elements perhaps being the most well-known. Vertebral infections, such as tuberculosis, may also result in kyphoscoliosis [1,2]. Conditions with dysplastic skeletal development should also be clinically excluded, including osteogenesis imperfecta, neurofibromatosis type I, Marfan syndrome, Ehlers-Danlos syndrome, and achondroplasia. Clinical presentation and physical examination in idiopathic scoliosis are negative for cutaneous stigmata that suggest underlying spinal dysraphism (hemangioma, hairy patches, nevi, dermal appendages, or sinus tracts) [10].

When radiographs reveal anomalies of vertebral formation or segmentation, the scoliosis is termed congenital, accounting for up to 10% of surgical patients [2]. Neural axis anomalies, such as hydrosyringomyelia, Chiari malformation, and cord tethering, have been reported to occur in more than 20% of such patients who thus may benefit from routine preoperative MRI [11].

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Overview of Imaging Modalities

Radiography

Spinal radiography, which can be performed rapidly without sedation, is the primary imaging modality employed for diagnosing and classifying scoliosis, evaluating severity, monitoring progression, and characterizing response to treatment. Both the ACR and the Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) have issued guidelines regarding the appropriate use of radiography in pediatric scoliosis. These include using PA instead of anteroposterior technique to reduce breast dose, lateral radiography on initial examination and then only as subsequently dictated by alterations in sagittal balance, and employing lower-dose radiography techniques [12,13]. These lower-dose techniques continue to evolve and currently include both computed and digital radiography, as compared to conventional cassette-film radiography [14]. Biplanar slot scanners, if available, may also be used to lower dosage in this setting [15]. Spinal radiographs also allow for concomitant assessment of the Risser index, a measure of the degree of iliac apophysis ossification and a marker for both skeletal maturity and potential curve progression [3].

MRI

MRI of the spine, with its superior soft-tissue contrast is selectively used in the setting of scoliosis to detect and characterize suspected intraspinal abnormalities. Intravenous (IV) gadolinium-based contrast agents are not routinely used in the setting of scoliosis, except in those instances when tumor or infection is a consideration.

CT

Multiphase and 3-D reconstruction CT of the bony spine can help in selected cases for presurgical planning. In addition, the volumetric CT data can be used for surgical navigation [16,17]. CT may also be used to characterize and define the extent of the lesion, such as with the nidus of an osteoid osteoma. CT can be rapidly acquired, and low-dose protocols have been developed and implemented [18]. IV iodine-based contrast is almost never warranted in the perioperative setting, the exception being when tumor or infection is suspected and MRI with contrast cannot be obtained because of a contraindication.

Tc-99m Bone Scan

Tc-99m methyl diphosphonate (MDP) bone scintigraphy has been advocated in the specific setting of painful scoliosis and is particularly sensitive in cases with primary bone tumors, such as osteoid osteoma or osteoblastoma, spondylolysis, and infection. However, generalized pain is common in scoliosis, occurring in up to a third of idiopathic cases, and radiography often demonstrates the etiology in those individuals with an underlying bone abnormality [19]. Bone scintigraphy findings are usually not specific. Therefore, after initial evaluation with radiography, MRI is generally the second-line imaging modality even in the setting where a primary bone tumor, such as osteoid osteoma, is a consideration [20].

Discussion of Procedures by Variant

Variant 1: Child. Congenital scoliosis. Initial imaging.

The body regions covered in this clinical scenario are the cervical, thoracic, and lumbar spine. These body regions might be evaluated separately or in combination as guided by physical examination findings, patient history, and other available information, including prior imaging.

Radiography Complete Spine

Congenital scoliosis, resulting from a failure of vertebral formation or segmentation, accounts for up to 10% of surgical patients with scoliosis. Following history and physical examination, initial PA and lateral radiographs of the spine are generally obtained as standard practice to diagnose and classify the scoliotic deformity, evaluate its severity, and assess risk for curve progression. For instance, a unilateral bar in association with a contralateral hemivertebra may have a curve progression of more than 10° per year [21-23]. PA radiographs are also used in serial follow-up to detect scoliosis progression so that early treatment may be initiated to limit deformity. The SOSORT suggests limiting these examinations to no more than once every 6 months [12].

MRI Complete Spine

Congenital scoliosis as a result of abnormal vertebral formation and segmentation has been shown to be associated with a high incidence of intraspinal anomalies, with a reported prevalence ranging from 20% to 58% [11]. Underlying anomalies include tethered cord, filar lipoma, syringohydromyelia, and diastematomyelia [11]. In a study of 76 patients, Belmont et al [11] noted a prevalence of intraspinal anomalies in 28% of patients with isolated hemivertebra and 21% of patients with more complex vertebral anomalies. Interestingly, history and

physical examination only demonstrated an accuracy of 62% for diagnosing an intraspinal anomaly with a hemivertebra. Shen et al [24], in a study of 226 Chinese surgical cases for congenital scoliosis, found a 43% incidence of intraspinal anomalies, the most common being diastematomyelia. Again, similar to the study by Belmont et al, a negative neurologic examination did not predict a normal MRI examination. MRI was suggested in both of these studies for the complete evaluation of congenital scoliosis.

CT Spine

CT may play a role in the initial imaging evaluation of congenital scoliosis. Multiplanar and 3-D volume rendered reformatted images derived from the axially acquired data set provide multiple views of the spine, allowing a perspective not readily available with conventional radiographs [25,26]. CT may specifically aid in the visualization and characterization of the osseous septum in type I split cord malformations [27]. CT is also helpful in presurgical planning for congenital scoliosis, facilitating visualization of the bony malformations and reducing instrumentation-related complications. Wu et al [26] reported a reduction in the rate of screw misplacement using CT-assisted planning, 6.5% as compared to 15.3% when using C-arm alone.

Tc-99m Bone Scan Complete Spine

Tc-99m MDP is not a primary imaging modality in the setting of congenital scoliosis as it provides no intraspinal information.

Variant 2: Child (0 to 9 years of age). Early onset idiopathic scoliosis. Initial imaging.

The body regions covered in this clinical scenario are the cervical, thoracic, and lumbar spine. These body regions might be evaluated separately or in combination as guided by physical examination findings, patient history, and other available information, including prior imaging.

Radiography Complete Spine

Early onset idiopathic scoliosis encompasses infantile (0–3 years of age) and juvenile (4–9 years of age) types and constitutes about 8% of the idiopathic scoliosis population in the United States [28]. By definition, it occurs in the absence of a vertebral anomaly or associated syndrome. As such, PA and lateral spine radiographs are obtained for differentiation from congenital scoliosis and to assess scoliosis severity [28]. Serial PA radiographs are used to assess progression, with a SOSORT consensus committee suggesting limiting radiographic follow-up to 6 month intervals [12].

MRI Complete Spine

Juvenile idiopathic scoliosis carries higher risk for intraspinal anomalies as compared with adolescent idiopathic scoliosis with a range of 13% to 27% [28-30]. Some suggest selective MRI for curve progression, neurologic status change, or routinely when surgical intervention is planned [30], or presurgically when there is back pain [9]. Other authors recommend total spine MRI for all patients with juvenile idiopathic scoliosis [28].

CT Spine

CT does not play a significant role in the initial diagnostic assessment of early onset idiopathic scoliosis as it is limited with respect to intraspinal assessment.

Tc-99m Bone Scan Complete Spine

Tc-99m MDP is not a primary imaging modality in the setting of early onset idiopathic scoliosis as it provides no intraspinal information.

Variant 3: Adolescent (10 to 18 years of age). Adolescent idiopathic scoliosis. No risk factors. Initial imaging.

The body regions covered in this clinical scenario are the cervical, thoracic, and lumbar spine. These body regions might be evaluated separately or in combination as guided by physical examination findings, patient history, and other available information, including prior imaging.

Radiography Complete Spine

Adolescent (10–18 years of age) idiopathic scoliosis is the most common scoliosis in clinical practice, occurring in 1% to 2% of otherwise healthy children [31] and constituting 75% to 80% of all scoliosis cases [2]. It is more common in girls, with a female-to-male ratio of 10:1 for larger (greater than 40°) curves [29]. Adolescent idiopathic scoliosis is a diagnosis of exclusion. When clinically suspected, upright PA and lateral spine radiographs are obtained to specifically exclude congenital vertebral anomalies and assess curve severity.

Serial PA spine radiographs are also an integral part of the follow-up of these patients. In those skeletally immature individuals with a Cobb angle of more than 20°, the likelihood of curve progression may exceed 70%. Skeletally mature patients with a thoracic scoliosis of more than 50° may also continue to progress at about 1° per year [31]. The Cobb angle, as determined on these radiographs, has been shown to play a key role in the surgical decision-making process [32].

Surgical decision making and planning is also influenced by the flexibility of the curves, which can be assessed using a variety of radiographic techniques, such as side bending, push prone, fulcrum bending, and traction radiographs [33-37]. Cheh et al [38] found that a single supine spine radiograph can predict curve type, flexibility, and structurality.

SOSORT suggests limiting spine radiographs to once every 12 months for adolescent patients at Risser stages 0 to 3 and every 18 months for patients at Risser stages 4 to 5 unless there are objective clinical changes in the appearance of the scoliosis [39].

MRI Complete Spine

Most (96%–98%) of adolescents with idiopathic scoliosis do not have an underlying abnormality [4,5]. As such, in the absence of risk factors, MRI screening of the entire population is inefficacious.

CT Spine

CT of the spine in adolescent idiopathic scoliosis is not routinely used in initial diagnostic assessment. Rather, some orthopedists use perioperative CT for presurgical planning and intraoperative navigation to optimize screw placement [16,17,40,41].

Tc-99m Bone Scan Complete Spine

Tc-99m MDP is not a primary imaging modality in the setting of adolescent idiopathic scoliosis as it provides no intraspinal information.

Variant 4: Adolescent (10 to 18 years of age). Adolescent idiopathic scoliosis. Risk factors. Initial imaging.

The body regions covered in this clinical scenario are the cervical, thoracic, and lumbar spine. These body regions might be evaluated separately or in combination as guided by physical examination findings, patient history, and other available information, including prior imaging.

Radiography Complete Spine

Adolescent idiopathic scoliosis (10–18 years of age) is the most common scoliosis in clinical practice, occurring in 1% to 2% of otherwise healthy children [31] and constituting 75% to 80% of all scoliosis cases [2]. It is more common in girls, with a female-to-male ratio of 10:1 for larger (greater than 40°) curves [29]. Adolescent idiopathic scoliosis is a diagnosis of exclusion. When clinically suspected, upright PA and lateral spine radiographs are obtained to specifically exclude congenital vertebral anomalies and assess curve severity.

Serial PA spine radiographs are also an integral part of the follow-up of these patients. In those skeletally immature individuals with a Cobb angle of more than 20°, the likelihood of curve progression may exceed 70%. Skeletally mature patients with a thoracic scoliosis of more than 50° may also continue to progress at about 1° per year [31]. The Cobb angle, as determined on these radiographs, has been shown to play a key role in the surgical decision-making process [32].

Surgical decision making and planning is also influenced by the flexibility of the curves, which can be assessed using a variety of radiographic techniques, such as side bending, push prone, fulcrum bending, and traction radiographs [33-37]. Cheh et al [38] noted that a single supine spine radiograph can predict nonstructural minor curves as well.

SOSORT suggests limiting spine radiographs to once every 12 months for those adolescent patients at Risser stages 0 to 3 and every 18 months for patients at Risser stages 4 to 5, unless there are objective clinical changes in the appearance of the scoliosis [39].

MRI Complete Spine

Up to 2% to 4% of adolescents with scoliosis have an intrinsic anomaly of their spinal cord or spinal contents that can only be identified with MRI [4,5]. The most common abnormalities revealed by MRI include Chiari I malformation, cord syrinx, cord tethering, and, more rarely, intrinsic spinal cord tumor [4,6]. Detecting these anomalies before scoliosis surgery may influence management [4,7,42]. However, there is no consensus on the

indications for selective use of MRI. Several risk factors for neural axis abnormalities have been suggested, including left thoracic curve, short segment curve (4–6 levels), absence of apical segment lordosis (hyperkyphosis), rapid curve progression (more than 1° per month), functionally disruptive pain, focal neurologic findings, male sex, and pes cavus [3-8,43]. Absence of apical segment lordosis/kyphosis is one of the more consistent risk factors [4,6,8]. Moreover, if detected, the clinical relevance of most of these intraspinal abnormalities, even in the presurgical setting, is unclear. Two studies on consecutive presurgical patients with idiopathic scoliosis and a normal neurologic examination demonstrated either a low rate of or no change in presurgical management [6,9].

Furthermore, the diagnosis of underlying neural axis anomalies changes long-term management and outcomes in only selected patients. There is no consensus on the significance of diagnosis and treatment of isolated hydrosyringomyelia. Some studies suggest that a clinically asymptomatic and isolated syrinx does not have substantial prognostic or treatment implications [44-46]. Other studies have suggested that underlying syrinx detection may be important, particularly in the setting of Chiari I malformation. Krieger et al [47] retrospectively studied 69 such patients who had undergone craniocervical decompression surgery. None of 49 patients with curves lower than 20° progressed, while 21 of 30 patients with curves greater than 20° progressed. Also, 87% of syringes decreased or resolved. The authors concluded that early intervention was important and suggested MRI in patients with scoliosis and risk factors.

CT Spine

CT of the spine in adolescent idiopathic scoliosis is not routinely used in initial diagnostic assessment. Rather, some orthopedists utilize perioperative CT for presurgical planning and intraoperative navigation to optimize screw placement [16,17,40,41].

Tc-99m Bone Scan Complete Spine

Tc-99m MDP is not a primary imaging modality in the setting of adolescent idiopathic scoliosis as it provides no intraspinal information.

Summary of Recommendations

- **Variation 1:** Radiographs of the complete spine and MRI complete spine without IV contrast are usually appropriate for the initial imaging of children with congenital scoliosis. These procedures are complementary (ie, both should be performed).
- **Variation 2:** Radiographs of the complete spine and MRI complete spine without IV contrast are usually appropriate for the initial imaging of children (0 to 9 years of age) with early onset idiopathic scoliosis. The procedures are complementary (ie, both should be performed).
- **Variation 3:** Radiographs of the complete spine are usually appropriate for the initial imaging of an adolescent (10 to 18 years of age) with adolescent idiopathic scoliosis and no risk factors.
- **Variation 4:** Radiographs of the complete spine and MRI complete spine without IV contrast are usually appropriate for the initial imaging of an adolescent (10 to 18 years of age) with adolescent idiopathic scoliosis and risk factors. The procedures are complementary (ie, both should be performed).

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document [48].

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
○	0 mSv	0 mSv
⊗	<0.1 mSv	<0.03 mSv
⊗⊗	0.1-1 mSv	0.03-0.3 mSv
⊗⊗⊗	1-10 mSv	0.3-3 mSv
⊗⊗⊗⊗	10-30 mSv	3-10 mSv
⊗⊗⊗⊗⊗	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

References

1. Musson RE, Warren DJ, Bickle I, Connolly DJ, Griffiths PD. Imaging in childhood scoliosis: a pictorial review. *Postgrad Med J* 2010;86:419-27.
2. Qiu Y, Zhu F, Wang B, et al. Clinical etiological classification of scoliosis: report of 1289 cases. *Orthop Surg* 2009;1:12-6.
3. Khanna G. Role of imaging in scoliosis. *Pediatr Radiol* 2009;39 Suppl 2:S247-51.
4. Davids JR, Chamberlin E, Blackhurst DW. Indications for magnetic resonance imaging in presumed adolescent idiopathic scoliosis. *J Bone Joint Surg Am* 2004;86-A:2187-95.
5. Nakahara D, Yonezawa I, Kobanawa K, et al. Magnetic resonance imaging evaluation of patients with idiopathic scoliosis: a prospective study of four hundred seventy-two outpatients. *Spine (Phila Pa 1976)* 2011;36:E482-5.
6. Diab M, Landman Z, Lubicky J, Dormans J, Erickson M, Richards BS. Use and outcome of MRI in the surgical treatment of adolescent idiopathic scoliosis. *Spine (Phila Pa 1976)* 2011;36:667-71.
7. Ozturk C, Karadereler S, Ornek I, Enercan M, Ganiyusufoglu K, Hamzaoglu A. The role of routine magnetic resonance imaging in the preoperative evaluation of adolescent idiopathic scoliosis. *Int Orthop* 2010;34:543-6.
8. Qiao J, Zhu Z, Zhu F, et al. Indication for preoperative MRI of neural axis abnormalities in patients with presumed thoracolumbar/lumbar idiopathic scoliosis. *Eur Spine J* 2013;22:360-6.
9. Benli IT, Uzumcugil O, Aydin E, Ates B, Gurses L, Hekimoglu B. Magnetic resonance imaging abnormalities of neural axis in Lenke type 1 idiopathic scoliosis. *Spine (Phila Pa 1976)* 2006;31:1828-33.
10. Cardoso M, Keating RF. Neurosurgical management of spinal dysraphism and neurogenic scoliosis. *Spine (Phila Pa 1976)* 2009;34:1775-82.
11. Belmont PJ, Jr., Kuklo TR, Taylor KF, Freedman BA, Prahinski JR, Kruse RW. Intraspinous anomalies associated with isolated congenital hemivertebra: the role of routine magnetic resonance imaging. *J Bone Joint Surg Am* 2004;86-A:1704-10.
12. Knott P, Pappo E, Cameron M, et al. SOSORT 2012 consensus paper: reducing x-ray exposure in pediatric patients with scoliosis. *Scoliosis* 2014;9:4.
13. American College of Radiology. ACR-SPR-SSR Practice Parameter for the Performance of Radiography for Scoliosis in Children. Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/scoliosis.pdf>. Accessed November 30, 2018.
14. Kluba T, Schafer J, Hahnfeldt T, Niemeyer T. Prospective randomized comparison of radiation exposure from full spine radiographs obtained in three different techniques. *Eur Spine J* 2006;15:752-6.
15. Deschenes S, Charron G, Beaudoin G, et al. Diagnostic imaging of spinal deformities: reducing patients radiation dose with a new slot-scanning X-ray imager. *Spine (Phila Pa 1976)* 2010;35:989-94.
16. Sakai Y, Matsuyama Y, Nakamura H, et al. Segmental pedicle screwing for idiopathic scoliosis using computer-assisted surgery. *J Spinal Disord Tech* 2008;21:181-6.
17. Ughwanogho E, Patel NM, Baldwin KD, Sampson NR, Flynn JM. Computed tomography-guided navigation of thoracic pedicle screws for adolescent idiopathic scoliosis results in more accurate placement and less screw removal. *Spine (Phila Pa 1976)* 2012;37:E473-8.
18. Abul-Kasim K, Overgaard A, Maly P, Ohlin A, Gunnarsson M, Sundgren PC. Low-dose helical computed tomography (CT) in the perioperative workup of adolescent idiopathic scoliosis. *Eur Radiol* 2009;19:610-8.
19. Ramirez N, Johnston CE, Browne RH. The prevalence of back pain in children who have idiopathic scoliosis. *J Bone Joint Surg Am* 1997;79:364-8.
20. Davies A, Saifuddin A. Imaging of painful scoliosis. *Skeletal Radiol* 2009;38:207-23.
21. Hedequist DJ. Surgical treatment of congenital scoliosis. *Orthop Clin North Am* 2007;38:497-509, vi.
22. Kim H, Kim HS, Moon ES, et al. Scoliosis imaging: what radiologists should know. *Radiographics* 2010;30:1823-42.
23. Kose N, Campbell RM. Congenital scoliosis. *Med Sci Monit* 2004;10:RA104-10.
24. Shen J, Wang Z, Liu J, Xue X, Qiu G. Abnormalities associated with congenital scoliosis: a retrospective study of 226 Chinese surgical cases. *Spine (Phila Pa 1976)* 2013;38:814-8.
25. Kawakami N, Tsuji T, Imagama S, Lenke LG, Puno RM, Kuklo TR. Classification of congenital scoliosis and kyphosis: a new approach to the three-dimensional classification for progressive vertebral anomalies requiring operative treatment. *Spine (Phila Pa 1976)* 2009;34:1756-65.

26. Wu ZX, Huang LY, Sang HX, et al. Accuracy and safety assessment of pedicle screw placement using the rapid prototyping technique in severe congenital scoliosis. *J Spinal Disord Tech* 2011;24:444-50.
27. Liu W, Zheng D, Cui S, et al. Characteristics of osseous septum of split cord malformation in patients presenting with scoliosis: a retrospective study of 48 cases. *Pediatr Neurosurg* 2009;45:350-3.
28. Koc T, Lam KS, Webb JK. Are intraspinal anomalies in early onset idiopathic scoliosis as common as once thought? A two centre United Kingdom study. *Eur Spine J* 2013;22:1250-4.
29. Malfair D, Flemming AK, Dvorak MF, et al. Radiographic evaluation of scoliosis: self-assessment module. *AJR Am J Roentgenol* 2010;194:S23-5.
30. Pahys JM, Samdani AF, Betz RR. Intraspinal anomalies in infantile idiopathic scoliosis: prevalence and role of magnetic resonance imaging. *Spine (Phila Pa 1976)* 2009;34:E434-8.
31. Trobisch P, Suess O, Schwab F. Idiopathic scoliosis. *Dtsch Arztebl Int* 2010;107:875-83; quiz 84.
32. Donaldson S, Stephens D, Howard A, Alman B, Narayanan U, Wright JG. Surgical decision making in adolescent idiopathic scoliosis. *Spine (Phila Pa 1976)* 2007;32:1526-32.
33. Chen ZQ, Wang CF, Bai YS, et al. Using precisely controlled bidirectional orthopedic forces to assess flexibility in adolescent idiopathic scoliosis: comparisons between push-traction film, supine side bending, suspension, and fulcrum bending film. *Spine (Phila Pa 1976)* 2011;36:1679-84.
34. Davis BJ, Gadgil A, Trivedi J, Ahmed el NB. Traction radiography performed under general anesthetic: a new technique for assessing idiopathic scoliosis curves. *Spine (Phila Pa 1976)* 2004;29:2466-70.
35. Li J, Hwang S, Wang F, et al. An innovative fulcrum-bending radiographical technique to assess curve flexibility in patients with adolescent idiopathic scoliosis. *Spine (Phila Pa 1976)* 2013;38:E1527-32.
36. Ni HJ, Su JC, Lu YH, et al. Using side-bending radiographs to determine the distal fusion level in patients with single thoracic idiopathic scoliosis undergoing posterior correction with pedicle screws. *J Spinal Disord Tech* 2011;24:437-43.
37. Watanabe K, Kawakami N, Nishiwaki Y, et al. Traction versus supine side-bending radiographs in determining flexibility: what factors influence these techniques? *Spine (Phila Pa 1976)* 2007;32:2604-9.
38. Cheh G, Lenke LG, Lehman RA, Jr., Kim YJ, Nunley R, Bridwell KH. The reliability of preoperative supine radiographs to predict the amount of curve flexibility in adolescent idiopathic scoliosis. *Spine (Phila Pa 1976)* 2007;32:2668-72.
39. Knott P, Mardjetko S, Nance D, Dunn M. Electromagnetic topographical technique of curve evaluation for adolescent idiopathic scoliosis. *Spine (Phila Pa 1976)* 2006;31:E911-5; discussion E16.
40. Liu J, Shen J, Zhang J, et al. The position of the aorta relative to the spine for pedicle screw placement in the correction of idiopathic scoliosis. *J Spinal Disord Tech* 2012;25:E103-7.
41. Malfair D, Flemming AK, Dvorak MF, et al. Radiographic evaluation of scoliosis: review. *AJR Am J Roentgenol* 2010;194:S8-22.
42. Singhal R, Perry DC, Prasad S, Davidson NT, Bruce CE. The use of routine preoperative magnetic resonance imaging in identifying intraspinal anomalies in patients with idiopathic scoliosis: a 10-year review. *Eur Spine J* 2013;22:355-9.
43. Wu L, Qiu Y, Wang B, Zhu ZZ, Ma WW. The left thoracic curve pattern: a strong predictor for neural axis abnormalities in patients with "idiopathic" scoliosis. *Spine (Phila Pa 1976)* 2010;35:182-5.
44. Magge SN, Smyth MD, Governale LS, et al. Idiopathic syrinx in the pediatric population: a combined center experience. *J Neurosurg Pediatr* 2011;7:30-6.
45. Joseph RN, Batty R, Raghavan A, Sinha S, Griffiths PD, Connolly DJ. Management of isolated syringomyelia in the paediatric population--a review of imaging and follow-up in a single centre. *Br J Neurosurg* 2013;27:683-6.
46. Sha S, Zhang W, Qiu Y, Liu Z, Zhu F, Zhu Z. Evolution of syrinx in patients undergoing posterior correction for scoliosis associated with syringomyelia. *Eur Spine J* 2015;24:955-62.
47. Krieger MD, Falkinstein Y, Bowen IE, Tolo VT, McComb JG. Scoliosis and Chiari malformation Type I in children. *J Neurosurg Pediatr* 2011;7:25-9.
48. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf>. Accessed November 30, 2018.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.