Normative values for the L5 incidence in a subgroup of transitional anomalies extracted from 147 asymptomatic subjects

D. Dominguez, A. Faundez, H. Demezon, A. Cogniet & J. C. Le Huec

European Spine Journal

ISSN 0940-6719

Eur Spine J
DOI 10.1007/s00586-015-4371-6

Springer

Eur Spine J
DOI 10.1007/s00586-015-4371-6

ORIGINAL ARTICLE

Normative values for the L5 incidence in a subgroup of transitional anomalies extracted from 147 asymptomatic subjects

D. Dominguez[1] · A. Faundez[1] · H. Demezon[2] · A. Cogniet[2] · J. C. Le Huec[2]

Received: 18 July 2015 / Revised: 26 December 2015 / Accepted: 28 December 2015

Abstract
Purpose Pelvic incidence angle is not always measurable due to lumbosacral transitional vertebrae (LSV). The fifth lumbar vertebra (L5) is rarely abnormal. The purpose of this study was to quantify from full-body standing X-rays, the L5 incidence angle (L5I) in a normal asymptomatic population and to correlate it with standard spino-pelvic parameters taking the sacrum (S1) as a reference.
Methods One hundred and forty seven asymptomatic volunteers were enrolled. The ethics committee approved the study protocol. Subjects underwent a low-dose full spine X-ray. 3D reconstructions were obtained and L5I was measured using the upper L5 endplate as the reference instead of the S1 endplate. A group of subjects with LSV was identified and subdivided in two subgroups. Standard spino-pelvic parameters and normative values for the L5 parameters were obtained. Statistical correlations were calculated between the standard and L5 parameters as well as L5I with L1–L5 lordosis in both subgroups.
Results Twenty two (14.96 %) subjects with LSV were found. Ten of these had an unidentifiable S1 endplate due to a sacralisation of L5. Mean values for the L5I, L5 tilt, L5 slope and L1–L5 lordosis were, respectively, 22.43, 4.65, 17.73, and 45.51 for normal subjects ($N = 137$) and 32.75, 6.63, 26.38, and 55.02 for sacralisation of L5 subjects ($N = 10$). Mathematical relationship found: $\text{L5I} = 0.7641 * \text{PI} - 17.725$ ($R = 0.83$) and $\text{L1–L5} = 0.67 * \text{L5I} + 30.7$ ($R = 0.64$).
Conclusion This prospective study is first to provide normative spino-pelvic values at the L5 level in an asymptomatic population, particularly in case of (LSV) sacralisation of L5 ($N = 10$) where L5I and L1–L5 lordosis appears to be 10° more important than in normal population. We propose L5I as a new spino-pelvic parameter to restore in case of L5-S1 disk disease. These normative values will help to control peri-operatively the adequate lordosis restoration, in the presence of LSV.

Keywords L5 incidence angle · Pelvic incidence · Lumbosacral transitional vertebrae · Lordosis restoration · Surgical planning

✉ J. C. Le Huec
j-c.lehuec@u-bordeaux2.fr

1 Division of Orthopaedics and Trauma Surgery, Geneva University Hospitals, Rue Gabrielle-Perret-Gentil 4, 1211 Geneva 14, Switzerland

2 Spine Unit 2, Surgical Research Lab, Bordeaux University Hospital, CHU Pellegrin, 33076 Bordeaux, France

Introduction

Since meticulous and exhaustive analysis of spino-pelvic parameters seems to be an important tool in daily practice for spine surgeon, the need for standard values is still present [1].

Amongst pelvic parameters, pelvic incidence (PI) is the most important. This angle first described by Duval-Beaupère [2] was defined as the angle between a line perpendicular to the sacral endplate (S1) at its midpoint and a line connecting the same point to the center of the bicoxo-femoral axis [2, 3]. PI is the only pelvic parameter that remains constant during the whole life once puberty ends. Different shapes of lumbar lordosis have been described according to the value of the pelvic incidence and its relation to a horizontal line (sacral slope) [4, 5]. Recently, most of biomechanical studies published have showed a strong correlation between PI and lumbar

Published online: 27 January 2016

lordosis, which is very useful for spino-pelvic assessment of pathologies [6, 7].

However, S1 is not always identifiable, like in lumbosacral transitional vertebra (LSV) conditions: L5 sacralisation. LSV are a congenital anomaly with a reported prevalence of up to 35 % [8]. When present, classic spino-pelvic parameters measurements might not be applied. The superior endplate of L5 vertebra is rarely abnormal and could be used as a reference instead of S1 in case of LSV. Although normal variation of sagittal spinal alignment based on S1 pelvic incidence has been well identified in previous publications [9], none of these have described normative values for L5 incidence angle (L5I) in a prospective study of an asymptomatic population.

Study purpose

The goal of this study was to obtain a radiological database of an asymptomatic population to provide normative values of L5I and to analyze the relationship between the L5I, PI and the lumbar lordosis angles (L1–L5 and L1-S1) routinely used to plan spinal surgeries for the to groups of populations: normal L5S1 group and L5 sacralization group.

Materials and methods

Population

One hundred and forty seven asymptomatic volunteers were recruited for this study. They underwent a radiological and functional spino-pelvic assessment. Those were all adults (mean age of 36.8 ± 14.3 years, 82 men and 65 women, mean age 35.9 and 36.3 years, respectively) with no previous history of spinal disorder, nor leg pain as confirmed by clinical examination performed by a neurologist, nor contraindication for radiographic exposure (e.g., pregnancy, tumor). All study subjects have given their informed consent for participation in the study. Ethics Committee of our institution approved the study protocol because radiation exposure with the EOS technology was very low as compared to standard telemetric radiologic techniques.

Clinical assessment

Generic questionnaires were used to assess back pain and function. The clinical inclusion criteria to define the asymptomatic population were an Oswestry disability index (ODI) below 10 % and back pain lower than 2/10 on a Visual Analogue Scale.

Radiological assessment

Sagittal spino-pelvic parameters were assessed from simultaneous full-body posteroanterior (PA) and lateral images. We used an EOS® 2D/3D X-ray imaging system [10] to deliver the lowest radiation dose possible to the study subjects, following the ALARA (as low as reasonably achievable) principle [11]. During radiologic exam, subjects were all asked to adopt an easily reproducible position, to obtain comparable measurement of spino-pelvic parameters: feet 20–25 cm apart and fingers tips leaning on clavicles [10]. In this position the location of the body center of gravity remained stable.

From the EOS™ biplanar images, a three-dimensional (3D) spino-pelvic model can be produced [12]. 3D models are the best available for assessing sagittal alignment and it is easy to rotate them in case femoral heads are not superimposed (Fig. 1). This is very important to obtain homogeneous spino-pelvic parameter measures. Using these 3D models, spino-pelvic parameters were calculated (Table 1). L5I was defined as the angle between a perpendicular line to the superior endplate of L5 at its midpoint, and a line connecting the same point to the center of the bicoxo-femoral axis (Fig. 1). The C7 plumb line was used to characterize global sagittal balance [13, 14].

A global analysis of the population was performed and LSV were identified based on Farshad method [15]: Measurement of vertical mid-vertebral angle (VMVA) of the most caudal vertebrae. A Difference VMVA $\leq +10°$ clearly identifies a non-mobile LSV (Fig. 2).

Statistical analysis

Statistical analysis was performed using Medcalc software. Descriptive statistics (mean, standard deviation, min, max) were calculated for all the spino-pelvic parameters. Subjects were divided into two groups: subjects with LSV and normal subjects (or NS).

For qualitative variables, we have used the *Chi*-square tests when it was possible (expected frequency >5), otherwise we used the Fisher exact test. The significance threshold was 5 %.

For quantitative variables we have used the Student *t* test. When the samples were small (<30 subjects), the *t* tests were completed using *F* test for variance comparison. The significance threshold was 5 %. Statistical correlations between the parameters were estimated via the Pearson correlation coefficient.

Results

All volunteers were white Caucasian; the mean Oswestry score was 0.65 ± 2.33. Within the 147 subjects of the study, we found 22 with LSV (14.96 %). These subjects

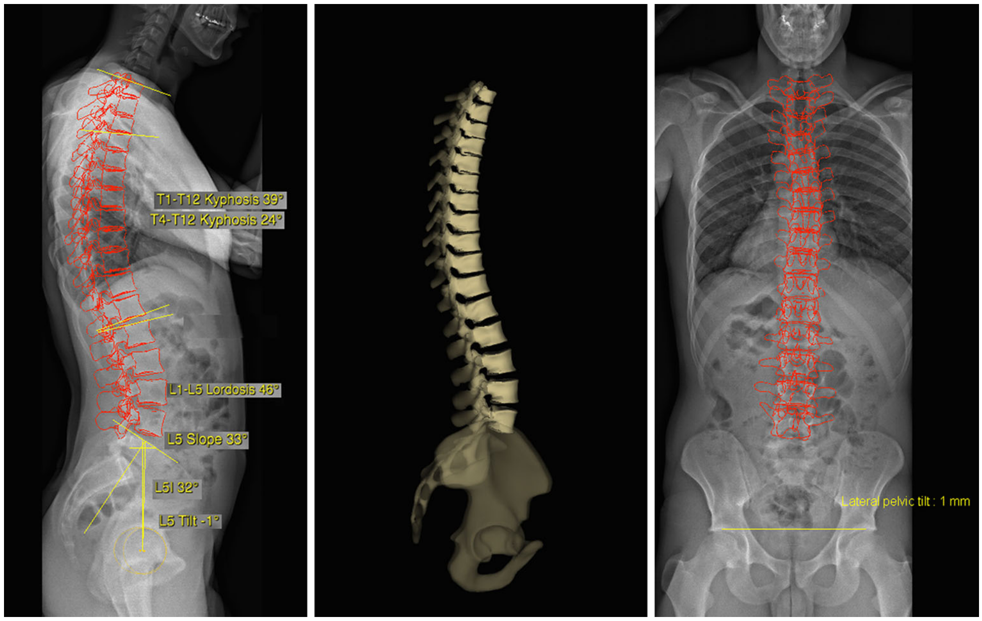

Fig. 1 Measurement of L5I parameters and L1–L5 lordosis in 3D reconstruction of the spine and pelvis from biplanar EOS radiographies

Table 1 Sagittal spino-pelvic parameters

Parameter	Description
Pelvic incidence (PI)	Angle between a line perpendicular to the sacral endplate at its midpoint and a line connecting the same point to the center of the bicoxo-femoral axis
Pelvic tilt S1 (PT)	Angle between a line connecting the center of the bicoxo-femoral axis to the midpoint of the sacral endplate and the vertical axis.
Sacral slope (SS)	Angle between a line passing through the inferior endplate of the sacral endplate and the horizontal axis.
L5 Incidence Angle (L5I)	Angle between a line perpendicular to the superior endplate of L5 vertebra at its midpoint and a line connecting the same point to the center of the bicoxo-femoral axis
L5 tilt	Angle between a line connecting the center of the bicoxo-femoral axis to the midpoint of the superior endplate of L5 and the vertical axis.
L5 slope	Angle between a line tangent to the superior endplate of L5 and the horizontal axis.
C7 Plumb line (C7PL)	Vertical line passing through the center of C7 vertebral body
Lumbar lordosis (L1-S1)	Lordosis angle measured between superior endplate of L1 and superior endplate of S1
L1–L5 lordosis	Lordosis angle measured between superior endplate of L1 and superior endplate of L5

were further separated in two groups: 12 subjects appeared to have a lumbarisation of S1 (5 lumbar vertebrae) and 10 subjects appeared to have a sacralisation of L5 (4 lumbar vertebrae) where L5-S1 disk was fused (Fig. 3). For the later group the measurements based on S1 were not possible reducing the sample for standard pelvic parameters measurement to $N = 137$. L5 parameters were possible to be determined in all study subjects.

Global statistical average for standard spino-pelvic parameters where S1 was identifiable ($N = 137$) and the new L5 parameters according the two subgroups ($N = 137$ and $N = 10$) are presented in Table 2. To improve accuracy of the results concerning L5 parameters we further divided it in two subgroups: a) subgroup including. NS and those with a lumbarisation of S1 ($N = 137$) and b) subgroup only those with a sacralisation of L5 ($N = 10$). Figure 4 shows a difference is obtained on average values between the two subgroups on L5 parameters.

Statistical correlation was measured via Pearson's coefficient between the standard (S1 reference) and new (L5 reference) parameters from 137 patients in which both measurements were obtained.

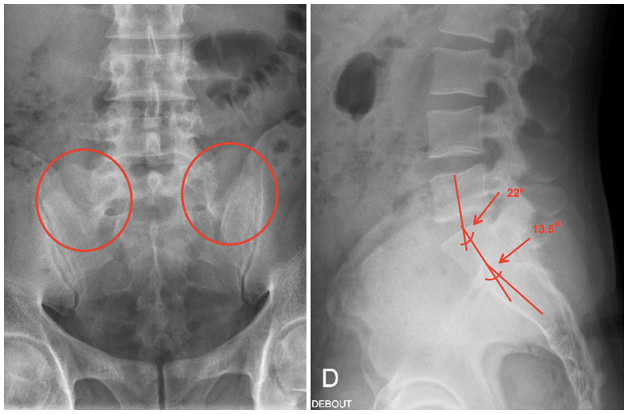

Fig. 2 X-ray of a patient with a Diff-VMVA +9 indicating a (LSTV) sacralisation of L5

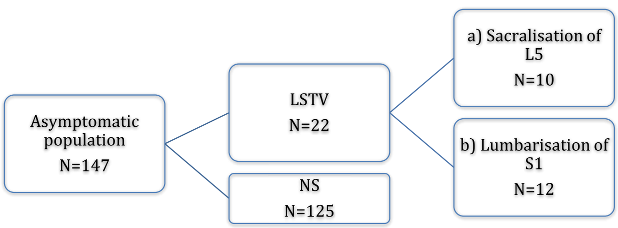

Fig. 3 Asymptomatic population divided in two groups normal subjects (NS) and LSTV within the two subgroups

Strong positive correlation was found between PI and L5I values. For instance, it was possible to determine the mathematical relationship between L5 incidence angle and pelvic incidence: L5I $= 0.7641 * \text{PI} - 17.725$ ($R = 0.83$) (Fig. 5).

The correlation between L5 incidence angle and L1–L5 lordosis are represented in Fig. 6 according the two subgroup: (a) L1–L5 lordosis $= 0.67 * \text{L5I} + 30.7$ ($R = 0.64$) and (b) L1–L5 lordosis $= 0.71 * \text{L5I} + 31.9$ ($R = 0.92$). These values show a positive linear relationship in both subgroups and we also noticed that L1–L5 lordosis appears to be more important in the subgroup (b) where the disk was fused.

Discussion

It has been demonstrated that the normal sagittal spino-pelvic alignment results from a balance between the spino-pelvic morphology and positional parameters. The pelvic incidence is an important fixed morphometric parameter that describes the anatomical shape of the pelvis and it greatly influences the positional configuration of the spine. Furthermore, several authors found a worse functional outcome in patients after lumbosacral fusion when values of spino-pelvic parameters (including lordosis) were not restored within normal range [4, 6, 7, 9].

The concept of "L5 incidence" was already proposed by Labelle [16] in pathologic situation. However, his work lacks further investigation, particularly with respect to the relationship between L5I and other sagittal parameters. Our study provides a prospective critical analysis of the relationship between L5I and commonly used sagittal parameters in healthy volunteers in which L5-S1 disk shape were supposed to be preserved. A subgroup of healthy subjects (LSV) having a sacralisation of L5 with an immobile L5-S1 disk was identified. The ODI and VAS scores demonstrated that patients were really asymptomatic which is something rarely reported in the literature.

In this study, a strong correlation between PI and L5I was confirmed. Mathematically, the following formula was found: L5I $= 0.764 * \text{PI} - 17.72$, with a high Pearson's coefficient of 0.83. This geometrical relationship between PI and L5I is shown in Fig. 4. The clinical relevance of this correlation could be applied on patient with L5-S1 degenerative disk disease where the relationship between L5-S1 has been loosen. On this population, if S1 endplate is visible and using this mathematical equation we should be able to calculate the missing L5-S1 lordosis to restore a theoretical L5I.

The limitation of our study is based on the small number of sacralisation of L5 subjects, nevertheless in view of the similarity of the subgroups and the positive linear correlation between the L5I and L1–L5, we should aim our surgical treatment to restore any lumbosacral malalignment in patients with sacralisation of L5 following this formula L1–L5 lordosis $= 0.67 * \text{L5I} + 30.7$. This concept would enhance accuracy of our surgical strategy in this population in view of the bigger amount of lumbar lordosis than in normal population.

This study provides thus new normative values for fusions above L5. Nevertheless, in case of previous L5-S1 fusion with insufficient lordosis correction, the new restoration of the lumbosacral alignment must be planed according to the standard spino-pelvic parameters based on PI.

Figure 7 shows an example of how L5I could be used to analyze the Lumbosacral alignment in a patient with sacralisation of L5. According to L5I of 26°, L1–L5 lordosis needs to match to a theoretical L1–L5 lordosis of 48.12° following the mathematical equation. During the surgical plan we need to take in consideration the lack of lordosis of 8° as his L1–L5 lordosis is 40°.

Conclusion

This prospective study is the first to provide normative values at the L5 level in an asymptomatic population. We propose L5I as a new parameter which has to be equal to

Table 2 Standard spino-pelvic parameters from S1 ($N = 137$) and new L5 parameters from L5 ($N = 137$ and $N = 10$)

		N	Mean (SD)	Min–Max
Spino-pelvic parameters from S1 (standard parameters)	Pelvic incidence (°)	137	51.57 (10.20)	[33.00–80.40]
	Pelvic tilt (°)	137	11.82 (6.50)	[−1.10–34.50]
	Sacral slope (°)	137	39.31 (7.47)	[5.00–59.00]
	Lordosis L1/S1 (°)	137	56.35 (8.90)	[35.00–88.10]
Spino-pelvic parameters from L5 (L5 parameters) for the normal asymptomatic population	L5I (°)	137	22.43 (9.85)	[4.00–58.00]
	L5 tilt (°)	137	4.65 (4.60)	[−5.80–21.90]
	L5 slope (°)	137	17.73 (8.49)	[−2.00–44.00]
	Lordosis L1/L5 (°)	137	45.51 (9.93)	[27.50–70.70]
Spino-pelvic parameters from L5 (L5 parameters) for the asymptomatic population with L5 sacralisation	L5I (°)	10	32.75 (11.20)	[11.00–52.00]
	L5 tilt (°)	10	6.63 (4.50)	[0.50–13.00]
	L5 slope (°)	10	26.38 (9.20)	[10.50–44.00]
	Lordosis L1–L5 (°)	10	55.02 (8.50)	[36.20–64.50]

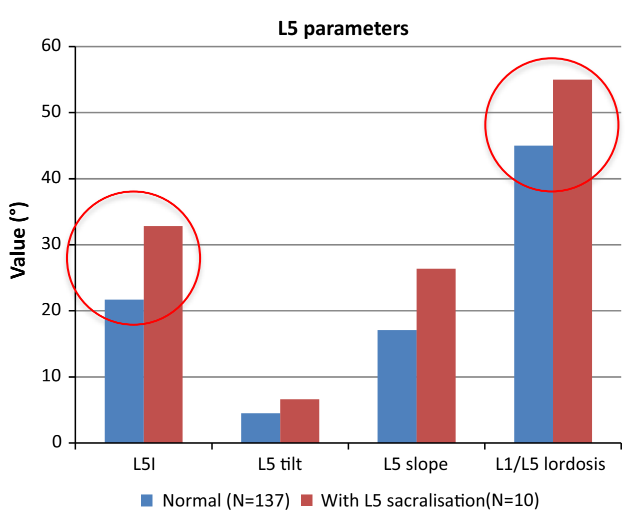

Fig. 4 Shows that average values in sacralisation of L5 subgroup is 10° bigger than in NS

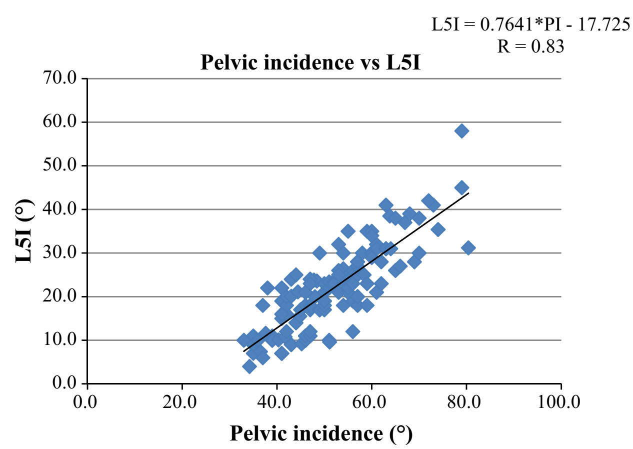

Fig. 5 Statistical correlation between pelvic incidence and L5 incidence

0.7641 * PI − 17.725 in asymptomatic population. In subjects with LSV where L5-S1 disk is fixed, L5I and lumbar lordosis between L1–L5 appears to be 10° bigger than in normal subjects which could be clinically relevant in small PI or L5I. The formula to be used to restore L1–L5 lordosis = 0.67 * L5I + 30.7.

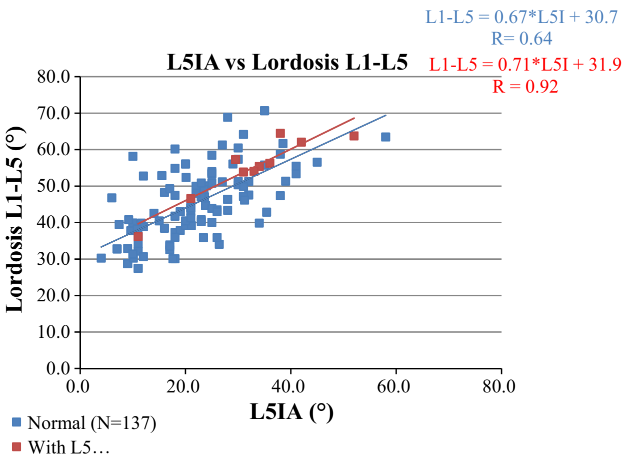

Fig. 6 Correlation between L5I values and L1–L5 lordosis in **a**. NS including lumbarisation of S1 ($N = 137$) and **b**. sacralisation of L5 where L5-S1 is fused ($N = 10$)

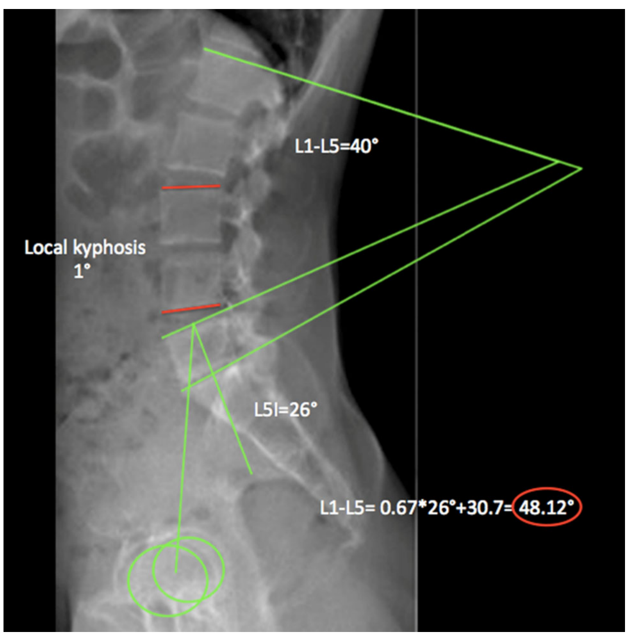

Fig. 7 Patient with a sacralisation of L5 who needs L3-L4 fusion and correction of a local deformity (1° of kyphosis and Modic I)

These values defined by our study will help surgeons to control peri-operatively the adequate lumbar lordosis restoration and better global spinal balance.

Compliance with ethical standards

Conflict of interest None.

References

1. Le Huec JC, Roussouly P (2011) Sagittal spino-pelvic balance is a crucial analysis for normal and degenerative spine. Eur Spine J 20:556–557. doi:10.1007/s00586-011-1943-y
2. Duval-Beaupère G, Schmidt C, Cosson P (1992) A barycentremetric study of the sagittal shape of spine and pelvis: the conditions required for an economic standing position. Ann Biomed Eng 20:451–462
3. Legaye J, Duval-Beaupère G, Hecquet J, Marty C (1998) Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. Eur Spine J 7:99–103
4. Roussouly P, Berthonnaud E, Dimnet J (2003) Geometrical and mechanical analysis of lumbar lordosis in an asymptomatic population: proposed classification. Rev Chir Orthop Reparatrice Appar Mot 89:632–639
5. Roussouly P, Gollogly S, Berthonnaud E, Dimnet J (2005) Classification of the normal variation in the sagittal alignment of the human lumbar spine and pelvis in the standing position. Spine 30:346–353
6. Boulay C, Tardieu C, Hecquet J et al (2005) Sagittal alignment of spine and pelvis regulated by pelvic incidence: standard values and prediction of lordosis. Eur Spine J 15:415–422. doi:10.1007/s00586-005-0984-5
7. Roussouly P, Pinheiro-Franco JL (2011) Sagittal parameters of the spine: biomechanical approach. Eur Spine J 20:578–585. doi:10.1007/s00586-011-1924-1
8. Apazidis A, Ricart PA, Diefenbach CM, Spivak JM (2011) The prevalence of transitional vertebrae in the lumbar spine. Spine J 11:858–862. doi:10.1016/j.spinee.2011.08.005
9. Mac-Thiong J-M, Roussouly P, Berthonnaud E, Guigui P (2010) Sagittal Parameters of Global Spinal Balance. Spine 35:E1193–E1198. doi:10.1097/BRS.0b013e3181e50808
10. Morvan G, Mathieu P, Vuillemin V et al (2011) Standardized way for imaging of the sagittal spinal balance. Eur Spine J 20:602–608. doi:10.1007/s00586-011-1927-y
11. Carreau JH, Bastrom T, Petcharaporn M et al (2014) Computer-generated, three-dimensional spine model from biplanar radiographs: a validity study in idiopathic scoliosis curves greater than 50 degrees. Spine Deformity 2:81–88. doi:10.1016/j.jspd.2013.10.003
12. Humbert L, De Guise JA, Aubert B et al (2009) 3D reconstruction of the spine from biplanar X-rays using parametric models based on transversal and longitudinal inferences. Med Eng Phys 31:681–687. doi:10.1016/j.medengphy.2009.01.003
13. Kuntz C4, Levin LS, Ondra SL, et al. (2007) Neutral upright sagittal spinal alignment from the occiput to the pelvis in asymptomatic adults: a review and resynthesis of the literature. J Neurosurg Spine 6:104–112. doi: 10.3171/spi.2007.6.2.104
14. Barrey C (2004) Equilibre sagittal pelvi-rachidien et pathologies lombaires dégénératives: etude comparative à propos de 100 cas [these]. Université Claude Bernard, Lyon
15. Farshad M, Aichmair A, Hughes AP et al (2013) A reliable measurement for identifying a lumbosacral transitional vertebra with a solid bony bridge on a single-slice midsagittal MRI or plain lateral radiograph. Bone Joint J 95-B:1533–1537. doi:10.1302/0301-620X.95B11.32331
16. Labelle H, Roussouly P, Berthonnaud E et al (2005) The importance of spino-pelvic balance in L5-S1 developmental spondylolisthesis: a review of pertinent radiologic measurements. Spine 30:S27–34