Chapter 6
Radiologic Imaging and Laboratory Evaluation of Back Pain in Children and Adolescents

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Introduction

Most children and adolescents presenting with back pain for the first time to their physician will not need radiographic imaging or laboratory studies. While back pain is increasingly common in childhood, reports have shown that pain resolves in roughly 90% spontaneously and is typically due to sprains, strains, and "nonspecific" etiologies [1]. Back pain becomes more common with older age, and it is more likely that a serious underlying condition will be identified under age 10 years than near skeletal maturity, at which time nearly 100% of the population reports at least one episode of back pain [2–4]. Imaging and/or laboratory studies are indicated if there are red flags as discussed in Chaps. 4 and 5, deformity, or persistent/recurrent pain unresponsive to conservative measures such as time (generally over 6-week duration), relative rest, physical therapy, and over-the-counter nonsteroidal anti-inflammatory drugs (NSAIDs). Red flags include radicular pain, numbness or subjective weakness, night pain, bowel or bladder incontinence, fever, unexplained weight loss, and abnormal neurologic findings on physical examination such as gait deviation, reflex asymmetry, atrophy, altered or lost sensation, limited straight leg raise, marked stiffness, and objective weakness on manual motor testing.

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Imaging

Role of Plain Radiography

When red flags, deformity, or persistent/recurrent pain are encountered, plain radiography is indicated. As a general principle for all musculoskeletal disorders in children, plain radiography is *always* performed prior to advanced imaging. For thoracic pain, standard two-view orthogonal (anterior to posterior (AP) and lateral) images are ordered. For lumbar pain, standard two-view orthogonal AP and lateral images are also ordered. In the past, *oblique views* of the lumbar spine were ordered to visualize spondylolysis, but recent studies have shown that the addition of oblique views does not improve the diagnostic yield, and therefore, these are rarely indicated today [5]. If more detailed imaging of very specific anatomic levels is desired, AP and lateral "Spot Films" of the thoracic, lumbar, and lumbosacral spine can be ordered.

When *deformity* such as scoliosis, lordosis, or kyphosis is the major finding, then the standard radiologic study to order is a two-view (posterior to anterior (PA) and lateral) standing full-spine film (Fig. 6.1). The film is shot PA rather than AP because of the slightly lower radiation exposure to the thyroid and vital organs compared with AP exposure and also because deformity surgeons typically view the films in the same manner they would clinically examine a patient's back: posterior to anterior. Exceptions are when the child is unable to stand due to young age or neuromuscular condition, in which case an AP film is taken either sitting or supine. It is critically important that the entire spine is visualized on these initial deformity films in order to properly assess overall spinal balance, determine pattern and type of curve, measure deformity severity using the Cobb method (see Chap. 13), and determine the presence or absence of congenital, infectious, or neoplastic lesions which may be incidental or causative. If an inadequate film is initially obtained, then the patient may require another film resulting in additional cost and radiation exposure. In addition to examining the spine itself, it is important to evaluate the soft tissue structures, looking for findings such as pulmonary nodules, kidney stones, and ingested foreign bodies. These non-spinal findings may be clues to the cause for the child's back pain or may be incidental findings with little or great importance. Finally, for known neuromuscular conditions, it is helpful to include the pelvis and hips in the initial images because pelvic obliquity with hip subluxation or dislocation can cause pain (Fig. 6.2).

In infants and young or disabled children with spinal *deformity*, it may be impossible to obtain standing films, and either sitting or supine films may be substituted. These films should be marked by the technologist as such for later comparison to follow-up films, which may be done standing. If the examiner is screening for scoliosis, a generally accepted scoliometer reading of 7 degrees or greater on the forward bend test indicates that radiography should be performed [6].

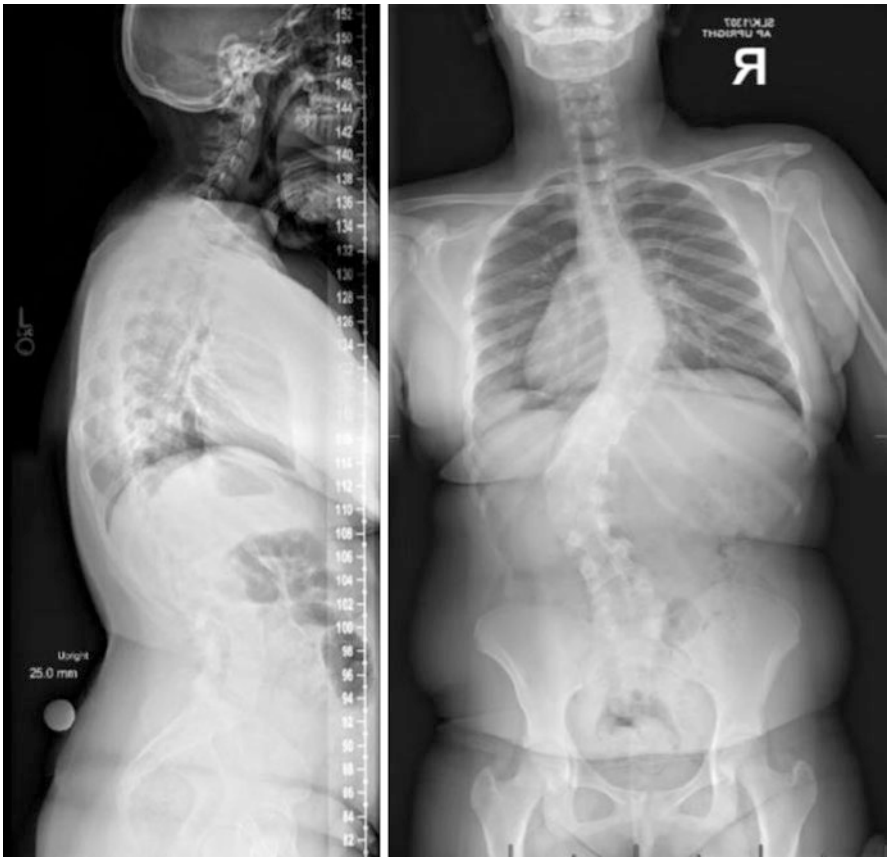

Fig. 6.1 PA and lateral standing radiograph of a teenager with adolescent idiopathic scoliosis. Note that the entire spine and pelvis are included on this initial PA film

Radiation Exposure

With modern digital radiologic technique, the radiation exposure to children and adolescents undergoing standard imaging studies is minimal. While there is no truly safe dose of radiation, exposure should rarely be a consideration when ordering indicated plain radiographic studies. The principles of as low as reasonably achievable (ALARA) and the Image Gently campaign (Society of Pediatric Radiology and others) should be applied to all ionizing imaging studies (https://www.imagegently.org/). This area does remain an area of active research, and the clinician should note changes in guidelines as they evolve [7, 8].

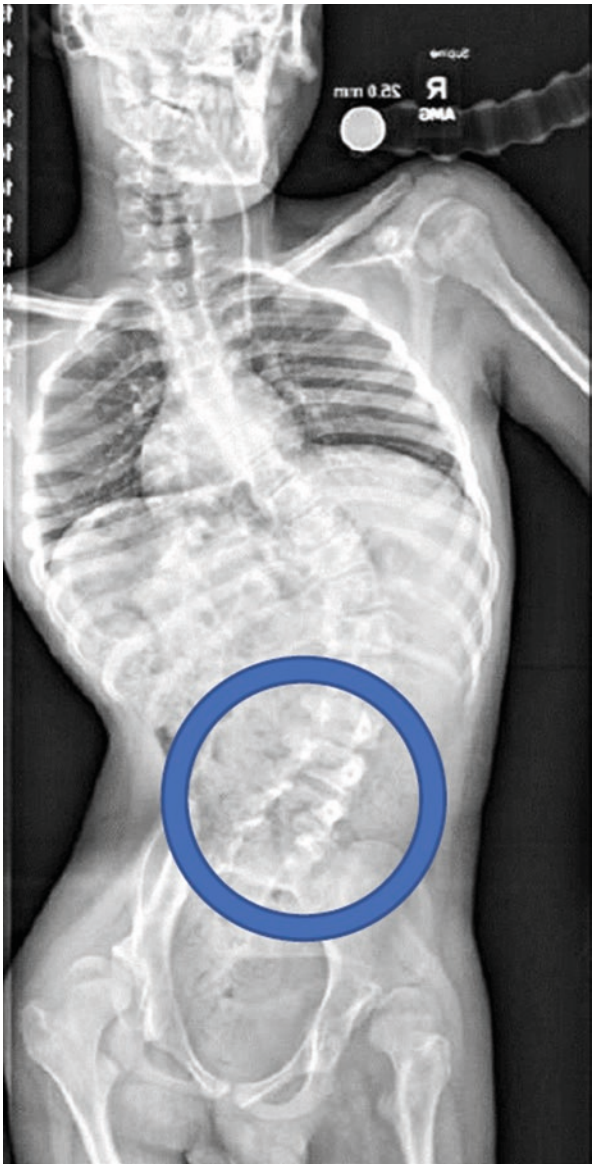

Fig. 6.2 An AP supine radiograph of a child with spina bifida. Note the importance of including the hips and pelvis which show dysplastic subluxated hips. The circle indicates inter-pedicular widening of the lumbar vertebrae with lack of posterior elements, characteristic of spina bifida

Special Views

In addition to the standard radiologic views noted above, other views may be obtained, but these should generally be ordered by the treating orthopedic surgeon. These include flexion/extension lateral lumbosacral images for spondylolisthesis, left and right lateral bending films for scoliosis, and thoracic extension films over a bolster for kyphosis. The reason for deferring these special studies to the treating

physician is that they are usually not diagnostic but instead help determine the treatment plan. They also may require special standardized equipment and techniques not readily available in all radiology departments.

Role of Computerized Tomography (CT Scan)

Computerized tomography (CT) has largely been supplanted by MRI because of associated radiation exposure but still has a role in the evaluation of pediatric back pain. CT technology has developed to become much faster and deliver less radiation than in the past. A full rotation of the CT scanner takes less than 0.5 seconds, and the technology builds a complete reconstruction based on that rotation in tenths of a second [8]. A typical CT scan will deliver radiation doses of between 3 and 9 millisieverts (mSv) (background US radiation is 3.1 mSv/year) [9]. Specific indications for CT scanning in the pediatric age group are evaluation of vertebral cortical integrity and 3-D modelling of the spine. CT is better than MRI at demonstrating bony cortical detail and spondylosis and may be used to demonstrate fractures or cortical tumors such as osteoid osteomas (Fig. 6.3). The relative value of CT versus MRI depends on the quality of local technology and the expertise of the technicians operating the scanner and the radiologists/specialists interpreting the study.

A frequent question is whether it is better to use a CT or MRI for diagnosis of early spondylolysis; the MRI (Fig. 6.4) will show bony edema and "pre-lysis" edema better than CT, but the CT will show whether there is an established cortical fracture line. Often it is best to consult with your institutional radiologist or orthopedic surgeon to determine the better study for a particular indication. As a general rule, it is wise to consult with the appropriate specialist whenever ordering an advanced study beyond initial radiography or defer to that specialist to order the study.

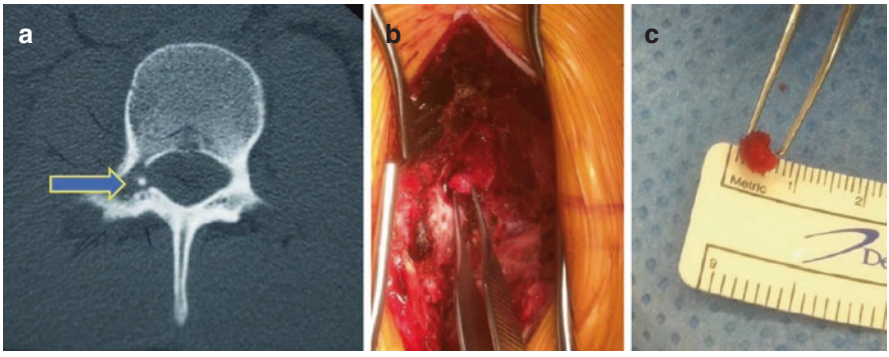

Fig. 6.3 Fine-cut CT scan showing a pea-sized osteoid osteoma of a vertebral pedicle. (**a**) CT of spine showing osteoid osteoma (*arrow*). (**b**) Surgical removal of osteoid osteoma from the spine. (**c**) Osteoid osteoma specimen

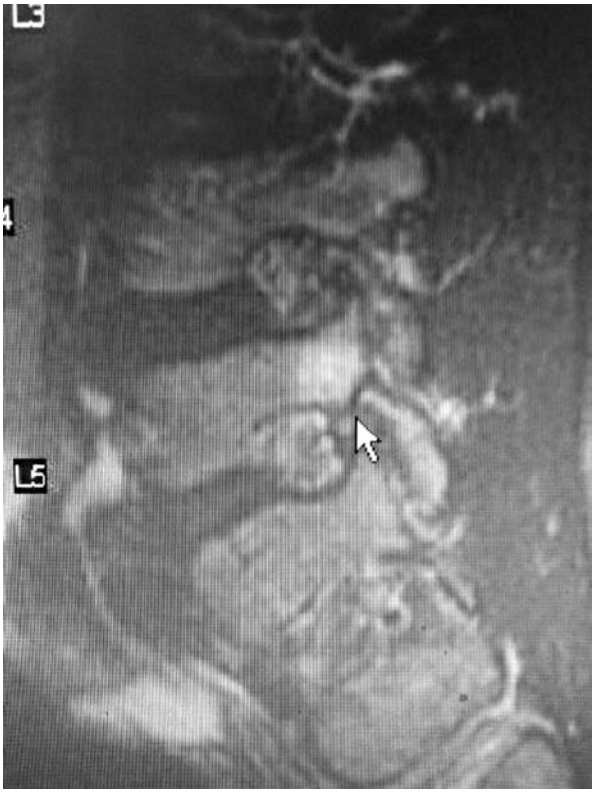

Fig. 6.4 Sagittal MRI showing edema of pars interarticularis indicating early spondylolysis (*arrow*)

Finally, CT may be used as a first-line study in the evaluation of the multi-trauma patient and will readily demonstrate vertebral fractures and dislocations. However, CT and plain radiography will by definition miss Spinal Cord Injury Without Radiographic Abnormality (SCIWORA) injuries, which only MRI can detect.

Spinal Cord Injury Without Radiographic Abnormality (SCIWORA)

This term was coined in 1982 to describe circumstances in which children were seen with traumatic spinal cord injuries but their radiographs were normal [10]. This is explained by a much larger percentage of non-bony elements of the spine present in children versus adults (cartilaginous end plates, discs, and facet joints) and the much greater flexibility of the pediatric versus adult spinal column. If a fracture through non-bony tissue is non-displaced or if the spinal column flexes, bends, or extends excessively even without fracturing, the much less flexible spinal cord may be damaged, with no acute changes observed on plain radiography or even CT. The

immature spinal column can stretch 5 cm before disruption, but the spinal cord can only stretch 6 mm. There may be injuries to the spinal column without spinal neurologic injury which will be apparent only on MRI.

Technetium Nuclear Bone Scan

Like CT, technetium nuclear bone scanning of the spine and other anatomic regions is becoming less frequently performed because MRI can show much more detail and without any radiation exposure. The best current use of a nuclear bone scan is in patients who present with concerning but vague symptoms (Fig. 6.5). Rather than

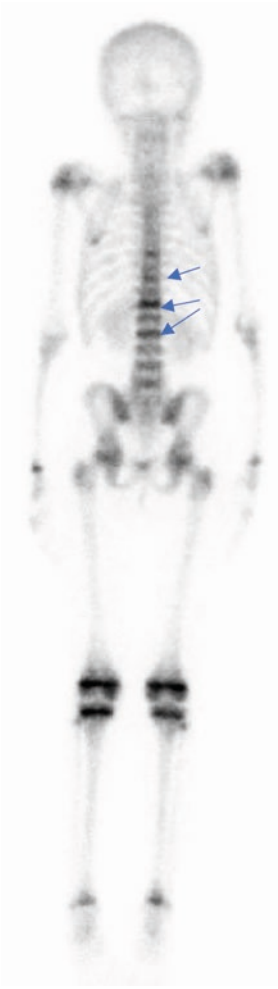

Fig. 6.5 Example of total body nuclear bone scan showing increased uptake in several vertebral bodies with disseminated neoplasm (*arrows*)

order a CT or MRI of an entire spinal region, the nuclear bone scan can image the entire spine and identify a specific anatomic site for further detailed investigation by CT or MRI. The nuclear bone scan works by intravenously injecting radioactive Technetium-99m methylene diphosphonate (MDP) which is taken up by the bone undergoing abnormally high metabolic activity and to areas of increased blood flow [11]. Areas such as growth plates which are metabolically active due to high bone turnover typically exhibit intense uptake in the pediatric population. Bone scan is sensitive but nonspecific in the detection of infection and tumors but may be falsely negative or "cold" in the setting of low bone turnover such as in eosinophilic granuloma and chronic Brodie's abscess. A more advanced form of nuclear bone scanning is single-photon emission computed tomography, or SPECT.

A common indication for nuclear bone scanning is seeking disseminated bone lesions such as metastases in patients with known cancers including neuroblastoma, Ewing's sarcoma, and osteosarcoma and in patients with suspected multifocal osteomyelitis.

PET-CT

Positron emission tomography-CT (PET-CT) is mentioned here for completeness but is ordered only as a tertiary study by a surgical or oncologic specialist in staging a neoplasm, measuring response to therapy, or performing surveillance for metastatic disease. It is not typically ordered for the initial evaluation of back pain. The technique combines the injection of a radiopharmaceutical with conventional anatomic CT to precisely identify areas of abnormal metabolic activity.

Imaging Findings on Plain Radiography

Keep in mind that radiography is not indicated for the majority of children and teens presenting for the first time with back pain unless red flags or deformity are noted. This section presents typical abnormal plain radiographic findings and their interpretation. Details regarding each clinical condition are described in Part II, case-based chapters.

Initial Approach to Reading Plain Radiographs of the Spine

Note carefully the name of the patient and the date the film was taken. Are there earlier or later films for comparison? Is left or right clearly marked? By convention, scoliosis films are taken and examined *posterior to anterior* (PA) so the patient's right side is seen on the right side of the screen; this can be confusing for most physicians who view chest films as anterior to posterior in dimension. Is the film marked

to indicate whether the film was taken standing, supine, or with any special positioning? Are the hips visible? Examine the soft tissues and margins of the film for incidental findings which may be obscure or otherwise overlooked. Then, focus on the spine itself. Note the maturity of the patient from the appearance of the triradiate cartilage and the iliac crest ossification.

Disc Disease and Schmorl's Nodes

Loss of disc height is easily appreciated by comparing adjacent levels. This could indicate traumatic injury, infection (spondylodiscitis), congenital anomaly, or tumor. Disc disease increases with age and is therefore much more common in adults than in children and teens. After about age 30 years, discs desiccate and start to lose their elasticity and "shock absorber" effect (Fig. 6.6).

Plain films may also show a *vertebral end plate fracture,* also known as *apophyseal ring fracture* or "hard disc" which is a unique pediatric form of disc pathology in which the posterior margin of a vertebral end plate and attached annulus break off and may then impinge on the spinal canal or nerve roots (Fig. 6.7). There will be a history of acute traumatic injury with immediate symptoms of severe pain and possible nerve root or cauda equina irritation. These children clinically present in a similar manner to adults with acute disc herniations, but by contrast, adult disc herniations are herniations of the nucleus pulposis through the annulus, rather than the annulus and end plate themselves.

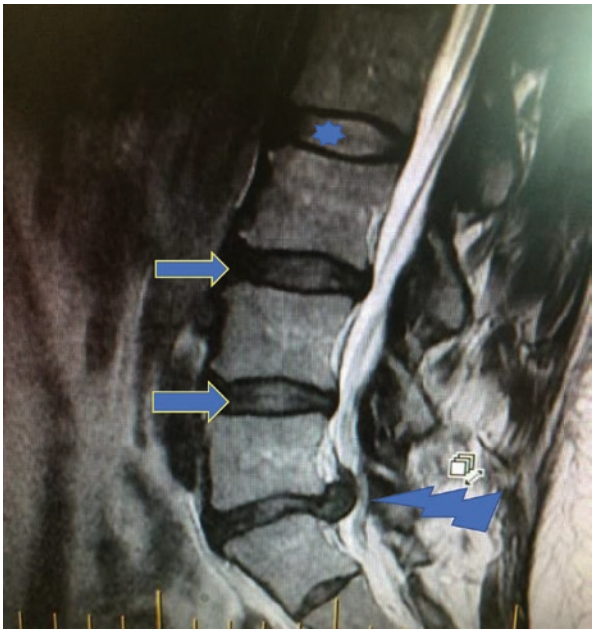

Fig. 6.6 MRI of lumbar spine showing dark discs which indicate loss of normal hydration and herniated L5/S1 nucleus pulposis (star = normal disc, large arrows = dehydrated "black" discs with posterior bulging, and jagged arrow = frankly herniated disc)

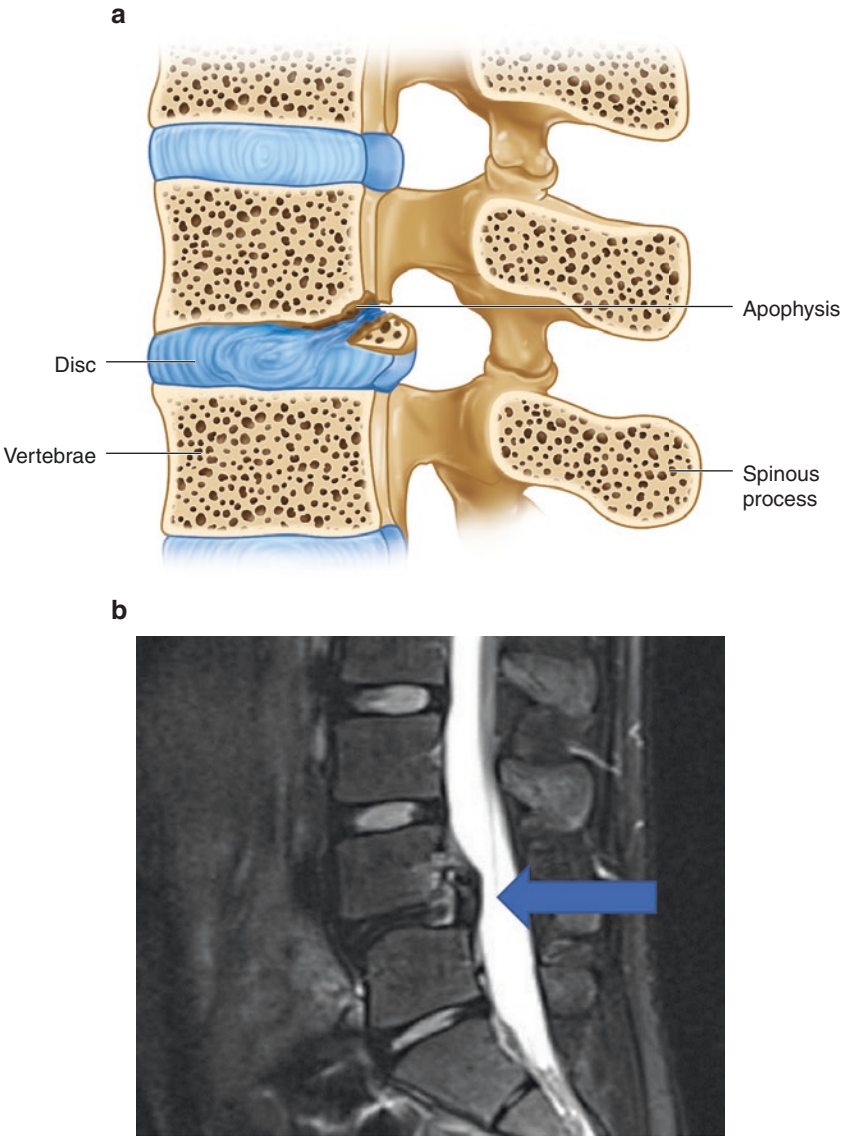

Fig. 6.7 (**a**) Illustration of vertebral end plate fracture also known as apophyseal ring fracture or "hard disc." (**b**) MRI of apophyseal ring fracture with extrusion of annulus into spinal canal (*arrow*)

Schmorl's nodes are developmental irregularities of the end plates of immature vertebrae (Fig. 6.8). They represent herniations of the disc into the adjacent vertebral end plates, not to be confused with disc herniations into the spinal canal or neural foramen. Schmorl's nodes are usually seen in the preteen and teen years and are *often incidental findings*. However, if they are prominent and at several levels,

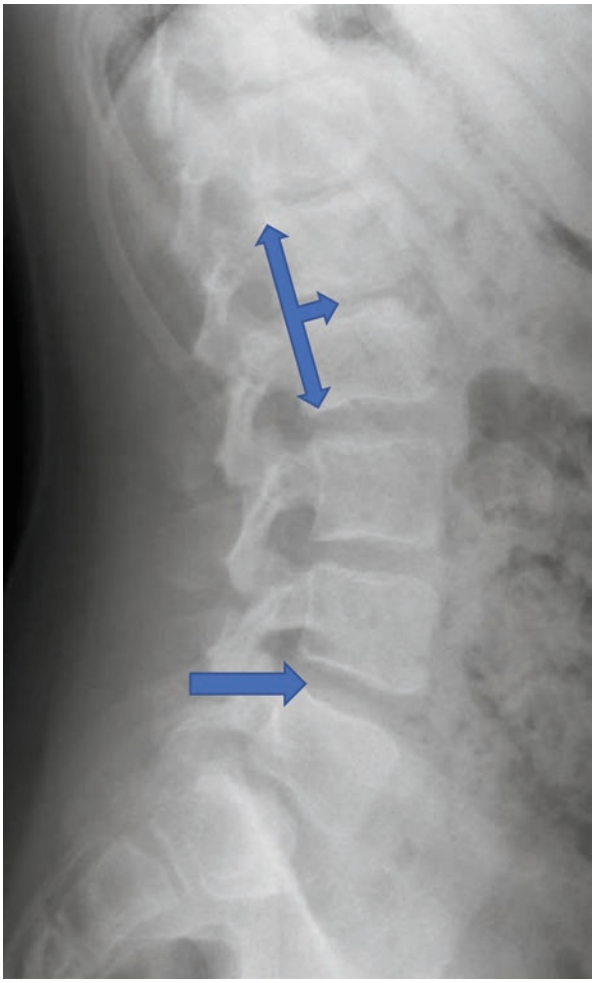

Fig. 6.8 Schmorl's nodes involving several lumbar vertebral body end plates (*triple arrow*). Single arrow shows normal disc space with normal vertebral end plates

they may become symptomatic, causing "discogenic" pain; this is pain localized to the back without nerve root irritation (sciatica). In most cases, pain gradually resolves over time, and treatment is symptomatic –not surgical. No advanced imaging is required unless other pain etiology is suspected.

Fracture or Dislocation

Fracture or dislocation of any part of the thoracic or lumbar spine is usually appreciated by a loss in the normal contour and alignment of the visualized spinal column. Adjacent levels are easily compared. Step-offs in the anterior or posterior vertebral body lines and perched, jumped, or fractured facets can be seen. One form of pediatric injury is the *Chance fracture*, most commonly caused by acute spinal flexion

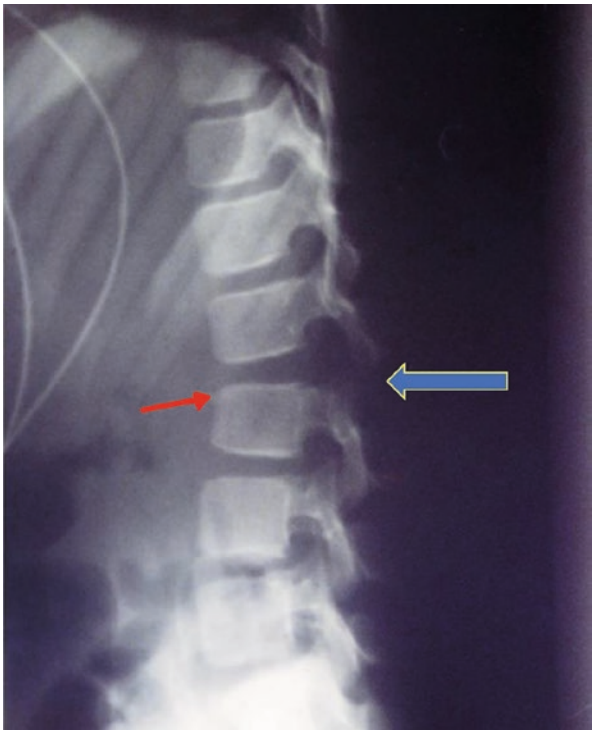

Fig. 6.9 A compression fracture of the vertebral body (anterior column, small arrow) combined with distraction injury (ligamentous or bony rupture, large arrow) of the posterior column is a variant of Chance fracture, seen most commonly with use of a lap belt without shoulder harness

as in the use of a lap belt without a shoulder harness; this causes compression injury of the anterior column and distraction of the posterior column (Fig. 6.9). The lateral film shows a gap between adjacent spinous processes (torn soft tissues) and various degrees of anterior column injury (compression or burst fracture) which together may cause spinal cord or cauda equina injury.

A generally benign type of spinal fracture seen commonly in the pediatric age group is a *compression fracture* (Fig. 6.10). Compression fractures occur with axial force to the spine such as when jumping from a height and landing on both feet or buttocks, often with a flexion moment. Isolated compression fractures are stable injuries that do not cause neurologic impairment, are more common in children than adults because of less dense pediatric bone, and generally heal without sequelae. It is not unusual to see two or three contiguous vertebral compression fractures or even more on MRI or CT imaging.

Scheuermann's Kyphosis

Scheuermann's kyphosis is a developmental disorder of unknown etiology which may affect either the thoracic or lumbar spine. Radiographs are typically ordered because a teen presents with a painful rigid kyphosis, and the diagnosis is readily made on the lateral film. Classically, the diagnosis is confirmed by three contiguous vertebrae wedged 5 degrees or more (Fig. 6.11). Advanced imaging is not usually indicated, and

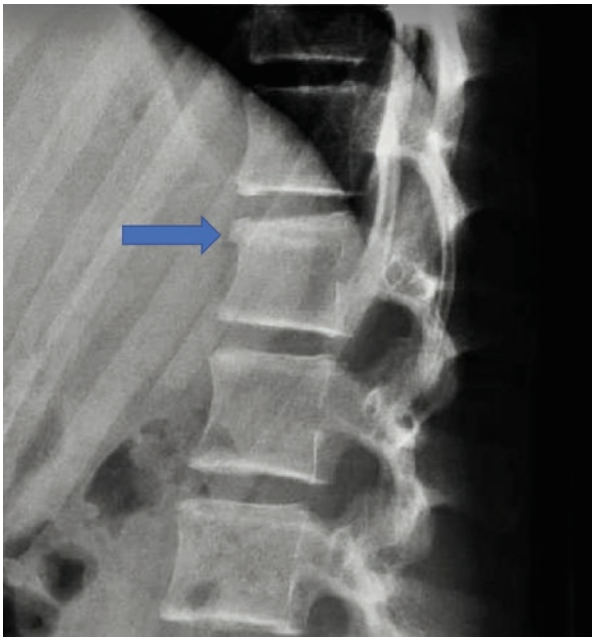

Fig. 6.10 Vertebral body compression fracture in 16-year-old girl (*arrow*)

treatment starts with physical therapy and possibly bracing, reserving surgery for more severe cases, such as when thoracic kyphosis exceeds 80 degrees. Any degree of lumbar kyphosis may be an indication for surgery, especially if there is pain.

Some experts consider Scheuermann kyphosis to be an extreme form of Schmorl's nodes; others do not. The mere presence of Schmorl's nodes does not lead to Scheuermann's kyphosis.

Transitional Vertebra

A transitional vertebrae occurs at the lumbosacral junction and may have combined features of either a lumbar or sacral vertebra. Sometimes there is an extra vertebra at the lumbosacral junction, and on one side, it may appear to be an extra lumbar vertebra and on the other an extra sacral vertebra. This is usually an incidental finding and rarely a cause for back pain. No additional imaging is required, and surgery is rarely indicated. A very large L5 transverse process that impinges onto the iliac wing or the sacrum can be painful and is termed Bertolotti syndrome

Spina Bifida Occulta

Like transitional vertebrae, *spina bifida occulta* is usually an incidental finding and not symptomatic. It is a small midline defect in the spinous process, usually of L5 and S1, occurs in about 6% of the population, and may be associated with an

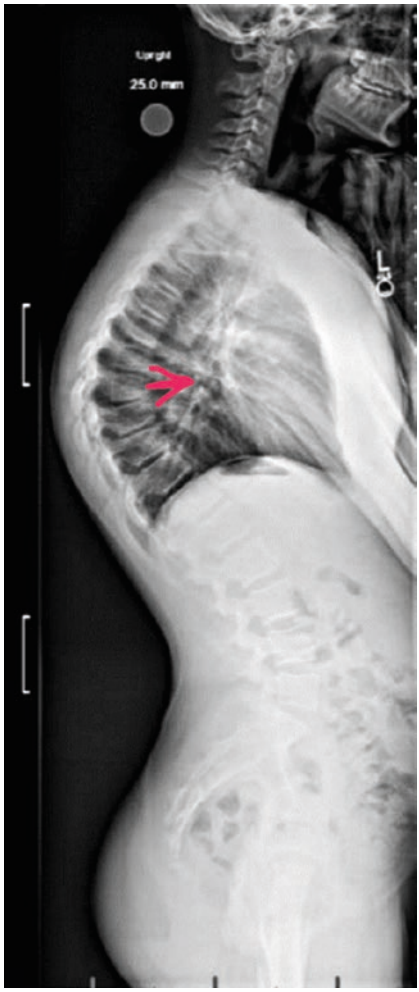

Fig. 6.11 Scheuermann's kyphosis is a developmental kyphotic deformity which may occur in the thoracic, thoracolumbar, or lumbar spine associated with anterior wedging of the apical vertebrae (*three red lines*)

increased risk of spondylolysis. Therefore, if it is seen in the setting of low back pain, consider spondylolysis as the possible etiology. An isolated radiographic finding of spina bifida occulta does not cause back pain and does not require further imaging.

Spondylolysis and Spondylolisthesis

Spondylolysis is by far the most common identifiable cause of back pain in the pediatric age group. It is a stress fracture of the pars interarticularis of a lumbar vertebra, usually L4 or L5 (Fig. 6.12). These typically occur in athletes for which

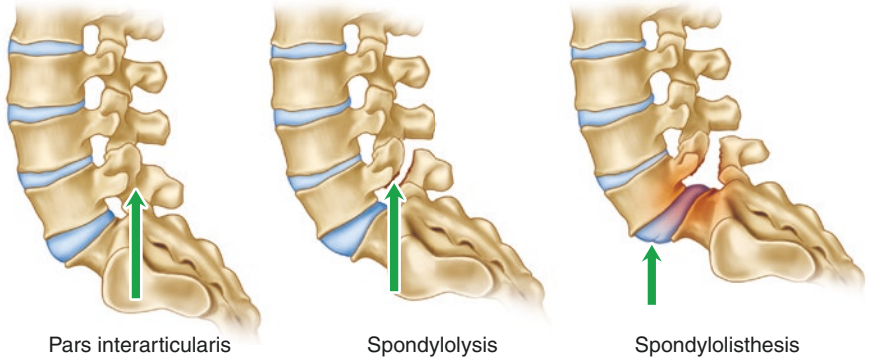

Fig. 6.12 Spondylolysis and spondylolisthesis. *Spondylolysis* is a non-displaced developmental, traumatic, or degenerative fracture through the pars interarticularis that may lead to *spondylolisthesis* which is a slippage of one vertebra over the subjacent vertebra

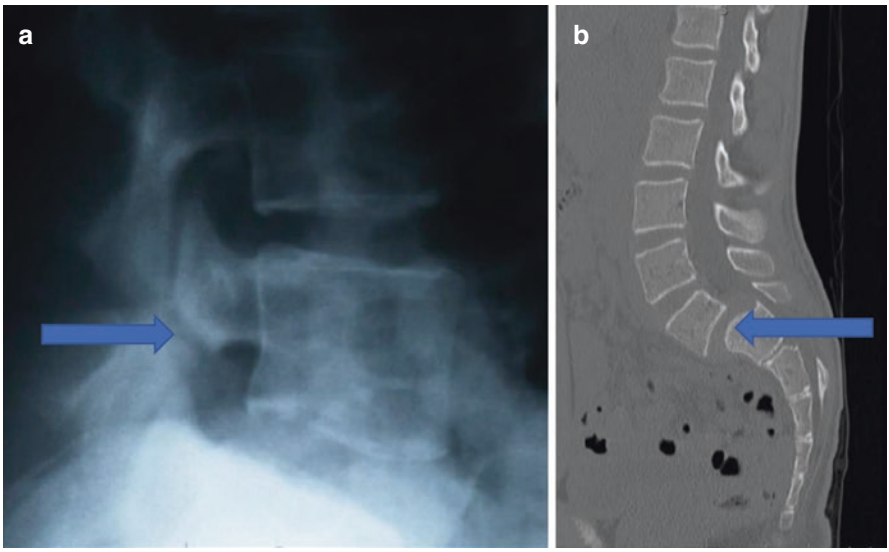

Fig. 6.13 (**a**) L5 spondylolysis in a 14-year-old gymnast (*arrow*). (**b**) An unstable high-grade L5/S1 developmental spondylolisthesis in a 13-year-old boy (*arrow*)

their sport requires repetitive lumbar extension such as dance, gymnastics, and football line positions. However, there is also a developmental component, and spondylolysis can be seen in any athlete or nonathlete. Spina bifida occulta is an associated radiographic finding and may be a predisposing factor.

Plain AP and lateral lumbar radiographs may show an established spondylolysis (Fig. 6.13a). In the past, oblique views were taken to look for the so-called "scotty dog" sign, but these have been shown to be no more sensitive than the standard AP

and lateral views [12, 13]. However, plain radiography may not reveal an early-stage spondylolysis in which a complete fracture has not yet occurred; in such cases where spondylolysis is clinically suspected by a history of low back pain associated with sport activity and tightness of the hamstrings, an MRI may reveal bone edema localized to unilateral or bilateral pars (see Fig. 6.4). In this early stage, complete cessation of aggravating sport, physical therapy, and bracing may result in true healing of the lesion. In later stages, once the fracture (also called a "pars defect") is visible on plain radiography, it will not heal without surgical intervention. However, the usual treatment is symptomatic and nonsurgical because most athletes are able to return to sport without complete bony healing of their defect. The symptoms resolve despite nonunion of the fracture. There is still a role for a limited-cut CT in assessing a defect which is suspected but not seen on plain film or MRI and for assessing healing potential (sclerotic borders unlikely to heal) or response to treatment. These are best ordered by the specialist physician.

In contrast to spondylolysis, *spondylolisthesis* is a slippage of one vertebra with respect to its adjacent vertebra (Fig. 6.12). Slippage requires an initial spondylolysis defect, after which the disc and anterior column structures become deficient, allowing one vertebra to slip forward over the one below it. In pediatrics, there are two basic types of spondylolisthesis: traumatic and developmental (Fig. 6.13b). The developmental type is much more common and can be further subdivided into stable and unstable variants [14]. Unstable slips may progress from low grade to high grade and even to complete *spondyloptosis* in which L5 slips completely over S1 and falls into the pelvis. It is critical to note that typical sports-related spondylolysis does not progress to significant spondylolisthesis, and therefore, surgery is not performed for most pediatric patients with spondylolysis. On the other hand, high-grade (more than 50% slipped forward) symptomatic unstable developmental or traumatic spondylolisthesis is usually surgically stabilized.

Spinal Deformity

As noted previously, radiography for spinal deformity includes the complete spine, PA and lateral, and standing if possible (see Fig. 6.1). Scoliosis, kyphosis, and lordosis are measured using the Cobb method (see Chap. 13). Generally, kyphosis greater than 60 degrees and scoliosis greater than 15 degrees are considered abnormal and reasons for orthopedic referral. Do not be fooled by *apparent scoliosis*: this occurs when there is a limb length inequality causing a pelvic tilt which then causes the spine to curve but without the rotational deformity typically seen in true idiopathic scoliosis (Fig. 6.14). The pelvic tilt (or pelvic obliquity) is readily seen on the standing film. Another film can be taken with an appropriate-sized block underneath the shorter limb, which levels the pelvis and lessens the scoliosis.

Scoliosis, kyphosis, and lordosis are descriptive terms and not diagnoses. An accurate diagnosis is made only after performance of a detailed general physical examination and appropriate imaging. The *neurologic* examination may reveal

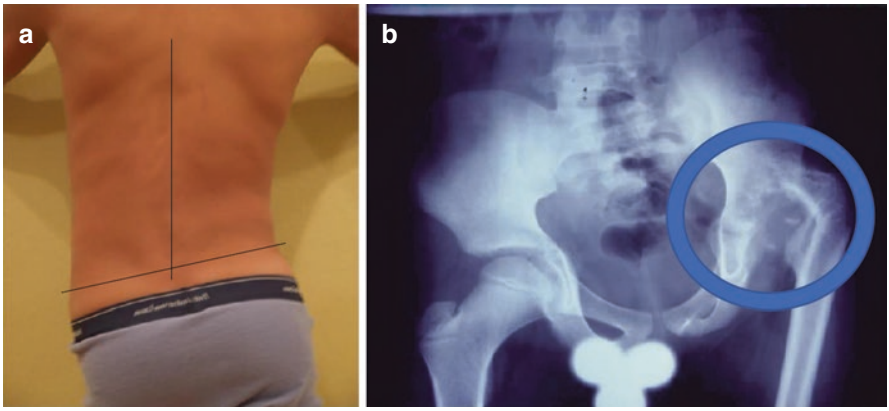

Fig. 6.14 (**a**) Apparent, but not true, scoliosis due to a limb length difference causing pelvic obliquity while standing. (**b**) In this case, the limb length difference is caused by a dislocated hip (*circled*)

asymmetric reflexes, spasticity, weakness, or gait disturbance, all indicating a neuromuscular etiology. The *skin* examination may reveal findings indicating a *syndromic* etiology such as multiple café au lait spots and axillary freckling typical of neurofibromatosis type 1 or hyperelasticity with multiple prominent scars characteristic of Ehlers-Danlos syndrome. The *musculoskeletal* examination may reveal long fingers and toes or painful foot deformity suggestive of Marfan's syndrome. A unilateral foot deformity such as cavus or equinus, along with a midline hair patch or dimple above the gluteal crease, may indicate a tethered spinal cord (see also Chap. 5: Physical Examination).

Adolescent idiopathic scoliosis is the most common type of scoliosis and typically occurs in otherwise healthy adolescent girls. The exact pathophysiology is unknown, but there is a definite genetic component. On PA imaging, there is not only a lateral spinal curvature (deformity in the coronal plane) but also a rotational component which accounts for the rib hump seen on physical examination and also a lordotic component creating a loss of normal thoracic kyphosis. The rotation is seen on PA imaging as asymmetry of the pedicles, and the loss of thoracic kyphosis is evident on the lateral film (Fig. 6.15). Indications for MR imaging for idiopathic scoliosis is controversial, with some orthopedic surgeons imaging every case of scoliosis and others reserving MRI for suspected non-idiopathic forms such apex left thoracic curves which occasionally are associated with Chiari malformations and syringomyelia. MRI may also be obtained before scoliosis surgery.

Beside*s adolescent idiopathic scoliosis*, there are neuromuscular, syndromic, neoplastic, and developmental etiologies of scoliosis. Clues about etiology found on plain films include a short sharp curve associated with a hemivertebra or fused ribs as seen in *congenital scoliosis*, in which one or more vertebrae are malformed at birth. These patients should be evaluated with cardiac and renal ultrasound imaging because these organs develop in utero at the same time as the spine and are often

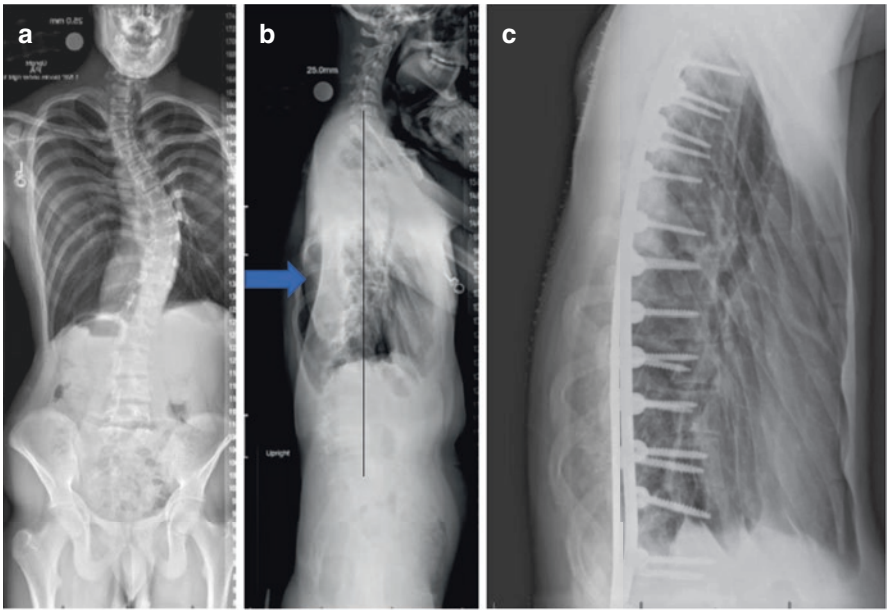

Fig. 6.15 (**a**) The PA image shows scoliosis with vertebral rotation (arrow points to prominent ribs resulting from the vertebral rotation and causing paraspinal prominence or "rib hump" seen on the Adams forward bend test). (**b**) The lateral film shows the thoracic hypokyphosis or lordosis commonly associated with idiopathic scoliosis (*vertical line*). (**c**) Postoperative film showing partial correction of thoracic lordosis

also malformed approximately 20% of the time. A long sweeping thoracic and lumbar scoliosis without rotational component can indicate a neurogenic disorder, such as cerebral palsy or chronic cervical spinal cord injury. It is important to examine the hips in these cases for subluxation or dislocation. Seating imbalance may aggravate the curve and lead to increased pain and decubitus ulcer formation.

Advanced imaging for spinal deformity is best determined by the treating physician. Usually, this will be an MRI of the *entire spinal axis* including the brain stem, looking for Chiari malformation, syringomyelia, intradural or extradural neoplasm, diastematomyelia, and spinal cord tethering. MRI is more likely to find an underlying etiology for *early-onset scoliosis* (those presenting under age 10 years) rather than *adolescent idiopathic scoliosis.* Young children, typically less than 8 years of age, will require sedation or general anesthesia for this study.

Vertebra Plana

Vertebra plana (flat vertebra) is seen on both AP and lateral images and may occur at any level. Classically, it represents an eosinophilic granuloma (Langerhans cell histiocytosis) which has weakened the vertebral body to a point of collapse but may be caused by any destructive process including infection such as tuberculosis,

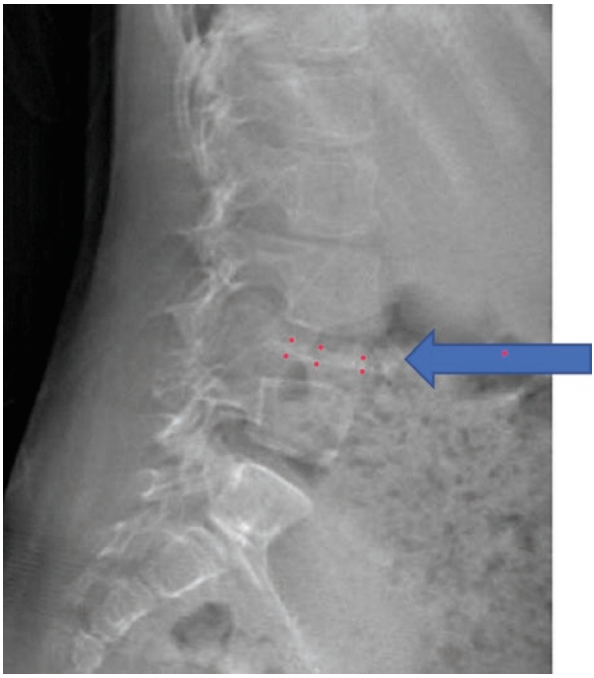

Fig. 6.16 Vertebral plana in a young child caused by vascular malformation weakening the bone (arrow points to flattened remnant of vertebral body, also outlined in red dots)

Ewing's sarcoma, and hemangioma (Fig. 6.16). Advanced imaging (MRI) and referral are always indicated, with biopsy depending upon clinical, laboratory, and MRI results.

MRI

MRI is never the first choice in spinal imaging: plain radiography is always done first because it is simple, readily available, inexpensive, and often diagnostic. The radiation exposure of plain films using modern radiologic equipment is minimal. Further, MRI in the absence of legitimate indications risks discovering clinically unimportant findings which may generate parental/patient/physician anxiety and further invasive unnecessary diagnostic and therapeutic tests which carry their own inherent risks.

In general, MRI following radiography is ordered for back pain associated with red flag signs, including pain that does not resolve within a reasonable amount of time (6 weeks), does not respond to usual conservative measures such as cessation from sport, occurs in child under age 10 years, has no apparent explanation, interferes with normal sleep, or is associated with fever, chills, weight loss, neurologic complaint, or impairment.

MRI is sometimes done with intravenous contrast: this decision is dependent upon the differential diagnosis and specifications of the equipment being used and therefore best left to the discretion of your informed radiologist.

Examples of Commonly Encountered Pediatric Variations and Abnormalities

"Bulging Discs"

Commonly reported "bulging discs" are normal variants with no clinical consequence. These are best thought of as incidental findings which do not correlate with symptoms of back pain. They are not disc herniations or "pre-herniations" and should be ignored.

Infection

Pediatric spinal infections are usually hematogenous and involve both the vertebra and adjacent disc space(s) – hence the name *spondylodiscitis*. Infection is suspected with nontraumatic onset of back pain and sometimes abdominal pain accompanied by fever, malaise, and in later stages neurologic findings secondary to epidural space encroachment. Infection may be acute as in acute staphylococcal bacterial spondylodiscitis or may be chronic and indolent as seen in fungal or AFB infections including coccidioidomycosis (valley fever) and tuberculosis. MRI for infection is usually done urgently (same or next day) but may be emergent if the child is very ill or demonstrating neurologic impairment (Fig. 6.17).

A condition which is often confused with bacterial or fungal spondylodiscitis is chronic recurrent multifocal osteomyelitis, or CRMO. This mysterious condition causes painful inflammatory bone changes often with elevation in serologic inflammatory markers and can occur in the long bones, pelvis, and spine. No etiologic infectious organism has been identified, and treatment is therefore symptomatic. Imaging clues are a mixture of new and healing lesions, typical multifocal pattern, and lack of abscess formation or sinus tracts [15].

Tumor

Many types of tumors and tumorlike conditions may affect the spinal column. Examples of the more common entities are provided here.

- Osteoid osteoma and its closely related larger cousin osteoblastoma
  - These benign neoplasms typically occur in the posterior spinal elements of teens and young adults and classically cause night pain without associated illness or neurologic symptoms. The pain responds to aspirin and NSAID medication quite dramatically, which is a reliable diagnostic clue. Histologically, these lesions are identical, but grossly osteoid osteomas are tiny pea-sized tumors (<1 cm), which may not be visible on plain films (see Fig. 6.3). Osteoblastomas are larger (>2 cm) and often visible as bone-forming lesions in the posterior elements on plain radiography (Fig. 6.18). Osteoid

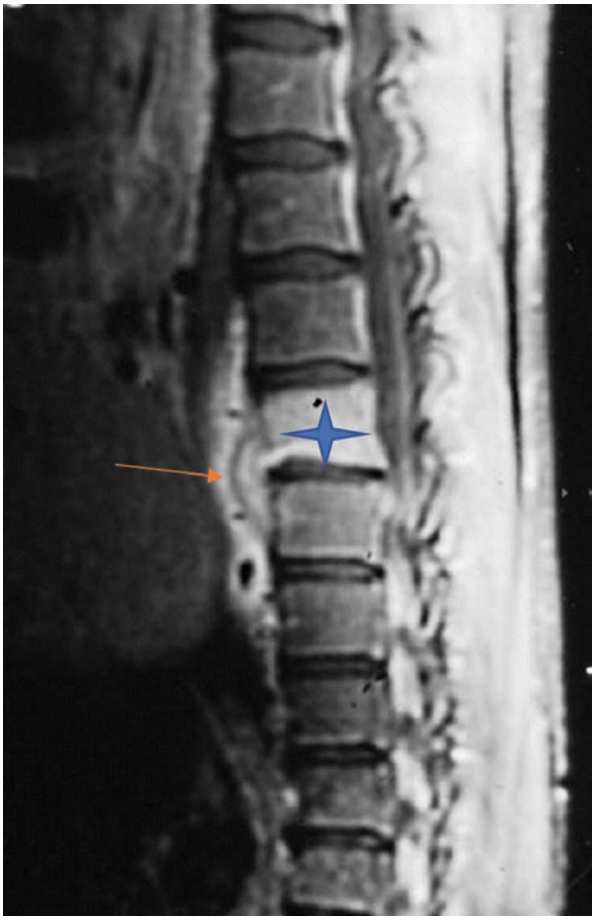

Fig. 6.17 Spondylodiscitis. Acute bacterial infection causing adjacent vertebral body edema (*star*), disc deformation, and abscess between vertebral bodies and anterior longitudinal ligament (*arrow*)

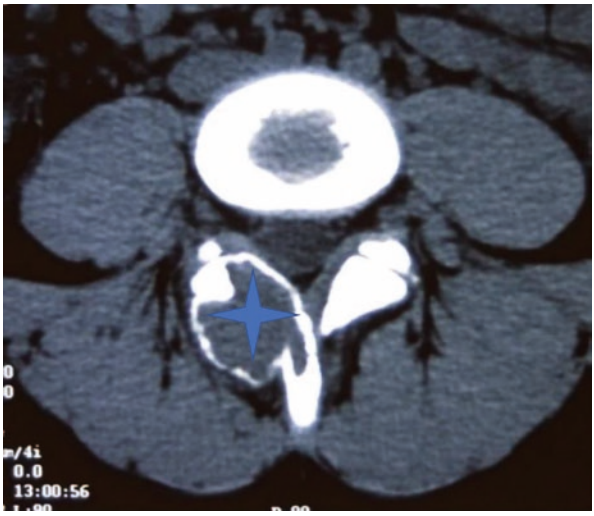

Fig. 6.18 CT scan of osteoblastoma (star indicates lytic expansile lesion in posterior elements of vertebrae)

osteomas are very painful due to high production of inflammatory prostaglandins, hence the dramatic pain relief with NSAIDS. If not readily seen on MRI, a SPECT technetium bone scan may be useful in locating the lesion, and CT can be done for confirmation and preoperative planning.

- Ewing's sarcoma and osteosarcoma
  - These are the two most common pediatric primary malignancies of the pediatric spine and are often symptomatic for months before diagnosis. This is because the lesions may be initially slow-growing and symptoms vague, combined with the extremely low incidence compared with benign back pain, thus lessening clinical suspicion. Clues are night pain, pain not improved with rest, relentlessly progressive pain, and, in late cases, neurologic deficit and systemic symptoms. Plain radiographs may initially be negative, but MRI is usually diagnostic. Sometimes it can be difficult to differentiate infection from neoplasm until a biopsy with cultures is obtained. As part of tumor staging, imaging of the entire spine and skeleton is done with MRI, PET-CT, and/or nuclear bone scan, looking for metastatic or skip lesions.
- Metastatic neuroblastoma
  - The spine is a common site for pediatric metastatic neuroblastoma. Lytic lesions may be visible on plain radiography, but advanced imaging is required for staging.
- Leukemia
  - About 20% of children with leukemia present with musculoskeletal symptoms, including back pain. Depending upon duration of symptoms, plain imaging may show characteristic "banding" of the vertebral bodies, along with diffuse osteopenia and multiple compression fractures (Fig. 6.19). A young child with leukemia may not explicitly complain of back pain, but parents will often observe decreased activity and inability to pick objects off the floor. Think of leukemia when faced with a young child with back pain or dysfunction who also appears ill.
- Langerhans cell histiocytosis (unifocal LCH, previously known as eosinophilic granuloma or histiocytosis X)
  - This benign but sometimes locally aggressive lesion can present with vague complaints of back pain and dysfunction but rarely progresses to neurologic sequelae. Discussed above, the plain films may show a wafer-thin vertebral body, known as "vertebra plana" (see Fig. 6.16). MRI is usually done to confirm the diagnosis and rule out mimics such as malignancy or infection; sometimes a biopsy is required. The systemic or multifocal forms of LCH have several confusing names including Letterer-Siwe disease and Hand-Schuller-Christian triad which may be aggressive and fatal [16]. Therefore, it is important to thoroughly evaluate a vertebra plana lesion and to consider referral to a pediatric oncologist to rule out systemic involvement. Of note, skeletal LCH may be "cold" on nuclear bone scan. LCH is still one of the rare

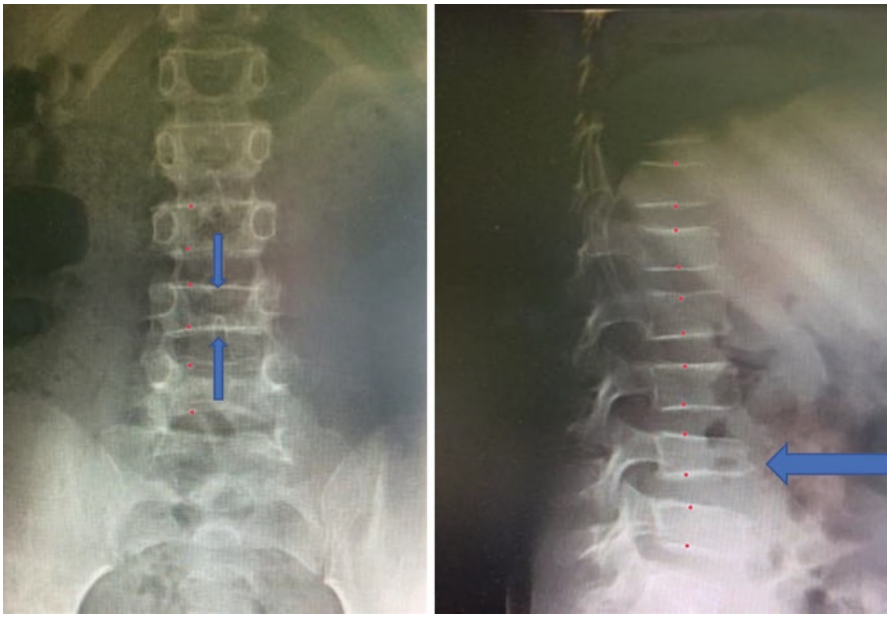

Fig. 6.19 AP and lateral radiographs of a 5-year-old girl with several weeks of back pain showing prominent vertebral end plates also known as "banding" (*red dots*), diffuse osteopenia, and compression fracture of L4 (*vertical arrows*). Her WBC count and differential were *normal*, but bone marrow aspirate showed leukemia

conditions for which a *skeletal survey* may be indicated. A skeletal survey consists of diagnostic plain films of the entire skeleton, including the skull, looking for lytic lesions.

- Aneurysmal bone cyst (ABC)
  - ABC is a misnomer; it looks like a cyst but is a true neoplasm. ABCs do not metastasize but may be fast growing and locally destructive. A patient with a spinal ABC typically presents with rapid onset of progressive back pain, cessation of sport activity, deformity, and possible neurologic impairment. MRI is almost always diagnostic showing local bone destruction and cystic fluid levels within the lesion (Fig. 6.20). Mimics are telangiectatic osteosarcoma and infection. Treatment is surgical, and recurrence is common.

Congenital

Arnold Chiari type 1 malformation and *syringomyelia* are closely related findings that may cause headaches, back pain, spinal deformity, and neurologic impairment (Fig. 6.21). They are the most commonly detected imaging abnormalities in the setting of scoliosis which may initially be thought of as idiopathic but for which MRI is ordered routinely or for suspicion of non-idiopathic (termed *atypical*) type. After

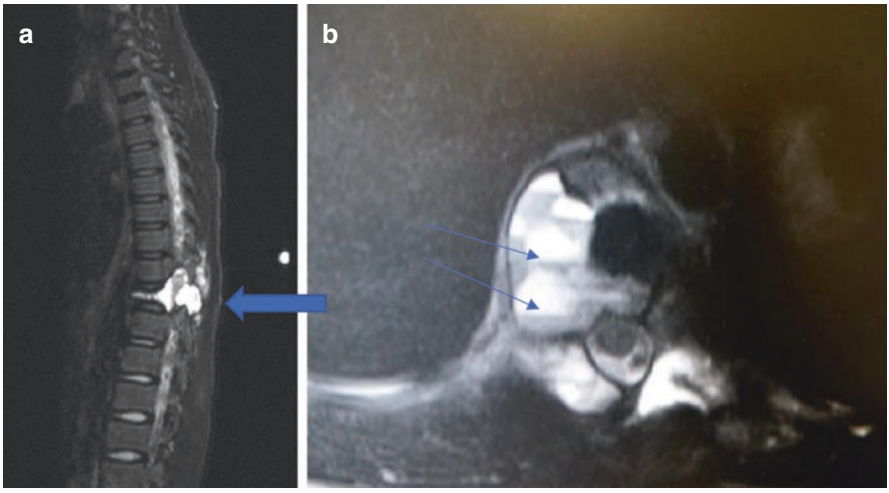

Fig. 6.20 (**a**) Aneurysmal bone cyst (ABC) presenting with rapid onset of back pain and disability in a 10-year-old boy. MR sagittal image shows vertebral collapse with high signal lesion replacing the vertebral body and occupying extradural space (*arrow*). (**b**) Transverse (axial) image shows cystic cavities with fluid levels (*small arrows*) characteristic of ABC

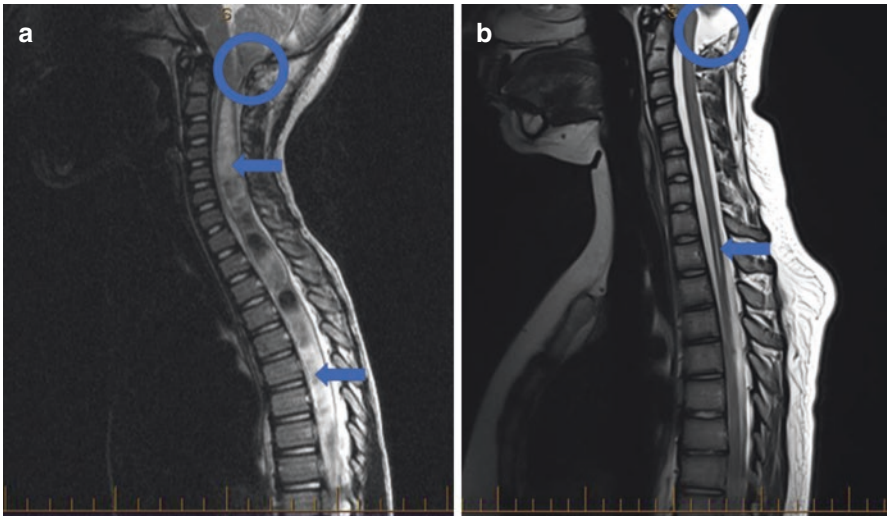

Fig. 6.21 (**a**) A 4 yo with early-onset thoracic scoliosis measuring 30 degrees. An asymmetric abdominal reflex was also noted. MRI showed a Chiari type 1 malformation (*circle*) and large syrinx extending the length of her cervical and thoracic spine (*arrows*). She underwent decompression of the Chiari malformation. (**b**) MRI at age 15 years showed resolution of the Chiari lesion (*circle*) and with only a small residual syrinx (*arrow*). Her scoliosis remained stable and never needed surgical treatment

neurosurgical consultation, the Chiari malformation is often decompressed. Rarely, the syrinx requires surgical shunt.

A *diastematomyelia* is a bone spur which runs anterior to posterior through the spinal canal, thus splitting the spinal cord or cauda equina (Fig. 6.22). As the child grows, this may create a tethering of the spinal cord or nerves and neurologic impairment. MRI will show it, but CT can be used to better define the bony anatomy preoperatively. Treatment is excision.

A more common form of *tethered cord* occurs in the filum terminale in which scar tissue from a spina bifida lesion or lipomeningocele prevents longitudinal growth as the child grows, resulting in neurologic deficits involving bowel, bladder, and lower extremities. This is best evaluated with serial MRI and neurosurgical release indicated for progressive impairment. Local clinical signs of tethered spinal cord are overlying spina bifida closure scar, nontender fatty soft tissue mass, midline dimple, or hair patch above the gluteal crease [17] (Fig. 6.23).

Congenital scoliosis is a spinal column defect present at birth, but which may not clinically or radiographically manifest until later growth and development (Fig. 6.24). There are different varieties of congenital spinal deformity described

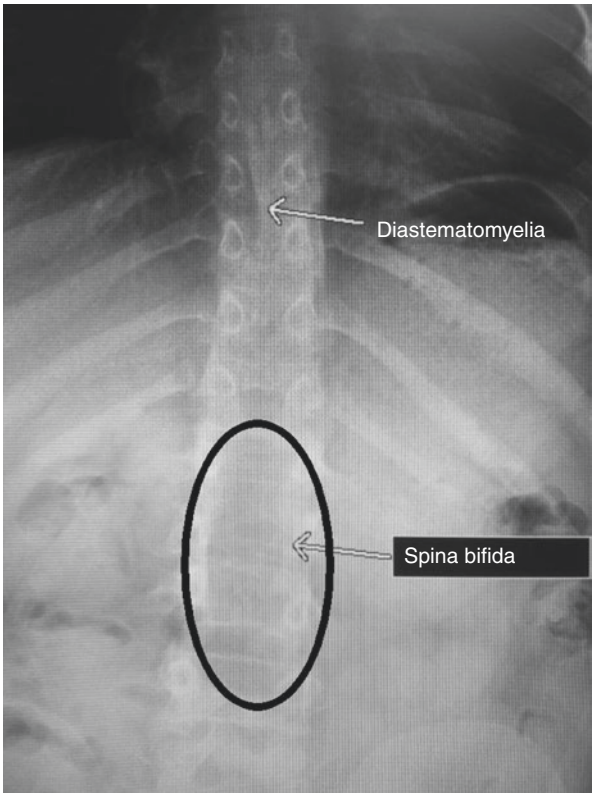

Fig. 6.22 Diastematomyelia (*arrow*). In this case, it is associated with spina bifida occulta; the circle indicates missing posterior elements in several spinal segments

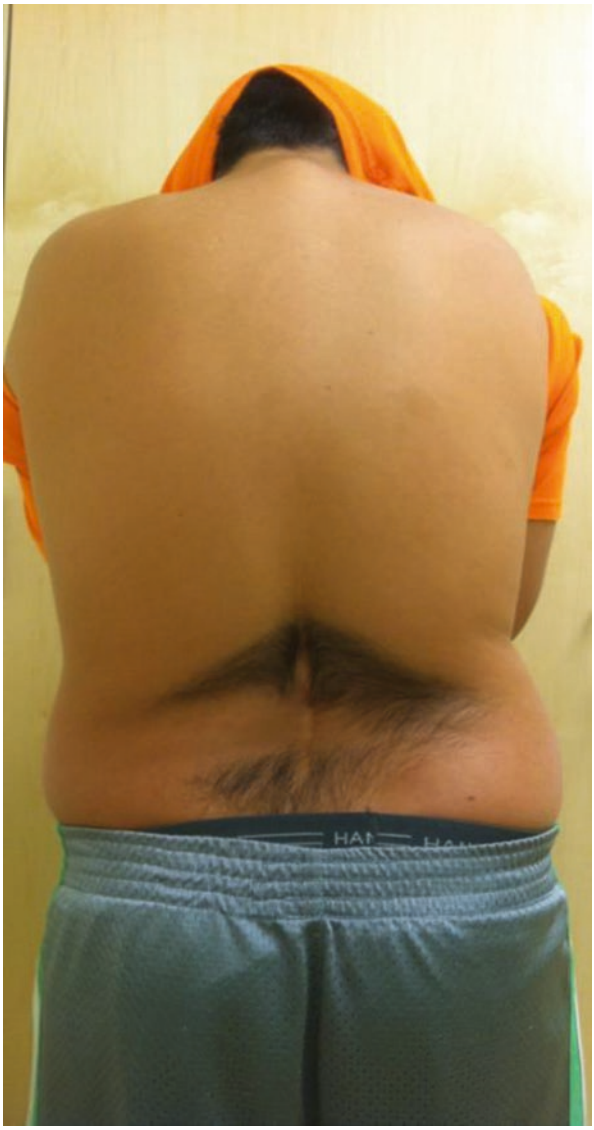

Fig. 6.23 Midline hair patch in same patient as shown in Fig. 6.22

by the shape of the malformed vertebrae such as hemivertebra, butterfly vertebra, block vertebra, and bar (unilateral fused vertebrae). Fused ribs seen on chest radiography may be a clue to the presence of congenital scoliosis. Because the heart and kidneys are forming at the same embryonic time as the spine, the finding of a congenital scoliosis requires further imaging (usually ultrasound) of the heart and kidneys.

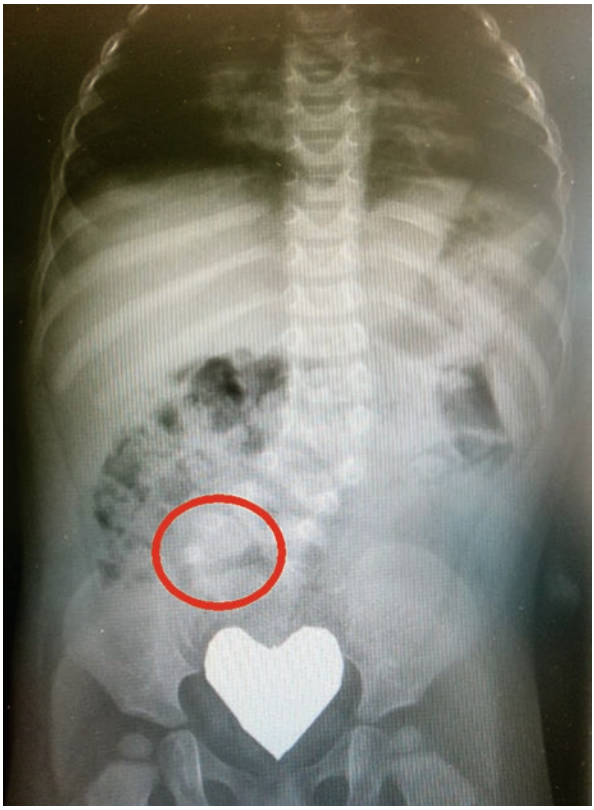

Fig. 6.24 Congenital scoliosis caused by a hemivertebra at the lumbosacral junction (*circle*) resulting in a markedly unbalanced spine

Laboratory Evaluation of Back Pain in Children and Adolescents

The initial laboratory evaluation of back pain in children and adolescents is straightforward. Laboratory studies will be normal for mechanical back pain and may be abnormal for inflammatory causes of back pain. Inflammatory causes are infectious, rheumatologic, and some neoplastic. The basic first-order studies are white blood cell (WBC), count with differential, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP). ESR and CRP are considered "acute phase reactants" which are general indicators of inflammation anywhere in the body and are therefore completely nonspecific. However, they are fairly sensitive, and it is important to know that the CRP will rise earlier than ESR in response to inflammation and will decline faster in response to treatment. Normative values depend on your hospital laboratory guidelines.

The WBC count with differential is not sensitive and therefore should not be relied upon to diagnose spinal infection or inflammatory tumor such as Ewing's

sarcoma. It is useful when elevated but not useful when normal. Also, the WBC count with differential may be perfectly normal in early cases of leukemia and even later when there are bony changes visible on plain radiographs. Do not be misled by a normal WBC count.

If infection is suspected, then routine blood cultures should be obtained, if feasible, before treating with antibiotics and may need to be repeated if initially negative. Serologic studies such as coccidioidomycosis titers and Lyme disease testing may be performed for patients with unusual exposures or those who live in endemic areas.

Rheumatologic Testing

Rheumatologic testing for spinal disease in children is usually not indicated initially except for testing for HLA-B27 antigen when ankylosing spondylitis is suspected. Ankylosing spondylitis may present in a teen or young adult with morning pain and stiffness, relieved with gentle activity and tenderness around the sacroiliac joints. The flexion, abduction, and external rotation (FABER) test (see Chap. 5) may be positive for pain in the low back and sacroiliac region. Plain films may show sclerosis of the SI joints, and MRI is useful in early stages when SI joints may appear normal on plain films. If MRI is considered for suspicion of ankylosing spondylitis, first speak with your radiologist because special sequences are required to detect early imaging findings [18].

Pearls for Imaging Studies

- Be especially suspicious of children less than age 10 years and especially those less than 5 years with back pain as having an underlying etiology.
- Plain radiographs should be obtained to *confirm* your clinical suspicion. If you suspect that a child with back pain does not have a serious condition (i.e., the out of shape teen with several week history of mechanical back pain), plain films may be delayed.
- When obtaining plain radiographs, always obtain two views (usually PA and lateral). Be careful of excessive shielding since the film may need to be repeated if a key area of concern is hidden. Make sure your institution adheres to principles of as low as reasonably achievable (ALARA).
- Be cautious about accepting a "normal" radiographic reading if you are suspicious of an underlying condition. Read the radiograph yourself, or go over the findings with the radiologist or orthopedic surgeon.

Editor Discussion

Ideally you will have a close working relationship with an orthopedic surgeon in your community who you can consult with for children who have more than the routine type of back pain. Although you may decide to order your own advanced imaging (CT or MRI) studies for children, there are many very distinct advantages to deferring to your orthopedic surgeon:

- For these atypical cases, you may want the specialist to see the child in consultation, so you can defer to the specialist to order the advanced imaging, if it is needed or not.
- It is not always clear what type of study is needed.
- If there are insurance precertification issues, then you will not have to deal with that.
- If the consulting orthopedic surgeon will be the treating specialist, it is often better for them to order the MRI or CT how they prefer it to be done.
- There are many decisions to be made in ordering advanced imaging: How much of the spine to image, i.e., entire cervical, thoracic, lumbar, and sacral spine? With anesthesia sedation or not? What to do with implants and other body metal? IV contrast or no contrast? Size of magnet needed? Special sequences needed? What to do with the abnormal findings? What to do with unexpected normal variations or incidental findings?
- It creates more work to have to follow up on normal MRI results and a LOT more work to follow up with the family on serious findings. The worse is to find out from the radiologist who is reading the study that you ordered that there is a spinal malignancy or infection on Friday evening, when all your staff are gone and you must talk with the family throughout the weekend.
- Often, the specialist, from her/his experience, can convince the family that MRI imaging is not needed or can be deferred to a later age, and parents will agree.

R.M. Schwend

Imaging and lab tests compliment the history and physical exam in the evaluation of a child with back pain. This well written, comprehensive chapter helps guide the primary care physician about what study to order for suspected causes of back pain. Two-view, AP and Lateral, plain x-ray films of the area in question is always the best initial imaging study. The pediatric orthopedic surgeon or neurosurgeon may be better prepared to order advanced imaging, and leaving the decision to her about the specifics of the advanced imaging test to order is prudent. Lastly, remember that all back pain does not come from the spine, and abdominal, renal, gynecological, and hematological etiologies should be considered.

W.L. Hennrikus

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