Imaging Adult Lumbar Scoliosis

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Introduction

Radiographic assessment is an integral component of the evaluation and management of lumbar scoliosis. Fortunately for patients and clinicians, modern imaging modalities permit the evaluation of the bony, neuromuscular, and soft tissue components of the spine with exquisite detail. The anatomic relationships and, occasionally, physiologic parameters provided by these studies are used to diagnose and quantify deformity, monitor progression, and inform decision-making by physicians and patients alike. Though plain radiographs are frequently adequate in the initial assessment of spinal deformity, the spine surgeon is equipped with several tools used to evaluate a patient radiographically with guidance based on history, physical exam, and specific clinical questions. The tools most commonly used in the radiographic evaluation of lumbar deformity include conventional radiography and advanced imaging modalities such as computed tomography (CT) and magnetic resonance imaging (MRI), each of which may be adapted or occasionally substituted as necessary to glean specific information. The primary goal of this chapter is to introduce the imaging modalities used to assess patients within each phase of evaluation and their applications to particular clinical scenarios.

Conventional Radiography

The earliest musculoskeletal imaging dates back to the first radiograph of the hand of Wilhelm Conrad Roentgen's wife in 1895 after he observed a new ray that could pass through soft tissues but not bones or metal objects. Despite significant technological advances in cross-sectional imaging, more than 100 years after that Nobel Prize winning discovery, radiography remains the primary imaging study used to evaluate the spine. In its modern application, plain film radiography is the foremost used imaging modality largely due to its widespread availability, low cost, and capacity to produce expedient, high-resolution images of the spinal column. Despite minimal utility in the imaging of soft tissues, plain radiographs remain indispensable in the evaluation of bony morphology and implants. In many instances this modality may be the only imaging required in the radiographic assessment of lumbar scoliosis, especially for patients without a previous history of spine surgery and those with deformity limited to the lumbar spine.

Plain film radiography is the principal tool used in the diagnosis of spinal deformity, particu-

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larly in adults with lumbar scoliosis. Initial evaluation includes global and regional assessment with AP and lateral views ensuring visualization of C2 to the pelvis including the femoral heads, which are used in the measurement of several spinopelvic parameters. Ideally, full-body imaging is obtained in the upright, unsupported, weight-bearing position. This evaluation illustrates the true degree of deformity with axial loading [1–3], the recruitment of compensatory mechanisms, and other pathology which may contribute to pain and disability [4]. For purposes of standardization and to optimally visualize critical landmarks used in the measurement of spinopelvic parameters, the "clavicle position" should be used. In this position, the patient is asked to stand comfortably without support, with elbows fully flexed and fingers placed at the supraclavicular fossa [5].

Since its introduction to commercial practice in 2007, the innovative, whole-body stereotactic radiographic imaging system (EOS imaging, Paris, France) has revolutionized radiographic evaluation of the spine. Using Nobel Prize winning particle detection technology, stereotactic radiography offers significant advantages compared to the traditional 36-inch cassette. Firstly, with the application of slot-scanning technology, stereotactic radiography produces a high-quality image with significantly less radiation compared to standard techniques [6, 7]. Previously, evaluation and long-term monitoring of deformity resulted in significant radiation exposure to patients. Extrapolated over a lifetime of monitoring, the relatively low-dose stereotactic radiographic technique substantially reduces radiation exposure and consequently the risk of radiation-related cancer and mortality [8]. Additionally, stereotactic radiography permits the simultaneous full-body posterior-anterior (PA) and lateral (LAT) image acquisitions in an upright weight-bearing position. This unique imaging technique not only allows for full-body evaluation including compensatory mechanisms such as pelvic retroversion and knee flexion but also permits the reconstruction of a three-dimensional (3D) image from the two-dimensional (2D) biplanar digital output [9].

Conventional radiography is an especially useful imaging modality in the longitudinal surveillance of spinal deformity. On initial evaluation, plain full-body films provide an illustration of coronal and sagittal alignment and often highlight osseous abnormalities related to the deformity's etiology. While the origins of scoliosis in the aging spine are remarkably diverse, adult lumbar scoliosis is most frequently the result of asymmetric degenerative changes occurring within the intervertebral discs and facet joints. Imaging of these patients frequently reveals late findings in the natural history of the degenerative pathophysiology including disc space narrowing, endplate osteophyte formation, and facet arthrosis while providing a method of exclusion for other uncommon causes of deformity. Furthermore, patient position during imaging can be adapted to improve visualization of structures. For example, oblique, Ferguson, or Stagnara views may be used to better examine the pars interarticularis, sacrum, and pedicles, respectively. Finally, thanks to its ease of acquisition, low cost, and informative capacity, conventional radiography is ideally suited for the serial evaluation of deformity, occasionally identifying progression [10, 11], or the origins of new neurologic complaints and informing treatment.

In addition to the utility of conventional radiography in the diagnosis and longitudinal monitoring of spinal deformity, digital radiography provides a wealth of information in the postoperative evaluation as well. With the now routine use of implants for immediate stabilization of the postoperative spine, plain radiographs are an especially important tool in the radiographic assessment of patients after instrumentation [12, 13]. Unlike the metal-induced artifacts generated by cross-sectional imaging techniques, indwelling implants produce minimal artifact on conventional radiography, permitting routine monitoring of patients in the perioperative period, staged during recovery, and pending clinical symptoms such as pain, new neurological deficit, or infection.

Routine postoperative evaluation, similar to the preoperative assessment, begins with PA and lateral full-body radiography. These images are used in the assessment of coronal and sagittal alignment, implant location, and integrity as well as fusion status. All of these outcomes are importantly monitored following the alteration of spinal biomechanics, given their long-term consequences and influence on the success of operative treatment. In the nonroutine evaluation, plain radiographs serve as a practical screening tool for the identification of generators of postoperative symptomology and complications such as implant failure, pseudarthrosis, and infection. For example, though plain radiography lacks the specificity of advanced imaging modalities, osteomyelitis may be visualized without the delay associated with advanced imaging and prompt immediate intervention.

In addition to the global and regional assessment provided by PA and lateral films, supplementary studies including oblique, supine, and dynamic radiographs may be used to address specific clinical questions and for preoperative planning as well. As discussed elsewhere, the restoration of sagittal and coronal alignment requires the anticipation of reciprocal changes in the unfused segments following surgery. The interpretation of standard PA and lateral whole-body films and dynamic radiographs provides unmatched insight into the overall alignment, the mechanisms of compensation, the stability of adjacent segments, and the degree of correction expected with a given procedure. Ultimately, each of these factors will guide the formulation of treatment strategy and the anticipation of outcomes.

Secondary to the degree of the deformity itself, flexibility and stability are among the most important preoperative considerations in the primary correction of lumbar scoliosis. Whether a deformity is fixed, rigid, or flexible will have radical implications on the prognosis and management of deformity [14–16]. Curve flexibility and the ability to compensate in adjacent regions will ultimately influence surgical approach, fusion levels, and the selection of implants. Unfortunately, there are few studies evaluating the effectiveness of radiographic methods used to determine curve flexibility among adult patients with deformity, and those evaluating adolescent idiopathic scoliosis (AIS) and neuromuscular scoliosis are instead extrapolated. To achieve this evaluation, supine, prone, standing, bending, flexion, and extension images offer a distinct advantage in allowing for a dynamic assessment of instability and flexibility which can be occulted using static imaging modalities alone. Furthermore, the severity and type of curve may instruct the use of additional studies such as push-prone, traction, or bolster radiographs which can be helpful in assessing flexibility of large, rigid scoliotic or kyphotic curves [5, 17–21].

The flexibility of a curve is often measured in the coronal plane using supine, PA, left and right lateral bending films, preferably obtained on a 36-inch cassette. While lateral bending films may be limited by strength and effort, fulcrum bending films, which involve the patient in the lateral decubitus position bent over a radiolucent fulcrum, may be more predictive of flexibility and correctability [15, 16], as they passively hinge the deformity. Additionally, because curve rigidity and adjacent compensation can vastly differ between weight-bearing and non-weight-bearing images [22], upright lateral bending films may provide additional information and influence correction. Similar to the evaluation in the coronal plane, active and passive correction of deformity is evaluated in the sagittal plane with lateral views demonstrating maximal extension and bolstered. Additionally, sitting and standing views are obtained to assess the involvement of the pelvis and distal compensatory mechanisms [23, 24]. With the combination of these views, clinicians are able to thoroughly investigate the flexibility of the deformity and optimally plan for operative correction (Fig.2.1) [22, 25]. For example, a patient demonstrating minimal flexibility on both hyperextension laterals may require anterior release and fusion or a three column osteotomy.

Despite the numerous advantages of plain radiography, advanced imaging modalities are occasionally indicated for the comprehensive evaluation and management of lumbar scoliosis. As the incidence of spinal fusion procedures is increasing nationally, it is not uncommon for patients to present with iatrogenic scoliosis, particularly affecting the lumbar spine. These patients with a history of previous surgery will often require cross-sectional imaging due to the alterations in anatomy and presence of indwelling

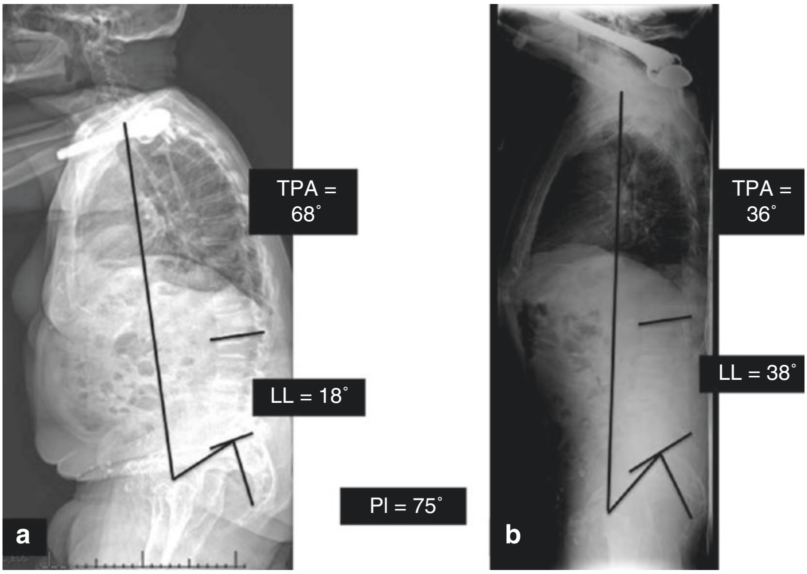

Fig. 2.1 (**a**) Standing lateral radiograph of a 73-year-old male with adult spinal deformity. T1 pelvic angle (TPA) is 68°, lumbar lordosis (LL) is 18°, and pelvic incidence (PI) is 75° with a PI-LL mismatch of 57°. (**b**) Supine lateral radiograph demonstrating considerable flexibility of the regional lumbar and global sagittal spinal deformity. TPA improves to 36° and LL to 38°; PI-LL mismatch improves to 37°

implants. In general, these patients are evaluated with a CT scan which provides axial views with superior bony characterization and soft tissue contrast when compared to plain films.

As discussed previously, plain radiographs are of little utility in the evaluation of the soft tissue components of the spine including the discs, neural elements, articular cartilage, and paravertebral musculature. Nevertheless, evaluation of these neurovascular and muscular components may be indicated as a significant proportion of patients suffer pain secondary to the compressive effects of deformity, causing stenosis, radiculopathy, or a combination of both [26]. Evaluation of these soft tissue structures, in the absence of contraindications, is generally achieved using MRI.

Computed Tomography

Computed tomography (CT) is an imaging modality which utilizes ionizing radiation, similar to conventional radiography, to generate cross-sectional images. CT offers superior characterization of bony and soft tissue abnormalities when compared to conventional radiography although the improved image quality comes at a cost of significantly increased radiation exposure [8] and image degradation in those patients with indwelling implants. The principal advantage of CT imaging over plain radiography is the assessment of bony and soft tissue structures in three planes with faster acquisition speed, lower cost, and fewer contraindications when compared to MRI.

Though CT has been largely replaced as the primary method of advanced spine imaging, there remain a number of circumstances for which CT is the preferred radiographic study. Because CT provides improved visualization of bony anatomy compared to conventional radiography and permits assessment in three planes, it is the modality of choice for nearly any indication requiring detailed evaluation of the spines bony elements.

Though not routinely indicated for the evaluation of isolated lumbar deformity, CT may be useful in the planning of operative correction. The most notable use of CT for this purpose includes the assessment of rotational deformity.

Despite high doses of radiation and limited interpretation secondary to supine positioning [2, 27], CT offers the advantage of axial imaging which most accurately illustrates rotational deformity [28]. As the degree of apical rotation is predictive for progression [10, 11] and influences curve rigidity [29], its detailed assessment may provide valuable information used to guide operative decision-making. Nevertheless, with the ability to generate accurate 3D images using EOS, the use of CT solely for this purpose is predicted to decline [30].

Prior to the widespread use of MRI, CT myelography was the study of choice in the radiographic evaluation of the neural elements. This invasive procedure involves standard CT imaging after the introduction of contrast material intrathecally. Using this study, examiners provide an indirect evaluation of the soft tissue abnormalities within the spinal canal and adjacent structures including spinal cord, nerve root bundles, vertebral discs, and thecal sac with simultaneous characterization of bony anatomy and the benefit of multiplanar reconstruction. Together, this information provides a helpful means for direct and indirect evaluation of the intrathecal contents and extradural soft tissues as well as the identification of compressive pathologies such as foraminal and central canal stenosis. Though largely replaced as an imaging modality due to its invasiveness, radiation exposure, and mediocre soft tissue contrast, CT myelography remains an important tool in the evaluation of those patients with contraindications to MRI.

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is a modern imaging modality that utilizes a strong magnetic field rather than ionizing radiation in order to characterize properties of a tissue. With the application of numerous sequences, MRI provides superior characterization of soft tissues and neural elements compared to all other imaging modalities with high tissue contrast and spatial resolution. In contrast with CT, MRI provides the direct visualization of many structures of interest including the spinal cord, nerve roots, and intervertebral discs with poor characterization of bony anatomy. Because of this superior soft tissue visualization, MRI can be an important modality for delineating the presence, extent, and complications of degenerative spinal disease.

Despite MRI's significant advantages, however, there are several limitations to its use. MRI is an expensive imaging modality with limited availability and long acquisition times, making it a poor choice as a first-line modality and for urgent applications where other studies may provide sufficient evaluation (i.e. trauma). Additionally, though modern advances in implant composition have reduced this obstacle, the presence of indwelling implants may produce important artifacts which preclude adequate image interpretation [31]. Furthermore, appropriate technique and interpretation are required in the postoperative setting, as normal postoperative imaging may include small epidural collections, granulation tissue, and osteoclastic bone resorption which can be misinterpreted as abnormal. Finally, and perhaps most significantly, there are several contraindications to MRI, imposed by its use of a strong magnetic field. The most common contraindication encountered within the aging population with lumbar scoliosis is the presence of electrically conductive devices including some permanent cardiac pacemakers, implantable cardioverter defibrillators (ICD), and implantable neurostimulators. Other relevant contraindications include metallic implants such as certain vascular stents, prosthetic heart valves, cochlear implants, and all other ferromagnetic foreign bodies.

While MRI is not indicated in the routine evaluation of isolated lumbar scoliosis, patients with neurologic complaints or physical exam findings consistent with neuropathy should receive evaluation of the implicated neural components as these findings will instruct the extent of decompression in corrective management [32, 33]. Despite the effect of axial unloading in supine imaging, conventional MRI is the most frequently used modality in the evaluation of a deformity's compressive effects, frequently illustrating varying degrees of spinal stenosis, radiculopathy, or a combination of both [26].

MRI demonstrates exceptional sensitivity in characterizing lumbar disc pathology, foraminal stenosis, epidural fibrosis, and spinal stenosis. As an example, MRI is uniquely suited for illustrating the integrity of the annulus fibrosis and hydration of the nucleus pulposus using T2-weighted or STIR sequences. Radiculopathy, resulting from nerve root impingement within the lateral recess, neural foramen, or extraforaminally, can also be visualized readily using MRI. Axial images are best used in the evaluation of lateral recess stenosis and may reveal facet osteophytes, posterior ligamentous thickening, or disc herniation. In contrast, sagittal images of neural foraminal stenosis may reveal a characteristic "keyhole" deformity, while imaging with gadolinium may illustrate inflammatory changes in and around the involved nerve root. The most common cause of spinal stenosis, degenerative change, may be characterized with equivalent accuracy to CT myelography; however, MRI offers the additional advantage of visualizing the neural structures and potential spinal cord pathology in a noninvasive procedure. Signal abnormalities associated with myelopathy, for example, are readily observed on T2-weighted images including increased intramedullary signal, potentially reflecting inflammatory edema, chronic ischemia, myelomalacia, or cystic cavitation [34].

Clinical Scenarios

In addition to the most common applications of spine imaging, there are a number of specific clinical scenarios which will occasionally require the use of special tests in combination with routine methods of evaluation. The vast majority of these scenarios include concerns for early and late complications following operative correction such as instrument malposition, CSF leak, pseudarthrosis, and infection. Despite the presence of artifacts attributed to indwelling implants, the development of metal artifact reduction techniques and advances in implant composition have significantly improved image quality and the ability to evaluate most postoperative complications. Given the challenges in evaluating these clinical entities, the modalities used in the assessment of these complications are presented separately.

Instrument Malposition/Failure

The evaluation of indwelling implant is an important undertaking in the postoperative period as instrument malposition and failure are not uncommon complications. With the increased use of bone graft, interbody cages, and plates and pedicle screws, the potential for postoperative neurologic injury secondary to malposition is not trivial. Acute L5 radiculopathy, for example, may result following anterior malpositioning of sacral pedicle screws, irritating the L5 nerve roots along the anterior sacral surface. In a retrospective study by Lonstein et al., authors identified an overall complication rate of 2.4 % *per* pedicle screw, most of which resulted from medial angulation and violation of medial cortex [35], highlighting the potential for impingement on exiting nerve roots in the lateral recess and neural foramina. Furthermore, implant failure such as fusion cage subsidence and pedicle screw fractures are encountered not infrequently [35]. In a recent series of interbody fusions using recombinant bone morphogenetic protein (rhBMP), for example, authors observed subsidence of fusion cage through the osseous endplate (>3 mm) at a rate of approximately 14 % [36].

Accurate radiographic assessment of instrumentation in the postoperative period can be achieved using multiple modalities including plain films, CT, and MRI. While plain films are often sufficient in the routine assessment of metal, the axial views generated with CT confer increased accuracy, particularly in determining pedicle screw position or loosening [37]. The selection of imaging modality, however, is greatly influenced by the implant type, size, and material composition being assessed. Interbody cages composed of carbon and titanium, for example, can be imaged using both CT and MRI, while satisfactory imaging of tantalum cages requires MRI. With the rapid advancements observed in implant composition and imaging technology, the radiographic evaluation of these implants is undoubtedly expected to improve in quality and ease.

Epidural Hematoma

Epidural hematoma is potentially devastating complication which may present with the acute onset of neurologic deficit in the immediate postoperative period. Given the potential for permanent injury, early identification of this complication is essential as is prompt surgical decompression.

The radiographic diagnosis of postoperative epidural hematoma can be complicated by the presence of instrumentation and its effect on image quality. The two most commonly used modalities for diagnosis of hematoma include CT myelography and MRI. Plain CT imaging is of little utility in the assessment of intraspinal hematoma due to the similar densities of muscle and hematoma; however, CT myelography in this setting may demonstrate the location of the compressive lesion. Nevertheless, similar to plain CT, CT myelography fails to differentiate hematoma from other forms of fluid and is therefore reserved for patients whom cannot undergo MRI evaluation. Given the limitations of other imaging modalities, MRI is the study of choice for the evaluation of this complication, despite implant-associated degradation [38–40]. If significantly sized, MR imaging may demonstrate an extradural convex, lens-shaped mass with increased signal intensity compressing adjacent thecal sac and transversing nerve roots.

Pseudomeningocele

Pseudomeningocele is the result of CSF extravasation through a dura-arachnoid tear that becomes encysted within the wound, adjacent to the spinal canal. Incidental durotomy is an underestimated event in spinal surgery with serious risks if left undiagnosed [41–45]. In a retrospective review including more than 2000 patients by Cammisa et al., authors estimated a 3.1 % incidence of dural tears among patients undergoing primary decompression for lumbar stenosis, of which 9 % were detected postoperatively requiring open surgical repair [44]. When unrecognized or repaired inadequately, persistent cerebrospinal fluid leak can result in symptoms including postural headache, vertigo, nausea, diplopia, photophobia, tinnitus, and blurred vision [46, 47] and may result in complications as significant as remote intracranial hemorrhage [48, 49].

Although myelography, CT, and MRI have been described as effective means for diagnosing postoperative pseudomeningocele, this complication can be difficult to diagnose. Due to superior soft tissue characterization mentioned previously, MRI is the neurodiagnostic study of choice in diagnosing CSF leak. CSF leak is often revealed on MRI with an evidence of epidural or paraspinal fluid collections, dilation of the epidural venous plexus, and diffuse dural thickening and enhancement. Dynamic CT myelography can also be a useful adjunct in identifying both fast and slow leaks. Studies have demonstrated an off-label use of MRI with intrathecal gadolinium to identify leaks occult to CT myelography [50].

Pseudarthrosis

Pseudarthrosis is a well-known complication of lumbar arthrodesis representing fibrous rather than osseous union of the fusion complex with rates ranging from 5 to 35 % [51–54]. Though there are numerous imaging studies used in the assessment of fusion, diagnosis remains challenging. Historically, fusion assessment was performed with surgical exploration however technological advancements in noninvasive imaging have made this practice nearly obsolete in the modern era. Currently, plain radiography and CT are the most commonly used modalities for fusion assessment [55].

Radiographs are the best suited modality for the postoperative surveillance of fusion. While signs of bridging bone are typically evident on radiographs 6–9 months postoperatively, as an early tool, plain films may be evaluated to assess for resorption versus incorporation of the graft material. In addition to the use of static imaging, dynamic lateral flexion and extension films may be used to assess the progress of interbody arthrodesis and intervertebral motion. Although pseudarthrosis may have a subtle appearance in its early development, mature pseudarthrosis characteristically demonstrates a well-defined corticate linear lucency around graft material. Several studies evaluating the utility of radiographs in diagnosing fusion have demonstrated sensitivities and specificities ranging from 42 to 89 % and 60 to 89 %, respectively, reflecting the subjective nature of this evaluation [56–58]. Nevertheless, criteria for fusion assessment with conventional radiography have been suggested (Table 2.1).

Despite adequate evaluation using plain radiography, CT is now the preferred method of fusion assessment to confirm findings or when radiographs are equivocal. Depending on the approach, distinct stages of fusion are identifiable with CT evaluation. Progress of an anterior fusion, for example, is evident by trabecular bridging without lucencies or cystic changes adjacent to hardware, while a posterolateral fusion mass begins as a conglomerate of morselized bone fragments and progresses to discrete fragments and finally solid bony bridge. In contrast to these findings, CT imaging of pseudarthrosis often illustrates cystic changes and lucencies adjacent to implants, suggestive of residual intervertebral movement [59]. Prior to numerous advances in high spatial frequency algorithms and multiplanar thin section CT, studies evaluating CT for detection of lumbar fusion estimated sensitivities and specificities ranging from 53 to 97 % and 28 to 86 %, respectively [56, 58, 60].

Table 2.1 Radiographic criteria for the assessment of fusion utilizing conventional radiography

1. Less than 3° of intersegmental position change on lateral flexion and extension views
2. No lucent area around the implant
3. Minimal loss of disc height
4. No fracture of the device, graft, or vertebra
5. No sclerotic changes in the graft or adjacent vertebra
6. Visible bone formation in or about the graft material

Source: Ray [62]

Infection

Despite substantial advancements in the operative treatment of spinal deformity, surgical site infections remain a significant source of morbidity and mortality. Postoperative infection can occur in the form of meningitis, arachnoiditis, discitis, osteomyelitis, and superficial or deep wound infection and may manifest well into the late postoperative period [61]. Identifying infection in the postoperative spine is an especially challenging task and will often require the use of several modalities combined with clinical judgment given the wide range of both normal and abnormal postoperative findings.

Evaluation and diagnosis of infections limited to the soft tissue structures of the spine are relatively straightforward. The modality of choice for evaluating this complication is most commonly CT.

In contrast to the more superficial wound infections which are readily observed on CT images, deep infections adjacent to the spinal cord pose additional diagnostic challenges: meningitis, arachnoiditis, and discitis.

Osteomyelitis is an especially difficult complication to identify radiographically and may require the use of several imaging modalities for diagnosis.

Assessment of Bone Mineral Density

The preoperative radiographic evaluation of patients with lumbar scoliosis is not complete without an assessment of bone mineral density. Degenerative scoliosis is more prevalent among elderly patients. Schwab et al. demonstrated that 68 % of volunteer subjects over the age of 60 had scoliotic deformities [63]. With the aging of our population, the prevalence of adult spinal deformity and that of osteoporosis will continue to increase [63, 64]. Osteoporosis is defined by the World Health Organization as having a T-score less than −2.5, which is a bone mineral density that is 2.5 standard deviation below that of an average 25 years old [64].

Dual-energy x-ray absorptiometry (DEXA) is the standard for assessing bone mineral density, and low DEXA scores have been correlated with increased fracture risk and diminished treatment efficacy [65]. The American College of Radiology recommends osteoporosis screening for all women older than 65 and men older than 70 years of age [66]. However, a DEXA assessment may be indicated in younger patients if there is reasonable clinical suspicion of low bone mineral density especially in the setting of planned surgical correction of lumbar scoliosis [64]. Schreiber et al. proposed an alternative to DEXA using Hounsfield units measured from CT scans which allows for a more direct regional assessment of bone mineral density of the spine [67]. They correlated Hounsfield units with DEXA T-scores, age, and compressive strength of the vertebra. Pickhardt et al. described using CT scans obtained for other clinical reasons as "opportunistic" screening tools for osteoporosis [68]. Meredith et al. demonstrated that patients with fractures adjacent to spine fusions had lower bone mineral density measured by Hounsfield units at the fracture level and globally in the spine when compared to nonfracture controls. Moreover, low bone mineral density has been found to be an important risk factor in the development of proximal junctional kyphosis and proximal junctional failure following adult spinal deformity correction [69, 70]. These findings demonstrate the clinical importance of bone mineral density assessment prior to correction of lumbar scoliosis.

Conclusion

A complete radiographic assessment of lumbar scoliosis includes the use of standing 36-inch cassette x-rays or full-body stereotactic radiography for the assessment of global spinal deformity and compensatory mechanisms, advanced axial imaging to define spinal canal stenosis and neurologic compression, supine imaging for the assessment of deformity flexibility, and DEXA or CT imaging for the assessment of bone mineral density. Only with a complete radiographic understanding of the spinal deformity can the surgeon undertake the appropriate preoperative planning and intraoperative execution of the surgical goals for an optimal postoperative outcome.

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