Clinical and Radiographic Evaluation

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2.1 Introduction

Planning for spinal procedures has been utilized throughout history. The first planned and documented fusion surgery was noted by Dr. Fred Albee in 1911, when he reported a tibial bone graft transplantation into the spine to treat Pott's disease [1]. Decades later, Dr. Francis Denis proposed the three-column theory of spinal stability [2], which led to a better understanding for the anatomical implications of osteotomies. Today, studies continue to reveal the superiority of surgical treatment for spinal deformities [3–7], and the reliability of osteotomies in the setting of rigid coronal and sagittal deformities [8–10]. The widespread use of osteotomies is evident in the statistics from the Agency for Healthcare Research and Quality (AHRQ), which showed a significant increase in the number of patients discharged with osteotomies and fusions within the most recent 14 years of available data in the USA [11].

Unfortunately, osteotomies are accompanied with a high rate of revision surgery; anywhere from 3.8 to 27.8 % of them have been reported to be caused by mechanical reasons such as implant failure, pseudoarthrosis, junctional failure, and loss of correction [12]. Furthermore, surgery is frequently the last resort for patients with spinal disease, and patients often have high expectations of their surgical outcomes [13]. Patients look at surgery as a way to assuage their pain and disability, and also potentially as a permanent cure which will elevate their quality of life and enhance their productivity.

If a gap between surgical outcomes and expectations exists, disappointment can potentially ensue. To narrow this gap, clinical and radiographic evaluation is crucial, and should be on the top of the spinal deformity treatment checklist to set realistic expectations and optimize surgical outcomes.

2.2 Clinical Evaluation

The clinical evaluation of a patient with sagittal deformity who may benefit from spinal osteotomy starts with a systematic history and physical exam. Through a patient's history, a surgeon can delineate the overall natural course of disease and identify the etiology be it degenerative, progressive idiopathic scoliosis, iatrogenic, congenital anomalies, or neuromuscular conditions [14]. The history also allows the patient to express concerns so that both the patient and physician can jointly establish reasonable expectations, which is key in achieving successful surgical outcomes [15–17]. In addition, it is important to document other health conditions, prior spinal

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surgeries, and psychosocial issues all which must be considered and carefully weighed for the risks and benefits of surgery.

A baseline picture of the surgical candidate can be quantitatively assessed with validated patient reported outcomes such as the disease-specific Scoliosis Research Society questionnaire (SRS-22), the region-specific Oswestry Disability Index (ODI), and the general medical outcomes Short Form 36 questionnaire (SF-36) [18–23]. Such a thorough assessment and documentation of a patient's pain and disability is best achieved with these health-related quality of life question-naires (HRQOLs). These are a subjective mea-sure of a patient's symptomatology and can be tracked across office visits like vital signs, giving the surgeon a quantitative trend of how the patient is improving, deteriorating, or maintaining in response to management. Pain scales and ques-tionnaires have been correlated with coronal and sagittal radiographic parameters [24–31] and form part of the evidenced-based reasoning for the application of spinal osteotomies [32].

Another important part of the history is to ascertain a patient's use of nonoperative manage-ment. Usually, by the time patients are referred to a spine surgeon, they are sufficiently symptom-atic to warrant treatment. In general, nonoperative treatment targets the symptom of pain. A patient with a history of muscle fatigue and strain may have used nonnarcotic analgesics and NSAIDs, or in more severe cases, narcotics [4, 33]. These are also not without side effects, as these medicines can cause sedation, gastrointestinal upset, addi-tion, or irreversible chronic pain syndrome [4, 33]. Other medications, such as tricyclic antidepres-sants and gabapentin, can help with neurogenic pain and are especially helpful in elderly patients [27, 34]. Patients often also incorporate other methods of dealing with their symptoms such as physical therapy, chiropractic manipulation, and yoga, but the long-term efficacy of these options is not well supported by the literature. Ultimately, it is important to determine what kinds of nonop-erative treatments a patient has received or sought out to best design a plan for surgery.

Finally, the physical exam should be a global assessment of the patient's deformity in a standing, sitting, and supine posture [14]. A general neuro-logical examination of the motor strength, sensa-tion, reflexes, and gait are also critical to judge functional impairment or point toward signs of myelopathy, which are suggestive of severe tho-racic or concomitant cervical disease. Particular attention must be paid toward the hip [31], and any pelvic retroversion, hip extension, or flexion contractures should be noted. In addition, the compensatory role of the lower extremities is important to notice, with knee flexion employed as a way to maintain the body's center of mass over the bicoxofemoral axis [35, 36]. Current research into the nuances of lower extremity compensation is still being elucidated.

2.3   Radiographic Evaluation

Radiographs are critical part of the current evalu-ation and management of spinal deformity, with full 36″ anteroposterior (AP) and lateral views being crucial for a full imaging evaluation of these patients. Regarding patient positioning, Horton et al. reported the free-standing subject with clav-icle position (elbows flexed with the hands in a relaxed fist, wrists flexed, and hands centered in each supraclavicular fossae) as superior visualiza-tion compared to other positions [37].

A newer form of radiography, the EOS machine, has been recently introduced into the medical field. EOS is a biplanar, orthogonal, full-body, low-dose X-ray [38]. Images are obtained in a standing, weight-bearing position in a very timely manner, relative to MRI and CT scans [39–41]. The EOS system provides a head-to-toe evaluation, giving a full image of the patient's deformity and unmasking all the compensatory mechanisms used to maintain an erect aligned position as noted in the clinical evaluation.

Although spinal deformity is reasonably com-mon, the complexity and uniqueness of a patient's specific deformity necessitates an accurate assessment of each individual case. To establish a better understanding for this diverse clinical entity, identification of radiographic spinopelvic measurements is an absolute necessity to develop a solid understanding of the pathological process

and formulate an effective treatment strategy. Although at first glance this may seem to be an arduous task, use of standardized radiographic techniques is an accurate and efficient method of analysis. Communication between health care providers will only be possible with a common language which accurately describes coronal and sagittal alignment for adult spinal pathologies.

2.3.1   Coronal Plane Analysis

Frontal radiographs should be oriented with a posterior–anterior view (right side of patient on rights side of displayed image) as though viewing the patient's spine in surgery. This allows assessment of coronal global alignment, endplate obliquity, and lateral olisthesis, frontal parameters which are correlated with HRQOLs.

Coronal decompensation can be measured by the distance from the C7 plumb line (C7PL) to the central sacral vertical line (CSVL); if the malalignment is to the right, the distance is considered positive, if to the left, negative [14]. Poor coronal alignment, especially over 4 cm, has been correlated with poor function and increased disability [25].

Assessment of the apex of the deformity using Cobb angles involves classifying the region of the scoliosis. An apex at T9 or higher is a thoracic curve and an apex at T10 or lower is a lumbar or thoracolumbar curve [42], and curves can either be structural or flexible. The larger curve is usually the primary deformity and the smaller curve is often compensatory. An apex in the thoracolumbar region has been associated with worse pain and function than curves in the thoracic spine [25].

On a closer radiographic analysis, L2 or L3 endplate obliquity, which is the angle between the superior endplate and the horizontal, is also an important radiographic parameter to note, as it has been correlated to pain scores [30].

Finally, olisthesis, measured from the horizontal offset between adjacent vertebrae, is the final focal parameter in the frontal plane which also correlates to pain scores [30].

In pediatrics, the Lenke Classification system for adolescent idiopathic scoliosis (Fig. 2.1) has been

the universally accepted scheme which characterizes the frontal plane in a way that allows comparisons of different operative treatments [43–46].

2.3.2   Sagittal Plane Analysis

Pure coronal deformities in adults are rare necessitating the need to evaluate pathological sagittal curvatures [47]. In the past, several efforts have been made to understand the sagittal plane [48–55], most of which dismissed the fundamental role of the pelvis in the complexity of the human standing and sagittal spinal alignment. Sagittal alignment involves an evaluation of pelvic parameters, regional curvatures, global alignment, and lower limbs (Fig. 2.2).

2.3.2.1 Pelvic Parameters
The importance of the relationship between the pelvis and spine was proposed by Duval-Beapere [56, 57] and supported thereafter by numerous studies. Three pelvic parameters (Fig. 2.2) have been described in literature: Pelvic incidence, a fixed morphological parameter, sacral slope, and pelvic tilt. There is a geometric relationship between the three components of the pelvic: "PI=PT+SS".
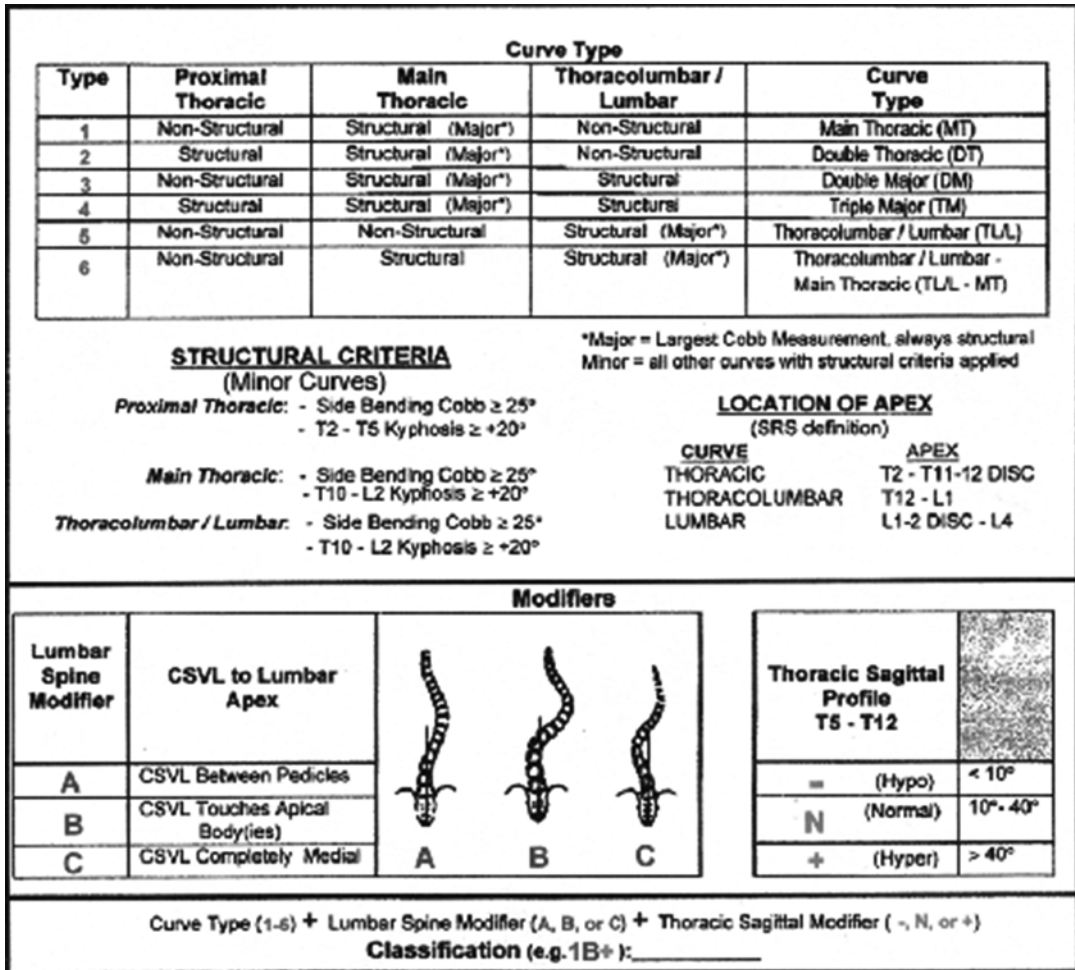
Pelvic Incidence (PI)
The PI is the angle between the perpendicular to the sacral plate at its midpoint and the line connecting this point to the middle axis of the femoral heads [57]. This fixed morphological parameter is specific to each individual and independent of the spatial orientation of the pelvis (i.e., the pelvic retroversion). Nevertheless, the pelvic shape changes from fetus to neonate [58] and again from neonate to adult [59], then stabilizing during adulthood [60].

Sacral Slope (SS) and Pelvic Tilt (PT)
Spinopelvic radiographic parameters have also been developed to assess the spatial orientation of the pelvis. The sagittal inclination of the sacral plateau, the SS, is quantified by the angle between the upper plate of S1 and the horizontal line. The magnitude of SS helps evaluate the orientation of the pelvis.

Pelvic Tilt (PT) provides information regarding pelvic orientation, and represents the angle

Curve Type

Type	Proximal Thoracic	Main Thoracic	Thoracolumbar / Lumbar	Curve Type
1	Non-Structural	Structural (Major*)	Non-Structural	Main Thoracic (MT)
2	Structural	Structural (Major*)	Non-Structural	Double Thoracic (DT)
3	Non-Structural	Structural (Major*)	Structural	Double Major (DM)
4	Structural	Structural (Major*)	Structural	Triple Major (TM)
5	Non-Structural	Non-Structural	Structural (Major*)	Thoracolumbar / Lumbar (TL/L)
6	Non-Structural	Structural	Structural (Major*)	Thoracolumbar / Lumbar - Main Thoracic (TL/L - MT)

*Major = Largest Cobb Measurement, always structural
Minor = all other curves with structural criteria applied

STRUCTURAL CRITERIA
(Minor Curves)

Proximal Thoracic: - Side Bending Cobb ≥ 25°
- T2 - T5 Kyphosis ≥ +20°

Main Thoracic: - Side Bending Cobb ≥ 25°
- T10 - L2 Kyphosis ≥ +20°

Thoracolumbar / Lumbar: - Side Bending Cobb ≥ 25°
- T10 - L2 Kyphosis ≥ +20°

LOCATION OF APEX
(SRS definition)

CURVE	APEX
THORACIC	T2 - T11-12 DISC
THORACOLUMBAR	T12 - L1
LUMBAR	L1-2 DISC - L4

Modifiers

Lumbar Spine Modifier	CSVL to Lumbar Apex
A	CSVL Between Pedicles
B	CSVL Touches Apical Body(ies)
C	CSVL Completely Medial

A B C

Thoracic Sagittal Profile T5 - T12		
=	(Hypo)	< 10°
N	(Normal)	10° - 40°
+	(Hyper)	> 40°

Curve Type (1-6) + Lumbar Spine Modifier (A, B, or C) + Thoracic Sagittal Modifier (-, N, or +)
Classification (e.g.1B+):_____

Fig. 2.1 The Lenke classification system for adolescent idiopathic scoliosis

between the line connecting the midpoint of the sacral plate to the femoral heads axis and the vertical. PT is a positional parameter and quantifies the amount of pelvic compensation. PT reflects the pelvic rotation around the femoral axis to maintain an upright posture (pelvic version). Lafage et al. [31] established the relationship between pelvic retroversion and clinical outcomes, asserting that the ability of a patient to compensate for a spinal deformity via an increase of pelvic retroversion is important in clinical evaluation. Underestimating the pelvis can lead to misjudgment related to the magnitude of malalignment. The spine which sits over a compensated pelvis is a malaligned spine.

Having outlined pelvic parameters, a review of the radiographic evaluation continues with the spinal curvatures, which have a significant chain of interdependence starting with the pelvis [57].

2.3.2.2 Regional Parameters

At birth, the entire spine is straight, or may even show a slight anterior concavity from occiput to the sacrum [61]. With growth and maturity, lumbar Lordosis, thoracic kyphosis, and cervical lordosis develop. This leads to the S-shape of the hominoid spine.

Lumbar Lordosis (LL)

LL is a well-known parameter measured using the Cobb angle between the upper endplate of L1 and the upper endplate of S1. This curve is well correlated with the pelvic morphology (PI) [56, 57, 62] such that PI and LL should be
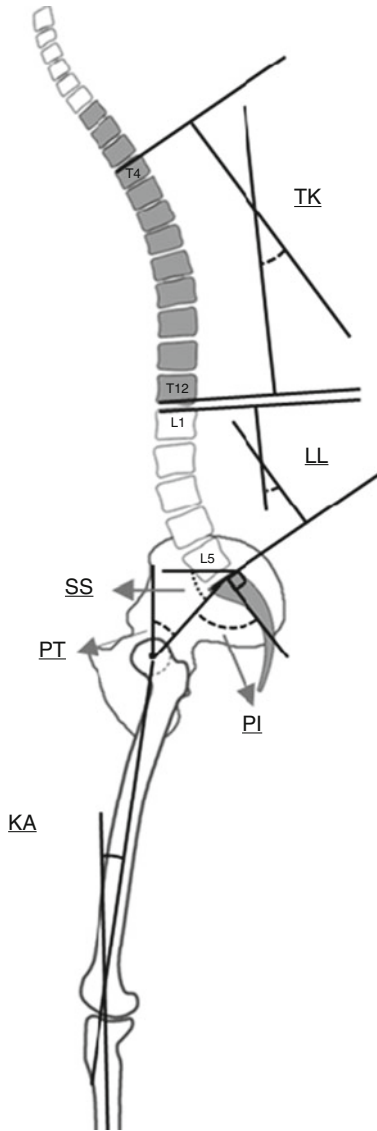
Fig. 2.2 Full body radiographic evaluation. *LL* Lumbar Lordosis, *TK* Thoracic Kyphosis, *SS* Sacral slope, *PT* Pelvic tilt, *PI* Pelvic incidence, *KA* Knee angle

within 10° of each other. Consequently there are variations of normal LL [63].

Upright standing posture and bipedal gait are possible by both hip extension and LL [64]. These compensations deteriorate in flat back syndrome [65–67] and aging [68]. When LL (especially the more distal segment) goes out of sync with the other spinopelvic features, sagittal malalignment occurs, and leads to a forward shift of the head far from the axis of pelvis. This loss

of LL is highly correlated with the severity of pain assessed by Visual Analog Scale (VAS) [30] and other HRQOLs [24, 26, 69].

Lack of LL can be a key deformity driver, in which case surgical intervention should be directed toward realigning this region. LL is also a radiographic parameter over which the spine surgeon has direct intraoperative control. Therefore, evaluating and measuring LL accurately helps clarify a controllable and modifiable part of spinal deformity, and as a result, the amount of correction needed.

Thoracic Kyphosis (TK)

TK is most commonly the angle between the upper endplate of T4 to the lower endplate of T12, though the upper and lower vertebrae can be selected differently depending on the apex of the thoracic curve. About hundred years ago, Scheuermann [70] defined juvenile kyphosis as "kyphosis greater than normal." Normal ranges of LL and TK, which have been described by many authors [63, 71, 72], are more suggestive and not necessarily target values. As mentioned earlier, there is variation in sagittal morphotype of spinopelvic alignment, and the purpose of measuring spinopelvic parameters is to define the deformity by component parts, and not necessarily to be tied simply to normative values.

In certain circumstances, such as young patients with a more flexible spine, reduction of TK is a response to the flat or kyphotic lumbar spine [73]. Conversely, in the aging spine, hyperkyphosis may ensure possibly due to muscular weakening, disc related and osteopenic changes.

The thoracic spine, such as the pelvis, also compensates and has reciprocal changes. The latter refers to spontaneous change in alignment following lumbar realignment. In some cases, marked increase in thoracic kyphosis can occur in unfused segments after spinal osteotomies in the lumbar spinal [74–77]. These reciprocal changes are still poorly understood and should be carefully anticipated, especially prior to lumbar spinal osteotomies.

2.3.2.3 Global Parameters

Global alignment can be understood by Dubousset's "Cone of Economy" concept. This cone (projected upward from a circle around the feet) is the cone within which the body can

Table 2.1 Normative radiographic parameters by age

Parameters	Mean age year old		
	7.3 ± 1.8	13.1 ± 2.1	35 ± 12
Lumbar lordosis (LL)	45.6 ± 12.1	49.2 ± 12.4	43 ± 11.2
Thoracic kyphosis (TK)	38.3 ± 9.8	44.2 ± 10.3	40.6 ± 10
Pelvic incidence (PI)	44.6 ± 10.6	49.3 ± 11.2	54.7 ± 10.6
Pelvic tilt (PT)	4.3 ± 8.1	7.9 ± 7.7	13.2 ± 6.1
Sacral slope (SS)	40.3 ± 8.7	41.4 ± 8.5	41.2 ± 8.4

remain aligned while using minimal effort. The aligned individual maintains a center of mass within a narrow range of sway in relation to the feet [78]. Even mild positive sagittal malalignment is somewhat detrimental [26]. Severity of clinical symptoms, quality of life, and disability correlate in a linear fashion with the progressive anterior translation of the head far from the pelvis and is quantified by sagittal vertical axis (SVA).

SVA is defined as the horizontal offset from a plumb line dropped from the center of C7 vertebral body to the posterosuperior corner of the sacral plate (S1) [79]. SVA gives a well-mannered idea about the general alignment of the trunk. SVA is highly sensitive to loss of LL, and well correlated with HRQOLs [25, 68].

However, SVA can be masked by pelvic version when the pelvis rotates posteriorly (retroversion) around the femoral axis to compensate for a forward leaning posture. Also, as a linear measurement, it requires calibration of the radiograph. Protopsaltis et al. [80, 81] proposed the T1 pelvic angle (TPA) as a novel radiographic measure of sagittal alignment which eliminates the need for calibration. TPA is the angle between a line from the center of T1 vertebral body to the femoral heads and a line from the femoral heads to the center of the S1 endplate. TPA is less dependent on postural factors, accounts for both spinal alignment and pelvic retroversion (in standing) and correlates similarly to other key parameters with HRQOLs in patients with adult spinal deformity (ASD).

Normative values, which change with age, for spinopelvic radiographic analysis are in Table 2.1 [59, 63].

2.3.2.4 Lower Limb Assessment

Since the femoral heads are highly mobile, they play an important role in the spatial orientation of the pelvic vertebra. They constitute the point at which the load from the spinal curvatures on the pelvis is transferred to the lower limbs [82].

When sagittal malalignment takes place, patients recruit compensatory mechanisms to maintain an erect posture and horizontal gaze. As previously mentioned, the thoracic spine contributes to this compensation, but is limited by the musculature of the back. The pelvis plays the role of equalizer in sagittal malalignment, and shifts posteriorly toward the heels [78, 83]. Knee flexion (measured by Knee angle, KA) is an angle made by the femoral mechanical axis and the tibial axis (Fig. 2.2) and assesses lower limb compensation. Obeid et al. [36] were the first to investigate the relationship between the deformity driver (loss of LL) and knee flexion.
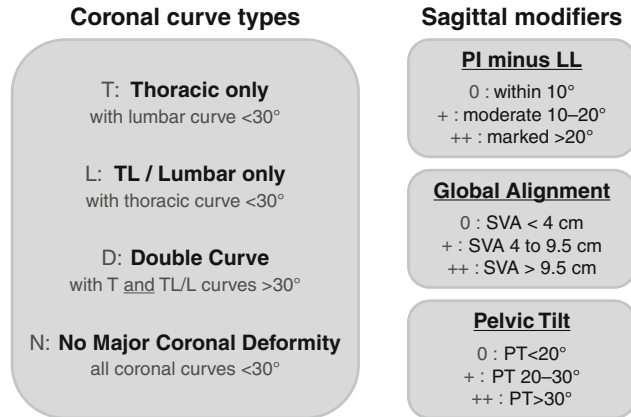
More recently, Lafage et al. studied these compensatory mechanisms, and their contribution to alignment [84]. Findings assured that PT is the main contributor to the chain of compensation, but as deformity progresses, pelvic compensation becomes exhausted. Once retroversion is at its maximum, compensation transfers to knee flexion.

It has become evident that alignment and stability run from ground up to the head. In the middle of this, there is the pelvic equalizer [57]. In malalignment cases, spinal curvatures load pass through the pelvis to be neutralized during standing or movement. A thorough understanding of pelvic morphology, compensation, and shift helps to form part of the larger deformity assessment. Lower limb evaluation will complete the full-body alignment and compensation picture.

2.3.3 Alignment Objectives

Optimal alignment of the spine and its position in relation to the pelvis and lower extremities has

Fig. 2.3 SRS-Schwab classification for adult spinal deformity

Coronal curve types

T: **Thoracic only**
with lumbar curve <30°

L: **TL / Lumbar only**
with thoracic curve <30°

D: **Double Curve**
with T and TL/L curves >30°

N: **No Major Coronal Deformity**
all coronal curves <30°

Sagittal modifiers

PI minus LL
0 : within 10°
+ : moderate 10–20°
++ : marked >20°

Global Alignment
0 : SVA < 4 cm
+ : SVA 4 to 9.5 cm
++ : SVA > 9.5 cm

Pelvic Tilt
0 : PT<20°
+ : PT 20–30°
++ : PT>30°

marked clinical implications. Starting from the trigonometric relationship between the three components of the pelvis: PI = SS + PT, and the correlation between SS and LL [56, 85], Schwab et al. [28] proposed a simple and clinically relevant formula to define the spinopelvic relationship. This formula limits the mismatch between PI and LL to ±9°. More recently, Schwab et al. modified this formula to consider both PI and TK: LL = (PI + TK)/2 + 10, which accounts for abnormal thoracic kyphosis [86].

The Scoliosis Research Society (SRS)-Schwab classification for ASD (Fig. 2.3) was developed based on the literature studies on normative values for PT [63] and SVA [79]. This classification also incorporates the latest research on alignment and correlations between radiographic parameters and clinical outcomes such as the Oswestry Disability Index (ODI), Short Form 36 (SF-36), and SRS-22 [42]. This classification scheme has excellent intraobserver and interobserver reliability as well as clinically relevant by its correlations to HRQOL instruments. Changes in classification category through surgery can impact HRQOLs. Smith et al. showed that patients who improved in SRS-Schwab sagittal modifiers (PT, SVA, or PI-LL) were more likely to reach a clinically noticeable difference in HRQOLs (ODI, SF-36, or SRS activity and pain) [87]. Classifying the deformity reflects the status of malalignment severity; the SRS-Schwab classification impacts the decision to pursue operative or nonoperative treatment, with operative patients having worse sagittal modifiers [69].

There have been many mathematical models and formulas that attempt to predict postoperative sagittal alignment. Smith et al. [88] evaluated 5 predictive models for predicting postoperative global alignment after osteotomies and demonstrated that the Lafage formulas, developed from a multivariate linear regression of 219 adult patients treated for spinal deformity, showed the greatest accuracy in predicting postoperative SVA [89]. Such formulas are essential in spinal reconstruction and can be another tool to use during preoperative planning for spinal osteotomies [11].

2.4 Simulation and Root Cause Analysis

Preoperative planning is an important part of surgical practice. Dedicated surgical planning software has been used across numerous subspecialty fields in orthopedics and neurosurgery and has emerged for preoperative spinal deformity correction [90, 91].

Using a single three-column osteotomy or multiple facetectomies, surgeons can directly control the amount of LL attained intraoperatively. One of the ways a surgeon can start to ensure ideal postoperative outcomes is to anticipate how the osteotomy may affect the overall postoperative global alignment. While there are numerous ways to plan, including the use of trigonometric formulas and radiographic cutouts, these techniques tend to be either limited in visual representation or cumbersome [82, 91,

92]. The advantages of surgical planning software is that it allows osteotomy simulation so that a surgeon can get an idea of how much LL they need to achieve intraoperatively to attain satisfactory SVA and PT.

Asymmetric osteotomies in the coronal plane can also be simulated. Depending on the software, these osteotomy simulations can incorporate evidence-based formulas, so that the planning is not only visually understandable (and can supplement preoperative counseling in the clinic to show patients what their surgery is actually trying to accomplish) but also scientifically sound. These planning tools can also be great teaching tools for residents and fellows and also establish a tone of teamwork in the operating room so that all members can see what the surgical goal is. Furthermore, preoperative planning allows a surgeon to assess the possibilities of different combinations of osteotomies at different levels so that the surgeon can go into the operation prepared; even though not all factors can be anticipated, planning ensures that the radiographic deformity is quantified and the most appropriate osteotomy is selected.

There are still many methods of planning with no clear evidence to support superiority of one strategy over another. In addition, there is still much room for improvement. Reconstructive surgery for deformity is a risky procedure, with failure rates as high as 22 % [93] and less than 23 % achieving complete correction [94], though a recent multicentered study showed there are significant variations in practice and surgical techniques [12]. Prior literature defining predictive factors are weak [95], thus a prospective root cause analysis on variability in surgical planning and intraoperative decision making needs to be the next step to figure out how to do better.

Preliminary data [96] suggests that X-ray quality, both at baseline and intraoperatively, can lead to either poor planning or poor intraoperative feedback. This study also found that intraoperative X-rays were a good prediction of postoperative LL, but in general, LL tended to be undercorrected. A deeper analysis revealed that deviation from the pre-operative plan also resulted in undercorrection, especially in patients

who needed large correction in LL [97]. Moreover, the reciprocal changes in the unfused thoracic spine following LL correction are still poorly understood and anticipated [98, 99]. In 2012, a comprehensive radiographic analysis by Lafage et al. revealed that significant postoperative alignment changes can occur through the unfused thoracic spinal segments. Furthermore, risk factors, such as older patients, and severe preoperative spinopelvic parameters, found to make these changes unfavorable and led to spinal malalignment following lumber PSO [77]. In fact, a study by Blondel et al. demonstrated that a lack of restoration of thoracic kyphosis may lead to sagittal overcorrection with posterior malalignment [88]. More studies should be done to better anticipate this postoperative response.

While radiographs are useful for evaluating deformity, they are limited to a two-dimensional (2D) assessment. Because most of the recent research in the past decades have been based off the coronal and sagittal planes only, errors in osteotomies and instrumentation have potentially led to surgical failures [47]. Thus, the three-dimensional (3D) nature of deformity needs to have as much attention. Recently, the 3D reconstructive capabilities of EOS system [99] has allowed ongoing research in understanding the third dimension of spinal deformity which may be concealed in traditional 2D radiographs.

A further way of improving outcomes may be to consider age-specific alignment objectives. It is well established that global sagittal alignment [78] and patient reported outcomes change with age [100], and perhaps surgery should be more tailored to a patient's age. A recent study demonstrated that older patients required more rigorous correction to achieve a minimal clinically important difference compared to younger patients at 2 year follow-up [101]. This may in part be due to the fact that younger patients are predominantly more coronally malaligned and older patients have more degenerative sagittal deformities. Furthermore, sagittal alignment changes as part of the natural history of aging and what may be considered normal alignment in a 20 years old, may not be physiologically acceptable in an elderly patients. Thus, etiology and age remain important
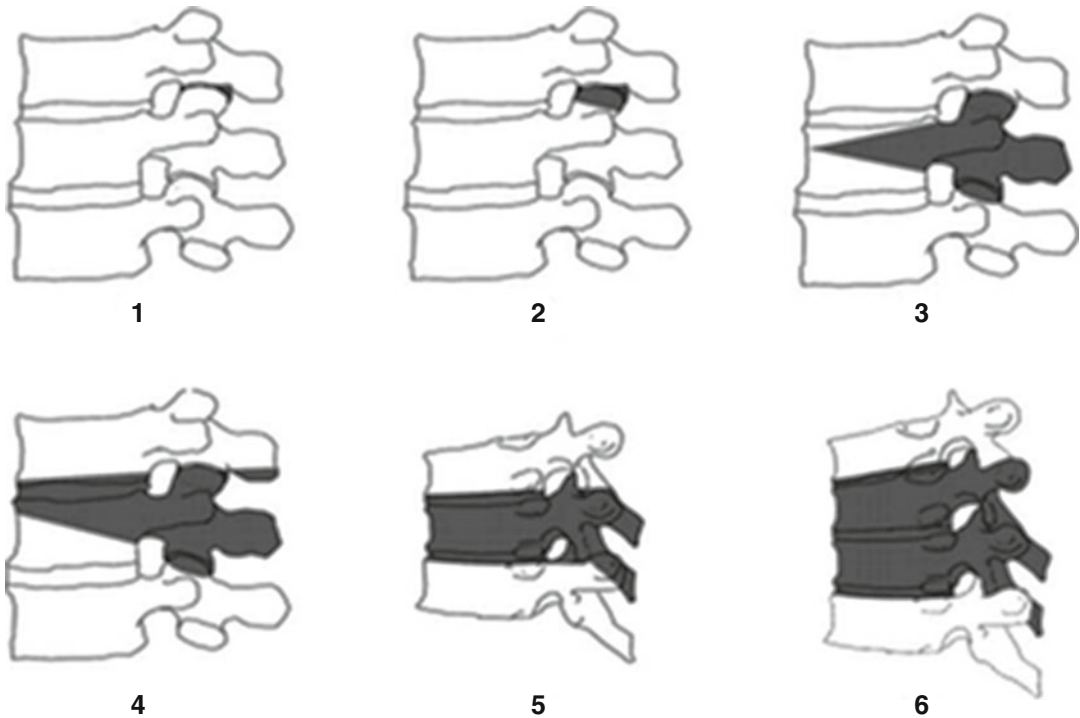
Fig. 2.4 Comprehensive anatomical spinal osteotomy classification

preoperative factors that a surgeon should consider to best optimize an operative plan.

Finally, in order to continue to improve preoperative planning and assess intraoperative techniques, there needs to be a common language in which surgeons from all over the world can dialog and share data. A comprehensive spinal osteotomy classification that is anatomically based can provide a universal and objective way of quantifying what works and what is not best practice. The most recent classification provides a simple way of categorizing spinal osteotomies into 6 grades of resection starting from a partial facet joint resection all the way up to a multiple vertebrectomy [32] (Fig. 2.4). These 5 grades provide a systematic, simple, and anatomic way of facilitating communication, standardizing outcomes research, and establishing indications.

Conclusion

Spinal osteotomies are useful procedures for patients with fixed deformity. Although osteotomies are technically challenging and associated with high rate of complications and revision surgeries, they can dramatically correct malalignment and offer substantial improvement in quality of life. The repercussions of osteotomies are difficult to predict; thus, detailed planning, accurate simulation, and superior intraoperative execution are the key factors to improving outcomes. Intersite variability studies have quantified the limitations of simplified planning and revealed a significant amount of room for improvement [12]. Management of spinal deformity starts with a thorough history of the condition, judicious clinical examination, and educating patients about the risks and benefits of surgical treatment. Using osteotomies for surgical correction involves skill not only in the operating setting but also a meticulous patient-specific plan prior to operative intervention. Imaging studies are critical to evaluate spinal deformity and much can be gained from a 2D picture. Spinopelvic parameters, which correlate with disability status and quality of life,

are crucial in the clinical and radiographic evaluation of patients who are candidates for a spinal osteotomy.

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