Chapter 4
Lumbar Spine Osteoarthritis

Y. Raja Rampersaud, Akihiro Nakamura, and Stephen J. Lewis

Key Points

- Spinal degeneration is often not considered in the same context as osteoarthritis (OA); however, the degenerative changes in the disc and, in particular, the synovial facet joints are consistent with those of OA elsewhere.

Y.R. Rampersaud, MD, FRCSC (✉)
Division of Orthopaedic Surgery, Department of Surgery, Toronto Western Hospital, University Health Network, University of Toronto, Toronto, ON, Canada

Arthritis Program, Toronto Western Hospital, University Health Network, University of Toronto, Toronto, ON, Canada

Spinal Program, Krembil Neuroscience Center, Toronto Western Hospital, University Health Network, University of Toronto, Toronto, ON, Canada

Division of Orthopaedic Surgery, Department of Surgery, University of Toronto, Toronto Western Hospital, University Health Network, 399 Bathurst St. East Wing, 1-441, Toronto, ON M5T-2S8, Canada
e-mail: raja.rampersaud@uhn.ca

A. Nakamura, MD
Division of Genetics and Development, Toronto Western Research Institute, University Health Network, Toronto, ON Canada

S.J. Lewis, MD, MSc, FRCSC
Division of Orthopaedic Surgery, Department of Surgery, Toronto Western Hospital, University Health Network, University of Toronto, Toronto, ON, Canada

Arthritis Program, Toronto Western Hospital, University Health Network, University of Toronto, Toronto, ON, Canada

Spinal Program, Krembil Neuroscience Center, Toronto Western Hospital, University Health Network, University of Toronto, Toronto, ON, Canada

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- The main clinical symptoms of lumbar spine OA (i.e., facet joint OA) are low back pain and associated leg symptoms (pain, numbness, and weakness).
- Various factors contribute to the degenerative changes, including age, biomechanical factors, systemic factors, genetics, and lifestyle.
- Although there is no universal nonsurgical or surgical treatment for spine OA, exercise and activity modification is typically accepted as an effective form of initial management.
- For end-stage disease, nonsurgical treatment has limited efficacy and surgical intervention in appropriately selected patients is associated with good patient-reported outcomes that are comparable to those associated with total knee replacement for OA.
- This chapter focuses on the latest knowledge on lumbar spine OA and associated clinical presentations to enable further understanding from both a clinical and a research perspective.

Introduction

Each spinal segment, except one cervical spine level (C1–C2), consists of an anterior situated intervertebral disc and smaller paired posterior facet joints (also termed the zygapophyseal joint), thereby comprising a "three-joint complex." Intervertebral disc degeneration and vertebral osteophyte formation do not share the exact same pathophysiological process of degeneration associated with osteoarthritis, in part due to a lack of synovial structures, and thus do not meet the definition of OA. However, the facet joint is a synovial joint (hyaline cartilage overlying subchondral bone, a synovial membrane, and a joint capsule) that shares the same pathophysiologic attributes of appendicular OA [1, 2]. Due to the wide variety of confounding factors, the interplay between disc degeneration and spine OA as they relate to clinical sequelae and OA as a whole remains unclear [3]. Given the increasing prevalence and tremendous disease burden of low back pain (LBP) and the overlap with that of OA [4–7], spine OA represents an important area of clinical and research focus.

OA is a major cause of disability and is one of the most frequent musculoskeletal disorders [8, 9]. LBP, including that caused by spine OA, is ranked as the single leading cause of disability worldwide [8, 9]. From a societal perspective, the annual economic burden of spine OA, including health-care costs and lost work hours, has been estimated in billions of dollars [10]. Clinically, OA is characterized by cartilage deterioration, persistent inflammation, synovial fibrosis, sclerosis of the subchondral bone, and osteophyte formation at the joint margin [11]. OA is observed throughout the appendicular and axial skeleton, affecting both weight-bearing and non-weight-bearing joints. There exists a tremendous amount of clinical and basic science research in OA. However, in the spine due to a historical focus on disc

degeneration and the association of spine degeneration with neurologically induced symptoms and sequelae, the epidemiologic, clinical, and basic research focus of appendicular OA and spine degeneration typically occurs in isolation from each other. Furthermore, the study of facet joint OA is grossly deficient.

A variety of both mechanical and nonmechanical factors can contribute to the pathogenesis of spine OA [3]. Aging is the most common risk factor; however, others such as genetic and systemic factors similar to what have been demonstrated for knee OA [1] may also play significant roles for the pathogenesis and warrant exploration and discussion. In particular, the identification of spine OA specific microRNAs (miRNAs) may have potential of being biomarkers that both enable early disease detection and enable targeted treatment(s). At present, we still rely on clinical diagnosis of facetogenic-based symptoms (i.e., extension-based LBP and/or neurogenic claudication relieved by forward flexion) and correlation with imaging such as computed tomography (CT) and magnetic resonance imaging (MRI) [12, 13]. However, imaging does not always correlate with clinical symptoms, with many asymptomatic individuals demonstrating significant structural abnormalities on spine imaging [14]. Consequently, in the absence of red flags (e.g., suspicion of cancer, infection, fracture, or neurological deficits), imaging is not required, nor recommended, for LBP that is manageable and nonprogressive. The treatment options for spine OA ranges from self-management to complex surgery. Although generally associated with a favorable natural history and manageable by conservative means [13], approximately 20 % of patients with spine OA have progressive or persistent severe symptoms that undergo surgical management [15]. Surgery is typically aimed at addressing the structural changes that have led to increasing nerve compression due to facet joint and ligamentous hypertrophy (i.e., lumbar spinal stenosis (LSS) causing neurogenic claudication) and/or failure of both facet joint and the disc, leading to spinal instability with resultant degenerative spondylolisthesis (slippage of one vertebrae over the next in the anterior-posterior plane) and/or degenerative scoliosis (coronal/rotational plane deformity that develops in late adulthood).

In this chapter, we focus on the latest knowledge on lumbar spine OA, including the epidemiology, pathogenesis, clinical characteristics, and treatments options. In addition, we will touch on areas requiring further research to improve our understanding of spine OA and its role in the overall bigger picture of OA.

Anatomy and Kinematics of the Spine

Basic knowledge of spine structure is necessary to understand spine OA. The human spine consists of 33 bony vertebrae: 7 cervical, 12 thoracic, 5 lumbar, 5 sacral (fused), and 4 coccygeal (usually fused). At every spine level below the second cervical vertebra, the term “three-joint complex” is often used in describing the spinal structure, which is formed by the three articulations between two vertebral levels: one disc and two facet joints (Fig. 4.1). Together, with the ligamentous

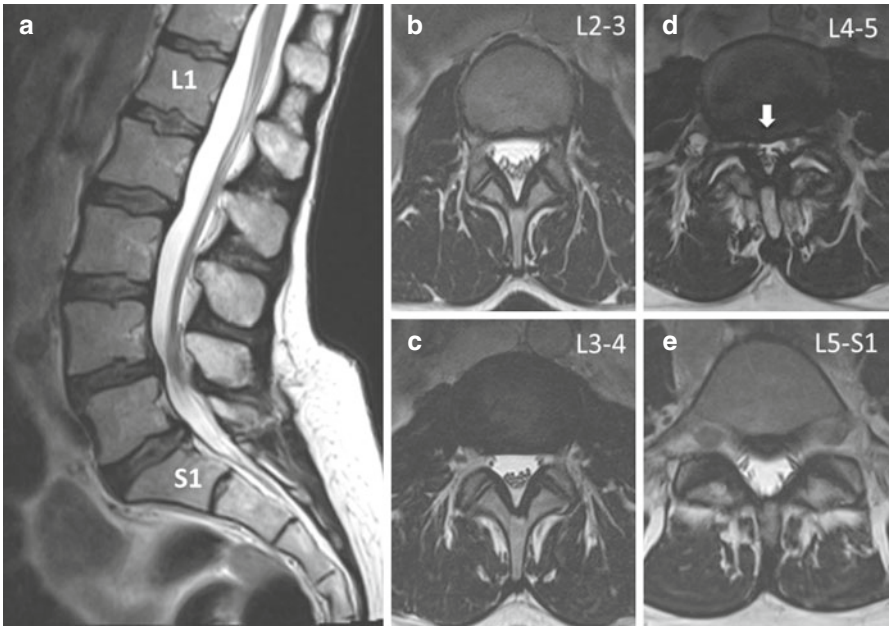

Fig. 4.1 (**a**) Midsagittal MRI demonstrating the L1–S1 vertebrae in a 47-year-old female. (**b**–**d**) Axial views of the facet joint from L2–L3 to L5–S1 vertebrae. Each vertebra connects to an adjacent vertebra with two facet joints (**b**–**e**) and intervertebral disc to form the three-joint complex that makes up the spine functional unit. As can be seen, the orientation of the facet joints progressively changes from a more horizontal orientation at L5–S1 to a more oblique or vertical orientation at L2–L3. This enables complex kinematics of the lumbar spine. Also demonstrated in (**d**) is the evidence of facet joint OA, with hypertrophy of the bony articulations and the ligament that is resulting in stenosis of the spinal canal (*white arrow*) compared to other levels where the facets are essentially normal in appearance. In addition, there is minimal disc degeneration in this particular patient

structures, the pairing of two vertebrae is termed the functional spinal unit. Although these three joints are closely related to each other functionally, the facet joints are anatomically distinct from the disc because they are true synovial joints, containing hyaline cartilage, synovial membrane, and a fibrous joint capsule [16]. The facet joints form an articulation between the inferior articular process of the vertebrae above and the superior articular process of the vertebrae below and enable the significant multiplanar motion of the spine. In the lumbar region, the facet joints are inclined to a nearly vertical and oblique orientation and are curvilinear, such that they limit rotation as well as forward displacement, but allow significant flexion [17, 18]. Clinically, the range of motion for the lumbar spine varies significantly and depends on age (reduces with increasing age), sex (greater in women than men), the presence or absence of LBP (reduced with LBP), and most significantly the method of measurement [19]. In healthy individuals, flexion has been reported to range between 23° and 92°, extension 17–56°, lateral flexion 28–44°, and rotation 5–15° (in either direction). The spinal musculature is also critical to spinal kinematic and dynamic stability. The musculature controls the movement of the

spine and dynamically stabilizes the spinal functional units throughout physiologic spinal movement [20].

Joint alignment, load distribution, and wide range of movement are thought to be major anatomical factors in the development and progression of spinal OA (see below) [21].

Prevalence

The exact incidence of spine OA is impossible to pinpoint due to the fact that the degenerative process is initiated years before the clinical symptoms and morphologic abnormalities are detected. In addition, many patients with mild and/or episodic symptoms do not seek health care. Nevertheless, cross-sectional population-based studies in adults give a reasonable estimate of the prevalence of spine OA. The lumbar region is the most common sight of spine OA. However, it must be clear that one has to consider the gross difference between symptomatic prevalence and radiographic or cadaveric prevalence of facet joint OA. For example, a recent population-based clinical study showed that the prevalence of symptomatic lumbar facet joint OA was 7.4 % [22]. Comparatively, cadaveric studies of the lumbar spine reported that at least 50 % of the population demonstrates lumbar facet joint OA [23]. It is well established that the radiographic prevalence of spine OA increases with age similar to other synovial joints. Kalichman et al., from the Framingham Heart Study, reported OA of the facet joints was present in 24.0 % of <40-year-olds, 44.7 % of 40–49-year-olds, 74.2 % of 50–59-year-olds, 89.2 % of 60–69-year-olds, and 69.2 % of >70-year-olds [24]. Surprisingly, even for individuals who are less than 40 years old, the presence of facet joint OA ranges from 3.4 to 36 % [1, 22, 25]. In terms of gender, data is limited and thus it is not clear which gender is more radiographically or clinically affected by spinal OA [25]. However, Kalichman et al. [26] have demonstrated a greater ratio of degenerative spondylolisthesis in women. Recent work by Goode et al. from the Johnston County Osteoarthritis Project has also shown facet joint OA is radiographically greater in women (61.6 %) than men (51.6 %); however, facet joint OA was not correlated to self-reported LBP.

Joint Areas Affected

Almost all studies showed that the level of L4–L5 is the most affected region among lumbar spines, followed by L3–L4 or L5–S1 [23, 24, 27, 28]. Kalichman et al. reported the prevalence at the spinal level and noted that the prevalence of facet joint OA was 15.1 % at L2–L3, 30.6 % at L3–L4, 45.1 % at L4–L5, and 38.2 % at L5–S1 [24].

Disc degeneration is considered as another important factor for progressing spine OA. Recent studies revealed that disc degeneration precedes the changes of OA in other joints such as the knee and hip and is more common [29–31]. Bajwa et al.

reported in the 340 specimens of a cadaveric human study that 35 % of specimens of age younger than 29 years had evidence of degenerative disc and 17 % of them had hip OA changes. At 70 years, 100 % of specimens had evidence of disc degeneration and 50 % of hip OA changes. They found that there was a significant association between lumber disc degeneration and hip OA changes and lumbar degeneration precedes hip degeneration [31]. Fujiwara and his colleague reported the relationship between facet joint OA and disc degeneration on the lumbar study assessing 84 lumbar facet joints by MRI [29]. They found all patients with facet joint OA had some degrees of disc degeneration, even the population under 40 years old. In addition, they noted that disc degeneration was the primary event leading to facet joint OA, due to increased loading of facets that occurs as a result of disc degeneration. A similar study reported by Vernon-Rogerts and Pirie showed that disc degeneration occurred in advance of facet joint OA and the formation of osteophytes [30]. In a community-based population study, Suri et al. demonstrated similar findings for the majority of individuals [32]. However, 22 % of the individuals studied demonstrate patterns of degeneration, beginning in the posterior joints. The authors found that increased age and BMI and female sex may be related to the occurrence of isolated posterior degeneration in these individuals. In a preliminary work for our center, we have found that this occurrence may also be associated with spino-pelvic parameters, in particular a higher pelvic incidence, which is a fixed anatomical relationship between the pelvis and sacrum that imparts greater lumbar lordosis and, hence, increased facet loading (Fig. 4.2) particularly at the lower lumbar levels [33]. The pelvic incidence in women is typically greater than men.

Symptoms of Spine OA

Activity-limiting LBP, in particular, has a worldwide lifetime prevalence of approximately 39 % and a similar annual prevalence of 38 % [9]. LBP is second only to the common cold in frequency [34], is the most common reason for time-off work, and has a total social cost of more than $100 billion annually [35]. Up to 85 % of patients never receive a definitive diagnosis and are classified as having nonspecific pain [36]. The source of LBP remains a very controversial topic, and a detailed discussion is not within the scope of this chapter, but suffice it to say that LBP, as is OA pain, is multifactorial involving both peripheral and central mechanisms [3].

As noted above, the prevalence of radiographic spine OA compared with symptomatic spine OA is grossly different. Previous studies assessing the association between LBP and imaging characteristics of spinal degeneration are listed in Table 4.1. The majority of studies have found that disc space narrowing (DSN) is the most significant radiographic factor associated with LBP. In a recent study of community-based US older adults, Suri et al. are the first to demonstrate that severe facet joint OA was more common in participants with back pain than those without (63.2 % vs. 46.7 %; $p=0.03$) [37]. In the study of 252 patients who were participants in the Framingham Heart Study multivariable analysis, adjusting for sociode-

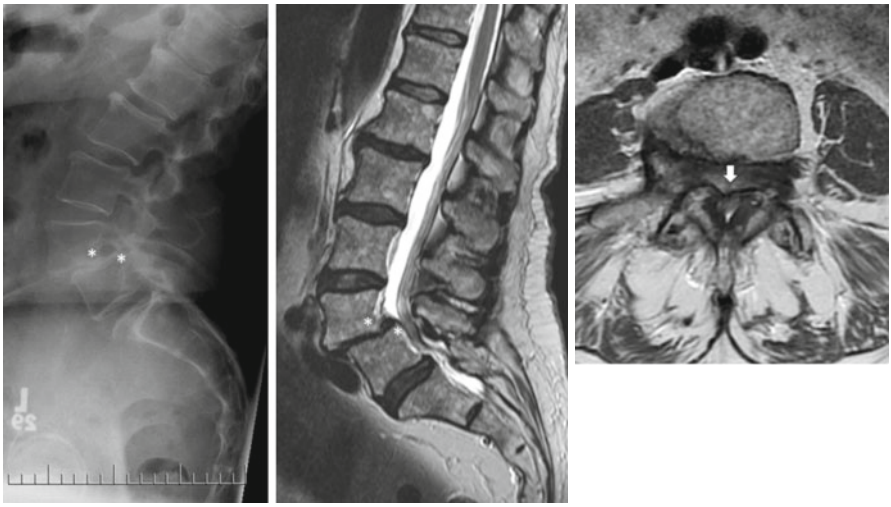

Fig. 4.2 Lateral standing radiograph, midsagittal MRI, and axial MRI at L4–L5 in a 71-year-old female with a degenerative spondylolisthesis at L4–L5 and associated back pain and neurogenic claudication with less than one-block walking tolerance. As marked by the *white asterisks*, the L4 vertebra has slipped forward on the L5 vertebra. In combination with the facet joint OA, this causes severe spinal stenosis to the point where the spinal fluid is no longer seen (*white arrow*) compared to the degree of stenosis demonstrated in Fig. 4.1. This particular patient has a high pelvic incidence (74°; normal is approximately 50 ± 10°) which gives her higher than normal lordosis, which increases the loading of the facet joints and decreases the load on the disc. Complete disc collapse is seen at the L4–L5 level, with relative normal discs above and below

mographics, health factors, and disc height narrowing, the association of severe facet joint OA remained significant (odds ratio of 2.15 (95 % confidence interval, 1.13–4.08)), with a greater number of joints with severe facet joint OA also conferring a greater odds of having frequent back pain. Interestingly, disc height narrowing was independently associated with back pain in younger adults < age 60 years, but not in older adults. These findings conflict with prior studies [4, 24, 38] showing no association or only minimal association between facet joint OA and LBP. In these studies, patients were relatively younger and the severity of OA was not considered. Interestingly, studies that have investigated edema of the lumbar facet joint have showed significant correlation with LBP [39, 40]. Bone marrow edema is considered a possible cause of pain in the musculoskeletal system [41]; however, its diagnostic or prognostic capacity function remains unclear in the spine.

Osteophytes resulting from facet joint OA and/or ligamentous hypertrophy that is associated with facet joint OA (i.e., spinal stenosis) may directly impinge on the spinal nerve roots or the spinal cord which may cause severe pain and/or neurologically based back and leg symptoms, commonly termed neurogenic claudication [13, 42]. It is estimated that LSS causing neurogenic claudication affects about 20 % of people older than 65 years and about half of that group suffer serious restrictions in their daily routines [13, 43]. In a recent study by Battie et al., the authors demon-

Table 4.1 Previous studies shown the association between low back pain and clinical images of the spine

	Imaging modality	Mean age (years)	Sample size	Country	FOA OR (95 % CI)	DSN OR (95 % CI)	OST OR (95 % CI)
Savage et al. [143]	MRI	36	149	The UK	4.4 (0.9–21)	N/A	N/A
Pye et al. [144]	Radiograph	65	585	The UK	N/A	1.7 (1.1–2.4)	0.7 (0.4–1.4)
Kjaer et al. [38]	MRI	40	412	Denmark	1.1 (0.7–1.6)	1.8 (1.2–2.7)	N/A
Kalichman et al. [24]	CT	53	188	The USA	1.0 (0.5–2.1)	[a]K–L ≥ 2	[b]K–L ≥ 3
Muraki et al. [145]	Radiograph	74	2,288	Japan	N/A	[a]Men = 1.4 (0.9–2.4) Women = 1.8 (1.4–2.4)	[b]Men = 1.2 (0.7–1.9) Women = 1.0 (0.7–1.4)
de Schepper et al. [146]	Radiograph	65	2,819	The Netherlands	N/A	1.4 (1.1–1.7)	1.2 (1.0–1.5)
Kalichman et al. [147]	CT	53	187	The USA	0.8 (0.3–1.9)	1.4 (0.6–3.3)	N/A
Goode et al. [4]	Radiograph	60	840	The USA	0.8 (0.6–1.2)	1.4 (1.0–1.8)	1.1 (0.8–1.5)
Suri et al. [37]	CT	67	252	The USA	2.2 (1.1–4.0)	0.7 (0.4–1.3)	N/A

FOA facet joint osteoarthritis, *DSN* disc space narrowing, *OST* osteophyte

[a,b] Used Kellgren-Lawrence grading

strated that the associated health burden of LSS on health-related quality of life was significant and is about the same or greater than diabetes, heart disease, arthritis, or stroke. The hallmark of neurogenic claudication is spinal symptoms that are relieved by forward flexion (e.g., sitting or walking in a flexed posture using a "shopping cart") [12]. The physical exam is often normal; however, in more severe cases of LSS, static objective neurological deficits may occur.

Diagnosis

The diagnosis of spinal OA is ultimately based on medical history and physical examination and confirmed by imaging. The most common presentation is LBP with or without radicular or claudicant leg symptoms that are typically brought on by standing or walking (i.e., erect posture) and relieved by forward flexion of the spine [12, 13, 44]. Due to multiple potential sources, the presentation of symptomatic spine OA must be differentiated from other common causes of LBP [44, 45].

Differential Diagnosis

In clinical practice, patients with LBP regardless of presentation must be screened for red flags (e.g., fevers, unexplained weight loss, progressive neurological deficit) that are associated with more serious but less common causes of back pain (such as infection, cancer, or fracture) and represent an indication for urgent or emergent investigation in patients who present with LBP [46, 47]. With respect to facet joint OA, it is important that the typical clinical presentation of other mechanical LBP disorders be excluded as they all can increase progressively with age (often coexisting) (Table 4.2) [44].

Imaging

It is important to note that the severity of symptoms, treatment decisions, outcomes of treatment, and even the existence of symptoms do not strongly correlate with spinal imaging [14, 48, 49]. For example, 22–51 % of asymptomatic individuals have been shown to demonstrate MRI irregularities in their lumbar spine, with this number increasing to between 57 and 80 % for those over the age of 60 [50, 51].

Multiple modalities exist that can assess spine OA including radiography, CT, MRI, and hybrid single-photon emission computed tomography/CT (SPECT/CT). Plain radiograph, CT, and MRI are most commonly used in clinical practice (Table 4.3, Fig. 4.2).

Table 4.2 Common clinical presentation of mechanical low back pain

Clinical observation	Spine osteoarthritis causing LBP	Herniated disc causing radiculopathy	Spinal stenosis (end-stage spine OA causing claudication)	Degenerative disc causing LBP
Age (in years)	>40	30–50	>60	30–50
Straight leg raising (SLR) test	No	Yes	Yes (after standing and walking; SLR is typically negative)	No
Leg pain, numbness, or tingling	No	Yes	Yes	No
Dominant location	Back	Back/leg (unilateral)	Leg (unilateral or bilateral)	Back
Onset	Insidious	Acute	Insidious	Insidious
Increased with standing erect	Yes	No	Yes	Variable
Increased with sitting	No	Yes	No	Yes
Increased with forward bending	No	Yes	No	Yes

Modified from Hall et al. [45]

Table 4.3 Utility of clinical images to detect OA changes in the spine

	Disc		Facet joint						
	Degeneration	Intervertebral narrowing	Joint space narrowing	Osteophyte of articular process	Hypertrophy of articular process	Sclerosis	Subchondral erosion	Subchondral cysts	Subchondral edema
Radiography	x	√	√	√	x	√	x	x	x
CT	x	√√	√√	√√	√√	√√	√√	√	x
MRI	√√	√√	√√	√√	√√	x	√√	√√	√√

Modified from Gellhorn et al. [1]
x no utility, √ moderate utility, √√ good utility

Radiographs

Due to their inexpensive cost and universal availability, radiographs remain the most common initial imaging choice of many bone and joint disorders [52]. They are typically limited to picking up gross abnormalities of the bone and to a lesser degree the soft tissue; however, due to the ability to easily image in an upright/loaded or dynamic posture(s), they are superior for the assessment of malalignment or instability of the spine. For spine OA, radiographs are limited to detecting disc degeneration by narrowed intervertebral spaces and the appearance of osteophytes (Table 4.3). Similarly, it is relatively easy to identify gross facet osteophytes (i.e., hypertrophy) and severe joint-space narrowing of facet joints (on oblique views) but very limited with respect to detecting lower grades of hypertrophy of articular process, subchondral erosion, and subchondral cysts. Pathria et al. divided the radiographic features of facet joints into four groups [52]. Normal facets were classified as grade 0, facets with joint-space narrowing as grade 1, facets with narrowing plus sclerosis or hypertrophy as grade 2, and facets with severe degenerative disease encompassing narrowing, sclerosis, and osteophytes as grade 3. They demonstrated that the sensitivity and specificity for oblique radiographs to distinguish between the presence and absence of degenerative disease in the lumbar facet joints in patients with LBP were 55 and 69 %, respectively. Since the specificity was high but the sensitivity was not as good for early or middle stage, they concluded that the utility of radiographs should be limited only when patients with LBP are being screened. Currently, unless there exist significant clinical concerns of serious underlying pathology, radiographic screening or other forms of imaging are strongly discouraged for the aforementioned reasons [14].

CT

The axial nature of CT provides much more detailed bony information for spine OA, especially with respect to facet joint changes compared with standard radiographs [53]. As shown in Table 4.3, CT can detect almost all changes seen in the spine OA, although it is not as useful as MRI in depicting the disc degeneration and subchondral cysts. Specifically, Leone et al. reported that CT clearly delineates most degenerative changes including articular process hypertrophy, osteophytes, subchondral sclerosis, and capsular and ligamentous calcification [54]. However, exposure to the radiation dose associated with CT should always be considered particularly when serial imaging is required.

MRI

MRI depicts internal structures of joint based on their chemical composition [55]. A major advantage of MRI in the evaluation of OA is its ability to evaluate non-calcified tissues. The periarticular soft tissues such as the ligaments, tendons,

muscles, synovium, and cartilage are directly visualized and are readily evaluated with MRI. However, with the exception of edema, MRI is less sensitive to detect bony OA changes of spinal structures [56]. More recent imaging techniques utilizing fat-suppressed MRI sequences, which are more fluid sensitive than conventional MRI such as fat-suppressed T2-weighted images (e.g., short T1 inversion-recovery [STIR] sequences). MRI has no radiation exposure, although there are several contraindications including orbital metallic foreign bodies, cardiac pacemakers or implanted defibrillators, and cochlear implants [57] and other metallic implanted devices.

Comparison of CT and MRI

Weishaupt et al. investigated the coefficient between MRI and CT in the assessment of facet joint OA [58]. They were using a four-point scale similar to that of Pathria, and images of both CT and MRI were assessed by two musculoskeletal radiologists independently. As a result, the weighted kappa coefficients for MRI versus CT were 0.61 and 0.49, for readers 1 and 2, respectively (0.41–0.60 = moderate, 0.61–0.80 = substantial). Looking at the agreement between CT and MRI imaging within one grade, it was at 95 % and 97 %, respectively. In addition, the majority of disagreements were in mild grades. From a clinical perspective, the authors suggested that the agreement between CT and MRI was adequate and, thus, a CT in the situation of existing MRI is not required for grading the severity of facet joint OA.

Fujiwara et al. reported that CT is better able to demonstrate the degenerative bony changes of facet joints; however, the detection of joint effusions and juxtafacet synovial cysts is less sensitive than MRI [29].

Leone et al. examined nine human autopsy specimens with CT and MRI and compared them with histopathologic findings. CT delineated the most degenerative changes including articular process hypertrophy, osteophytes, subchondral sclerosis, and capsular and ligamentous calcification. On the other hand, MRI was better able to depict cartilage surface tears in specimens demonstrating mild and advanced stages of degeneration [54].

SPECT/CT

Recently, hybrid SPECT/CT imaging has been introduced for spine OA. SPECT/CT provides functional imaging and is used to detect microcalcification due to increased osteoblastic activity [59]. Hosam et al. reported identification of potential pain generators in 92 % of cervical spine scans and 86 % of lumbar spine scans with SPECT/CT supported by a good response to the intra-articular steroid injections. The most common method for diagnosing a facetogenic source of LBP is with low-volume intra-articular and medial branch blocks, both of which are associated with high false-positive rates. SPECT/CT may represent a noninvasive alternative. Dolan et al. noted that there are 95 and 79 % response rates at 1 month and 3 months, respectively, after injection therapy in patients with SPECT-positive facets [60].

Pneumaticos et al. also reported that significant improvement in LBP was shown only when SPECT-positive facet joints were subjected to injection therapy [61]. Hariankar et al. investigated the correlation of SPECT/CT findings with clinical features and MRI findings. They concluded SPECT/CT had less sensitivity for detecting facet arthropathy but is likely to be more specific as compared to MRI [62]. Furthermore, because of its significantly higher accuracy, SPECT/CT could be the conventional nuclear medical procedure of choice for patients with lower back pain after lumbar fusion surgery to clarify the pathogenesis of persistent pain [63].

Diagnostic Blocks

Facet pain often overlaps disc pain and may coexist with disc disease. In 1976, Mooney and Robertson introduced a technique of injecting steroid preparations and local anesthetic into the facet joint [64]. It is generally accepted in clinical practice that diagnostic blocks are the most reliable and minimally invasive procedures for diagnosing facet joints as pain generators [65]. Intra-articular injections and medial branch block (MBB) are readily available and are equally effective [66]. Due to their location, size, and orientation, facet blocks are performed under radiographic guidance such as CT or fluoroscopy. Ultrasound-guided blocks have been proposed, although they may be less likely to detect low-volume intravascular uptake and are less accurate in obese woman [67]. It is well known that single diagnostic blocks have been shown to be associated with a high false-positive rate [68] and repeated blocks are recommended. The use of local anesthetics enables the determination of pain relief and is used for diagnostic purposes, whereas the use of corticosteroids may provide short-term therapeutic relief (see section "Treatment" below).

Pathogenesis/Risk Factors

Degenerative spine OA is a multifactorial process, with contributions from both systemic and local factors. Genetic predisposition and mechanical factors can contribute to both disc degeneration and facet joint OA with disc degeneration typically proceeding that of facet joint [69]. Spine OA can lead to associated subconditions, such as spinal instability and deformity (see section "Treatment" below).

Aging

Aging is a normal process in all structures. Similar to other sites, advanced age is one of the strongest risk factors associated with spine OA [70]. The prevalence of disc degeneration clearly increases with age, in both the cervical and the lumbar

spine. Aging leads to degenerative changes starting with subtle biochemical alterations followed by microstructural and finally gross structural changes of the spinal unit. The human intervertebral disc is one of the tissues most vulnerable to degeneration in the human body with degeneration beginning as early as the second decade of life [71]. The disc itself has great variation in the matrix organization, composition, cell morphology, and activities in different regions of the disc. The annulus is a collagen-rich, concentrically organized tissue. Its outer cells are thin and elongated, while the cells of the inner annulus are rounded. The annulus protects the nucleus pulposus. The nucleus pulposus consists of chondrocytes that produce and maintain a well-hydrated proteoglycan-rich matrix. These cells have a notochordal origin and are replaced in the first decade of life by rounded chondrocyte-like cells. The disc does not have a uniform cell density. The cell density is greatest in the regions closest to the blood supply, which is generally near the end plate and at the periphery of the annulus. Aggrecan is the most prevalent proteoglycan in the disc, making up approximately 70 % of the nucleus and 25 % of the annulus. Studies have demonstrated that aging leads to the decrease of nutrient supply to the intradiscal chondrocytes [72], which in turn lead to loss of proteoglycans. As a result, a loss of glycosaminoglycans leads to the decrease in hydration of the disc, as well as the loss of mechanical competence and ability of the disc to withstand and distribute load in a normal manner [73]. These changes lead to the migration of inflammatory cells and the production of various cytokines and proteases [74], which contribute to further cellular and matrix degradation. As noted above, degeneration of the facet joints can occur secondary to disc degeneration. The altered mechanics caused by disc degeneration, including loss of disc height and segmental instability (increased micro- or macro-motion), leads to increased and unbalanced loading on the facet joints and results in cartilage alteration [71]. In addition to those two main aging processes, the aging of the ligaments, muscles, and bones is reported as a contributing factor to spinal aging [75, 76].

Genetics

For disc degeneration, the contribution of various factors including vitamin D receptor, genes encoding the collagen IX molecule, aggrecan, collagen I, and matrix metalloproteinase 3 have been reported [3, 77]. Recent studies related to miRNAs are beginning to shed light on the mechanisms of disc degeneration, as well as OA of other joints [78–81]. We are not aware of any study that has specifically looked at or identified definitive factors or pathways for facet joint OA; however, we would postulate that they would be similar to OA in other joints.

Although there are many hurdles for the translocation of current research into clinical practice at this time, several pathways related to miRNAs are expected to be targets for disease modification of OA or disc degeneration. In addition, miRNAs may also prove to be reliable biomarkers for the severity of OA and determination of treatment response. At present, miRNA expression from facet joints has not been

reported. We feel that specific assessment of the facet joint concurrently with changes in the disc is required for further understanding of the pathogenesis for spine OA.

Systemic Factors

Recently, metabolic syndrome (MetS) has been reported as an independent risk factor for OA [82]. MetS is a combination disorder including dyslipidemia, hypertension, diabetes or insulin resistance, and obesity [83] and increases the risk of cardiovascular diseases. Longitudinal hyperglycemia may disrupt chondrocyte homeostasis via multiple direct and indirect mechanisms [84, 85], hypertension may decrease the blood flow in the subchondral microvessels and impair subchondral bone remodeling [86], and hyperlipidemia may also affect chondrogenesis, osteogenesis, and mesenchymatous cell differentiation [87]. Our group investigated the association between MetS and spine OA [88] and found that patients with severe spine OA had more composition of factors of MetS than those with early spine OA statistically [88], although significant further investigation is required.

Obesity has been well established as a risk factor for OA in weight-bearing joints such as the hip and knee, with mechanical overload being the causative link [89–91]. However, studies have also identified obesity as a predictor of OA in non-weight-bearing joints such as the hands, which supports the influence of an independent systemic metabolic effect. It has been demonstrated that white adipose tissue (WAT) secretes inflammatory mediators into the systemic circulation and negatively impacts cartilage degeneration [90, 92, 93]. Although a comprehensive understanding of the association between obesity and OA in both weight-bearing and non-weight-bearing joints is lacking, adipokines such as adiponectin, leptin, and visfatin seem to play important roles [94]. It has been shown that adipokines stimulate similar chondrocyte activation as that seen with mechanical stress and proinflammatory cytokines [95, 96].

Mechanical Factors

The lumbar spine transmits loads between intervertebral levels through the "three-joint complex." The percentage of load transferred through the anterior or posterior spine depends on the spinal posture and the degree of disc degeneration [97]. The lumbar facet joints may normally carry up to 33 % of the total compressive load [98, 99], which increases to 47 % in the presence of facet joint spondylosis and up to 70 % in the presence of intervertebral disc degeneration [100]. Disc degeneration, including loss of disc height and segmental instability, leads to the asymmetrical stress distribution. Increased degree of degeneration may be influenced by the variation of pelvic incidence and associated lordosis from one individual to the next.

Inflammation

Although OA is not classified as an inflammatory disorder, inflammation is a major factor associated with the risk of both progression of cartilage loss and symptoms of the disease, including joint pain, swelling, and stiffness [101]. The cytokine mediators detected in the synovial fluid of OA can come from the three-joint sources: the cartilage, the subchondral bone, and the synovium. Synovitis, involving infiltration of mononuclear cells into the synovial membrane and production of proinflammatory mediators, including interleukin-1β (IL-1β), tumor necrosis factor-α (TNF-α), and chemokines, is common in early-stage and late-stage disease [101]. In spine OA, only a few studies related to inflammation are available. Igarashi et al. reported IL-1β positivity in a third of cases with facet joint OA. In addition, the presence of IL-1β in facet joint cartilage was associated with leg pain and poorer quality of life [102]. Similarly, Xu et al. revealed that overexpression of MMP-1 induced by IL-1β plays an important role in the inflammatory process of lumbar facet joint degeneration [103]. As more attention has been focused on the association of inflammation in peripheral OA, the role of inflammation in the pathogenesis of spine OA requires further investigation.

Treatments

The treatment of spinal OA consists of various approaches comprising self-management, supervised exercise therapy, medical management, interventional procedures, and surgery. The goals of therapy for patients with spinal OA are to control pain, minimize disability, improve the quality of life, and educate the patient about their role in chronic disease management.

Nonsurgical Treatment

Exercise

Spine OA pain is exacerbated by activities that involve lumbar extension such as standing and walking; thus, treatments are directed at avoiding those positions and promoting exercises that involve flexion of the lumbar spine. Flexion exercises will increase the relative space of the posterior spinal elements (i.e., unloads the facet joints), which opens up the spinal canal and the foramina to help alleviate the symptoms of neural compression and/or facet overload. Simply stretching in the flexed position will provide temporary relief for these patients. An exercise program can be formulated under the guidance of a physiotherapist, chiropractor, kinesiologist, or personal trainer. The desire and encouragement of others to have a good (i.e., "erect") posture generally aggravates the spine OA back and/or leg pain. Significant education is required to undo this counterintuitive reasoning and to promote "bad posture" to help alleviate the symptoms. While the use of a walker will greatly improve

walking tolerance by allowing ambulation with the spine in a flexed position, many patients are resistant to using these devices for reasons of practicality and vanity.

Pharmacotherapy

Oral medications for spine OA are the same as those commonly used in patients with peripheral OA. Nonsteroidal anti-inflammatory drugs (NSAIDs) and acetaminophen are widely used as first-line drugs for the treatment of LBP or neck pain. NSAIDs might be considered for younger patients without significant renal, gastric, or cardiovascular comorbidity. Acetaminophen should be considered for patients without hepatic compromise who cannot tolerate NSAIDs, although it is not typically useful for LBP [104]. Although there is no evidence to support chronic use of muscle relaxants [105], they have been understood as more effective agents than placebo for short-term relief of acute LBP (RR 0.80, 95 % CI 0.71–0.89), regardless of etiology [106]. Opioid therapy is occasionally indicated for severe pain and should be prescribed for short-term use on a fixed schedule [107] with monitoring of side effects such as sedation, confusion, nausea, and constipation. Several other medications, including anticonvulsants and tricyclic antidepressants, have been also used clinically. Tricyclic antidepressants have been found to be beneficial in the setting of chronic back pain but have not been studied for acute back pain or spine OA [108].

Interventional Procedures

The use of glucocorticoid injections into the epidural space or facet joint to treat neurogenic claudication or facet joint pain, respectively, is still a controversial subject. Despite significant increase in the utilization of these interventions, evidence-based reviews have concluded that there is not sufficient evidence to support their ubiquitous use [109, 110]. The overall risk of these intervention is actually quite low; however, they are not without the potential for very rare but severe neurological complications (e.g., paraplegia) [111]. Globally, epidural steroid injections are the most commonly performed pain procedure; however, multiple reviews suggest they offer little if any benefit for low back pain and only short-term benefit for leg symptoms [112–114]. Facet joint intervention typically involves image-guided steroid injection, medical branch nerve block, or facet joint radiofrequency denervation (FJRD). There is no strong consensus regarding the treatment efficacy of FJRD and how it compares with nerve blockades and joint infiltration with anesthetics and/or corticosteroids [115]. A recent review by Falco et al. [116] suggests there is good evidence for the use of FJRD and fair to good evidence for lumbar facet joint nerve blocks for the treatment of chronic lumbar facet joint pain resulting in 6–12-month pain relief and functional improvement. They noted that there was limited evidence for intra-articular facet joint injections.

In a recent systematic review of nonoperative treatment of spine OA (i.e., stenosis) causing neurogenic claudication, Ammendolia et al.[117] noted that most current nonoperative treatment had no or limited (effect size and/or duration) impact in patients with neurogenic claudication.

Surgical Treatment

The rate of spine surgery has steadily increased in recent decades, even after adjustment for the aging of the population [118]. The only absolute indication for surgery in spine OA is in the uncommon scenario of a progressive neurological deficit or cauda equina syndrome. Otherwise, surgical treatment is a preference-based decision for patients that have significant symptoms that have not been well controlled with appropriate nonsurgical treatment methods. In the current surgical practice, LSS patients without instability or deformity most commonly undergo direct spinal decompression (removal of bony and ligamentous structures causing neural compression) [119]. Those with significant back pain, instability, or deformity typically undergo decompression along with instrumented fusion (placement of bone screws into the spine to stabilize the movement and facilitate bony bridging of one vertebra to the other (i.e., fusion)) [119]. The majority of surgery for spine OA is in patients with stenosis-related back and leg symptoms. In select cases, surgery for isolated axial low back pain may also be indicated, particularly in those with associated instability or deformity (see below).

Overall, the best evidence regarding patient-reported outcomes has been from the Spine Patient Outcomes Research Trial (SPORT). In general, better outcomes are reported for patients choosing to proceed with surgery compared to continued nonoperative treatment for patients with lumbar stenosis or degenerative spondylolisthesis (see below) [120]. In addition, surgical intervention appears to be cost-effective in this scenario. Furthermore, patients with leg dominant symptoms tend to have the best overall outcomes [121]. Compared to the generally accepted excellent outcomes of primary hip and knee replacement for OA, work from our center has demonstrated comparable improvement in patient-reported health-related quality of life (HRQoL) and cost per quality-adjusted life year following spine surgery for level 1–2 spine OA compared to total knee replacement at a minimum of 5 years' follow-up [122, 123]. Total hip replacement was associated with superior outcomes compared to both spine surgery and total knee replacement. Spine surgery, however, was associated with a significantly higher long-term reoperation rate compared to either hip or knee replacement surgery.

Morbidity of Surgical Care

The best available adverse event (AE) data stem from the multicenter SPORT studies for LSS and degenerative spondylolisthesis [119]. In general, the intraoperative complication rate was 12 %, with dural tears (10 %), which typically did not affect outcome, representing the most common AE. The majority of postoperative events are medical adverse events (AEs) (7 %), with urinary tract infections being the most common. Major medical AEs such as myocardial infarction or pulmonary embolism are uncommon (<1 %). The wound infection rate was 2 %. While the majority of infections are curable with appropriate treatment, there may be permanent

negative effects regarding pain and function. Permanent neurological injury was less than 1 % with varying impact on postoperative outcome. The reoperation rate (same or adjacent level) at 2 and 4 years for decompression and fusion was 12 and 15 %, respectively [124]. The reoperation rate for decompression alone is similar (8 and 13 % at 2 and 4 years, respectively) [125].

Distinct Spine OA Subpopulations

Spine OA has two distinct radiographic subgroups that demonstrate secondary instability (termed degenerative lumbar spondylolisthesis) and/or deformity (termed degenerative scoliosis). Although, clinically similar to other spine OA patients, these patients often require different decision-making regarding management, particularly from a surgical perspective.

Degenerative Lumbar Spondylolisthesis (DLS)

In this subgroup, the arthritic changes result in the forward movement of one spinal vertebra over the other, often referred to as a "slip" [126]. DLS creates increased narrowing of the spinal canal and instability (hypermobility) of the spine. The prevalence of LSS with DLS in the general population is estimated at 6 % [127] and progressively increases from the fifth to the eighth decade of life [128]. DLS typically occurs in patients over the age of 50 and is five times more common in women than men [127]. The majority of DLS patients have a grade 1 listhesis (i.e., <25 % slip), and nearly 60 % of patients with DLS will have recurrent/persistent symptoms [127]. Limited studies looking at demographic and radiographic predictors of progression of degenerative spondylolisthesis have found contradictory results regarding the significance of facet angles, facet fluid volumes, or pelvic incidence at the relevant vertebral levels [129–131].

Nonoperative treatment of DLS is as noted in section "Treatment" for spine OA. In current surgical practice, LSS patients without DLS typically undergo decompression (removal of bony and ligamentous structures causing neural compression). On the other hand, decompression along with instrumented fusion (placement of bone screws into the spine to stabilize the movement and facilitate bony bridging of one vertebra to the other (i.e., fusion)) is recommended for those with DLS [126] (Fig. 4.3). Current decompression techniques that preserve the stabilizing midline spinal anatomy have been proposed as an effective and less morbid alternative to fusion for patients with stable DLS (i.e., <3–5 mm of motion on flexion/extension radiographs or supine to standing (i.e., unloaded to loaded films)) [132–134]. Overall, the surgical outcomes for DLS, which is typically limited to level 1–2 surgery, seem to more durable and provide greater cost-effectiveness compared to surgery for LSS [120].

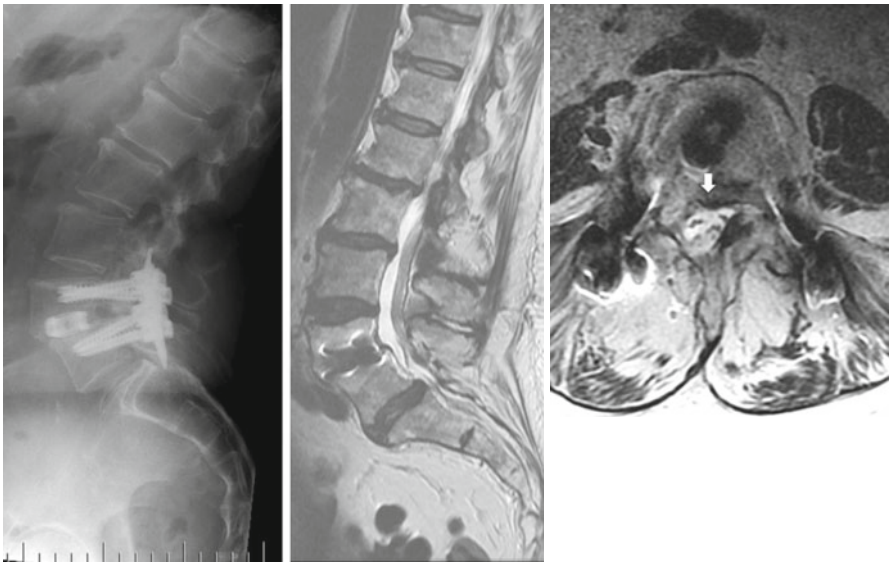

Fig. 4.3 Five-year postsurgical lateral standing radiograph, midsagittal MRI, and axial MRI at L4–L5 in the same patient as in Fig. 4.2. Due to the instability, the patient required a decompression of the spinal canal (*white arrow*) and spinal fusion with instrumentation that is seen on the lateral radiograph. This resulted in dramatic reduction of her pain and improvement of her functional ability

Degenerative Scoliosis

Degenerative scoliosis is defined as an abnormal coronal curvature of the spine greater than 10° that develops in adulthood in the absence of a preexisting childhood deformity [135]. It is considered to be "de novo," another term used to describe the deformity, as it is felt to arise through asymmetrical degeneration of the discs or facets [136]. It occurs almost exclusively in the lumbar spine and is often associated with the progression of the coronal plane deformity over time. Secondary listhesis, generally in the coronal or rotational plane, may occur as well. The associated spine OA generally occurs on the concave part of the curve (increased loading). This can be on the concavity of the main curve, the concavity of the fractional lumbosacral curve, or concavity at both sites [137] (Fig. 4.4). The etiology, epidemiology, clinical course, and treatment of degenerative scoliosis remain unclear.

Etiology

Spinal deformities are associated with asymmetrical disc wear. Whether this is a result of asymmetrical wear of the disc resulting in the deformity or the deformity leading to the asymmetrical disc wear is not known [138]. These deformed discs

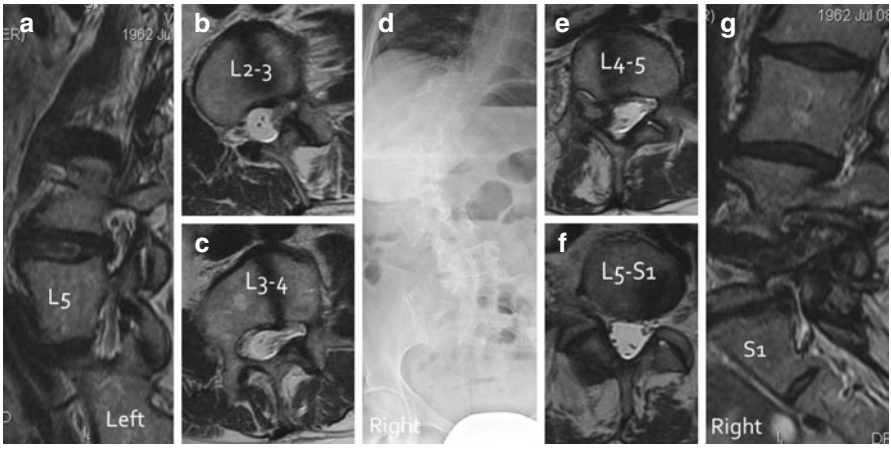

Fig. 4.4 Spinal stenosis in the setting of a coronal plane deformity will develop on the concave side of the curve. For example, a lumbar curve with a right convex apex at L1–L2 (**d**). Stenosis will develop on the left concave aspect at the curve apex (**b**, **c**). Because of the main curve, a secondary fractional curve develops in the lumbosacral region with an opposite configuration to the main curve. This results in lumbosacral stenosis on the right side (**e**–**g**), which is the concave side for the lumbosacral fractional curve. Because the distal lumbar levels are more prone to stenosis secondary to smaller foramens and underlying degeneration, nerve compression most often occurs in the fractional curve. Note the wide open foramens in the lower lumbar region on the convex left (**a**) compared with the tight distal foramens (**g**) on the concave side of the fractional lumbosacral curve. For these reasons, a right lumbar degenerative scoliosis with an upper lumbar apex will most often lead to right-sided neurological symptoms of the distal lumbar roots

often have calcifications and osteophytes on the concave side of the disc with noted changes in cell number and collagen types and composition of the disc matrix.

Demographics

Adult scoliosis has a prevalence rate of up to 10 % in some series. The adult de novo degenerative type is generally seen in patients older than 40 years without a previous history of scoliosis [138]. The most common site for the curves is in the lumbar spine without a thoracic component. The Cobb angle measurement of these curves is often less than 10°; however, the majority of curves that require treatment are greater than 20°. Males and females are equally affected. Characteristic radiographic features can include a coronal plane deformity, a rotational deformity to the apex vertebra, and a lateral or rotational listhesis of one or more vertebrae with varying degrees of sagittal plane (i.e., leaning forward) deformity. The curves can progress over time, usually at about a mean rate of 3° per year [139]. Unlike idiopathic curves, which tend to be left-sided lumbar curves (the convexity of the curve points to the left), the curves in adult degenerative scoliosis have similar distributions of right- and left-sided curves.

Clinical Presentation

Patients with adult-onset scoliosis present essentially the same as other spine OA patients with back and/or leg pain [140]; however, leg pain is frequently unilateral, secondary to the asymmetrical degeneration of the disc and facet joints [141, 142]. As the curves are usually less than 30°, few patients complain of spinal deformity as a primary complaint. For mild curves, a small prominence may be apparent in the lumbar region on the convexity of the curve. For patients with larger deformities, evidence of global sagittal and/or coronal imbalance (i.e., head/trunk is not centered over the pelvis) may be evident. Patients with progressive curves and symptoms can be profoundly limited in function and quality of life.

Treatment

Conservative treatment is as outlined above for spine OA. Specific to degenerative scoliosis, brace treatment has no role in the treatment of spinal stenosis in association with degenerative scoliosis [138]. While radiographic parameters are not considered surgical indications per se, patients requiring surgery generally have significant spinal stenosis in association with progression of the curve, lateral listhesis, and increasing symptomatology. There is a large gamut of surgical treatments that can range from a limited decompression to a large multilevel instrumentation with osteotomies.

Decompression Alone

Similar to patients with spondylolisthesis, decompression alone for degenerative scoliosis is generally reserved for patients with normal sagittal and coronal balance, presenting with leg dominant pain secondary to spinal stenosis [132]. Back pain should be minimal or absent, and radiographically, there should be no sagittal or coronal plane listhesis. Care during surgery must be taken in these cases to preserve as much of the anatomy as possible, as progression of the curve and worsening of the symptoms can be associated with these limited procedures.

Decompression and Limited Fusion

In patients with well-balanced spines in the coronal and sagittal planes with focal levels of degeneration and listhesis, a decompression and fusion of only the affected level is a reasonable option [140]. This allows for a more complete decompression at the affected level without the concern of focal progression of the deformity. This can help alleviate the symptoms without subjecting the patient to a large procedure. This can be an excellent compromise in older patients or those with serious medical comorbidities.

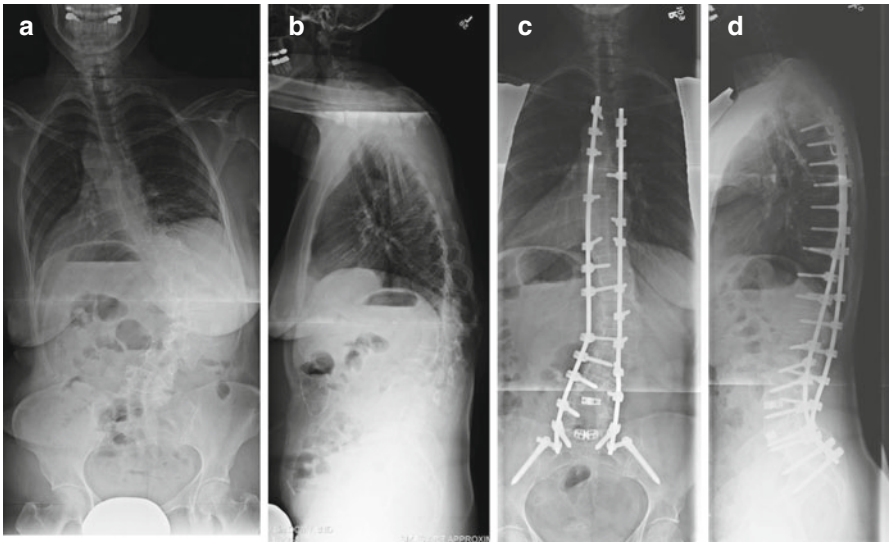

Fig. 4.5 Preoperative standing posteroanterior (**a**) and lateral (**b**) views of the patient depicted in Fig. 4.4. A pedicle screw-based construct extending from T4 to the pelvis was performed restoring her coronal (**c**) and sagittal balance (**d**). Interbody devices placed posteriorly were placed at L4–L5 and L5–S1 to help promote fusion at these levels. A decompression was performed from L2 to S1 to relieve the spinal stenosis

Decompression and Fusion of the Entire Lumbar Curve

Patients with reasonable sagittal and coronal balance with large symptomatic curves are candidates for fusion of the entire curve with partial correction of the deformity and decompression of the affected levels. These patients often have larger curves (Cobb angles greater than 30°) with levels of sagittal or lateral listhesis. The fusions extend along the entire curve and generally require fusion to the sacrum and pelvis. The choice of the proximal level of the fusion can be somewhat controversial but often either extends to L2, when there is no deformity or rotation in the upper lumbar levels, or crosses the thoracolumbar junction to T10 or T11. For patients with structural deformities in the thoracic spine, kyphosis or scoliosis, the constructs can extend proximally up to T4 (Fig. 4.5). Patients with sagittal or coronal imbalance will require spinal osteotomies in conjunction with the fusion to rebalance the spine [138]. A variety of techniques exist regarding fusion and correction of alignment [138].

Morbidity of Surgical Care

Despite the highest degree of planning and attention to perioperative care, spinal deformity surgeries are associated with a relatively high complication rate. Short-term complications include deep wound infection, dural tears, the need for blood

transfusions, and others. Relatively common later complications include failure to fuse at one or more levels and junctional failures, most frequently at the proximal end of the construct. Despite the high complication rates, outcomes from these procedures are quite successful, with the majority of patients enjoying improved function and quality of life [138].

Future Directions

Increased genomic and proteomic investigations that include the facet joints will hopefully increase our understanding of the mechanisms of spine degeneration and ultimately lead to the development of advanced diagnostics (i.e., biomarkers) and treatments that can mitigate the tremendous burden of disease and need for complex surgeries in the treatment of advanced spine OA.

Conclusion

Spinal degeneration is often not considered in the same context as OA; however, the degenerative changes in the disc and particular the synovial facet joints are consistent with those of OA elsewhere. The main clinical symptoms of lumbar spine OA (i.e., facet joint OA) are low back pain and/or associated leg symptoms (pain, numbness, and weakness). Various factors contribute to the degenerative changes, including age, biomechanical factors, systemic factors, genetics, and lifestyle. Although there is no universal nonsurgical or surgical treatment for spine OA, exercise and activity modification is typically accepted as an effective form of initial management. For end-stage disease, nonsurgical treatment has limited efficacy and surgical intervention in appropriately selected patients is associated with good patient-reported outcomes that are comparable to those associated with total knee replacement for OA. Further research in spine OA pathophysiology, biomarkers, and early disease management is critically required to mitigate the increasing socioeconomic burden of spine OA.

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