Standing lateral lumbar spine and pelvis (SLLP) radiograph: a screening, reduced radiation method, for sagittal imbalance

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Abstract

Introduction Sagittal imbalance is a predictor of failure after surgery for lumbar degenerative pathology. For this reason, specialists advocate correction of sagittal deformity and systematically perform preoperative standing whole spine films. Such diagnostic investigations expose patients to significant doses of radiation. The authors propose an easier radiographic investigation helpful as a screening test to identify patients likely to have sagittal imbalance.

Methods Fifteen whole spine lateral films were evaluated, classifying subjects into three categories: balanced, compensating imbalanced or imbalanced. A second specialist evaluated the reduced SLLP versions of the film (from L1 to proximal femora), measuring spinopelvic parameters.

Results In the SLLP film, the combination of two parameters (femoral inclination $>10^\circ$, pelvic tilt $>1/3$ pelvic incidence $+5^\circ$) identified 94 % of patients with altered sagittal balance.

Conclusions This study preliminarily suggests that the SLLP film can be a useful screening test for sagittal balance abnormalities.

Keywords Sagittal imbalance · Diagnosis · Screening · X-ray

Introduction

Sagittal imbalance is defined as the loss of shape of the spine in the sagittal plane, causing in the subject inability to maintain the standing position with little muscle effort. Sagittal imbalance has been identified as an independent predictor of back pain, function and health related quality of life in unoperated subjects, and in adults undergoing surgery for scoliosis. It is also an independent predictor of surgical result in adult patients undergoing surgery for scoliosis, sagittal deformity or lumbar degenerative conditions [1–3].

Assessment of sagittal imbalance exclusively relies on radiographic assessment. Most authors suggest using a full-spine lateral radiograph in a single film, including the hip joints [4–6] (or the proximal 10 cm of the femora [7, 8]) to make appropriate measurements of the parameters necessary to diagnose the sagittal balance status of the subject.

Thus, sagittal balance status is evaluated comparing the observed values of pelvic tilt, lumbar lordosis, thoracic kyphosis and sagittal displacement of the C7 plumb line to the predicted values based on the pelvic incidence of the subject. Data from recent research [9–13] support that for a given individual, normality of lumbar lordosis, pelvic tilt and thoracic kyphosis depends on their relationship to the value of pelvic incidence, currently the most important parameter defining sagittal shape of the pelvis.

Sagittal balance status has been classified into three categories [14]: sagittally balanced (C7 plumb line within 5 cm from posterior corner of S1 endplate), sagittally compensating imbalance (C7 plumb line within 5 cm from

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the posterior corner of S1 endplate but with increased pelvic tilt) or sagittally imbalanced (C7 plumb line more than 5 cm from the posterior corner of S1 endplate).

Due to the impact of sagittal imbalance on spinal symptoms and function, and on surgical results, there is a trend to assess sagittal balance during clinical evaluation of patients, as candidates for conservative or surgical care, and in postoperative evaluation. This means that a large number of patients could need undergoing sagittal balance evaluation, and a subset of patients (surgical patients) could need doing it repeatedly.

Lateral standing full-spine radiographs are not always easy to obtain. Special films or chassiss are necessary, and, especially in large individuals, differences of tissue density

between areas of the body (pelvis, lumbar spine, mid-thoracic and upper-thoracic spine) make it necessary to compensate exposure. This result in difficulty to get adequate exposure for all the areas included in the film and poor image quality that can lead to repeated exams. Finally, X-ray exposure in a large body volume with high-energy beams causes undesired exposure to high radiation doses.

The hypothesis of this study is that a short lateral standing film can be sufficient to identify patients with sagittal imbalance without the need for a standing full-spine film. This would mean that abnormality in lumbar or pelvic parameters is always present in patients with sagittal imbalance.

Methods

Fifteen patients representing the spectrum of sagittal balance (all three sagittal balance categories were included) were evaluated with full-spine standing lateral radiographs. The patients were asked to stand relaxed upright with the tips of the fingers lying on the ipsilateral clavicles and the knees extended as much as possible. The lateral film included in a single shot the spine from C7 to the sacrum, the hip joints and the proximal 10 cm of the femora.

Two sets of radiographs were produced by a technician: the first set included the full-spine film as described in the paragraph above; the second set was prepared eliminating the upper part of the full-spine films, and included only the

Fig. 1 Sample full-spine film

Fig. 2 Sample SLLP film

Fig. 3 Spinopelvic parameters evaluated on full-spine film (PI = 57°, PT = 23°, LL = 71°, FF = 3°, SVA = -20 mm)

lumbar spine from L1 to sacrum and extended caudally to the proximal 10 cm of the femora (SLLP film—standing lateral lumbar spine and pelvis film).

One spine fellow evaluated both sets of blinded radiographs. In the full-spine set, pelvic incidence, femoral inclination, pelvic tilt, lumbar lordosis, thoracic kyphosis and C7 plumb line translation were measured. In the reduced SLLP film, pelvic incidence, femoral inclination, pelvic tilt and lumbar lordosis were measured (Figs. 1, 2, 3, 4).

With these data, every film was classified as corresponding to a patient in sagittal balance or sagittal imbalance (compensating or not). A 2 × 2 table was created comparing the diagnosis coming from the gold standard

Fig. 4 Spinopelvic parameters evaluated on SLLP film (PI = 57°, PT = 23°, LL = 71°, FF = 3°)

Table 1 2 × 2 table comparing diagnosis coming from the gold standard (full-spine film) and alternative test (SLLP film)

Full-spine film	SLLP		
	B	C/I	Total
B	4	0	4
C/I	1	10	11
Total	5	10	15

Full-spine standing films diagnosed as normal four of fifteen patients, as compensating imbalance eight patients and as sagittally imbalanced three patients. The short films diagnosed as normal five patients and as altered the other ten patients. One patient classified as normal in the short-spine standing film was classified as imbalanced in the long film (criteria for abnormal balance in SLLP films: pelvic tilt >1/3 pelvic incidence +5° and femur inclination >10°). Sensitivity = 93.6 %, specificity = 100 %. (B balanced, C compensating imbalanced, I imbalanced)

(full-spine film) and alternative test (SLLP film) (Table 1). Sensitivity and specificity were calculated with 95 % confidence intervals for the SLLP film compared to the gold standard.

Results

Full-spine standing films diagnosed as normal four of fifteen patients, as compensating imbalance eight patients and

Table 2 Study database

Case number	Pelvic incidence (°)	Expected pelvic tilt (°)	Pelvic tilt (°)	Increased pelvic tilt	Sacral slope (°)	Expected lumbar lordosis (0°)	Lumbar lordosis (°)	Decreased lumbar lordosis	Thoracic kyphosis (°)	Femoral inclination (°)	Increased femoral inclination	SVA (cm)	Increased SVA	First set of diagnostic criteria		Second set of diagnostic criteria	
														Short film	Whole-spine film	Short film	Whole-spine film
1	54	16.2	18	No	36	61.72	68	No	60	3	No	0	No	Normal	Normal	Normal	Normal
2	55	16.5	16	No	29	62.26	39	Yes	46	0	No	12	Yes	Normal	Imbalanced	Altered	Imbalanced
3	43	12.9	34	Yes	19	55.78	24	Yes	11	7	Yes	1	No	Altered	Compensating	Altered	Compensating
4	35	10.5	13	Yes	19	51.46	19	Yes	47	10	Yes	2	No	Altered	Compensating	Altered	Compensating
5	72	21.6	27	Yes	46	71.44	40	Yes	32	3	No	12	Yes	Altered	Imbalanced	Altered	Imbalanced
6	62	18.6	15	No	46	66.04	63	No	20	0	No	2	No	Normal	Normal	Normal	Normal
7	54	16.2	53	Yes	0	61.72	−9	Yes	42	11	Yes	3	No	Altered	Compensating	Altered	Compensating
8	40	12	52	Yes	9	54.16	14	Yes	84	29	Yes	20	Yes	Altered	Imbalanced	Altered	Imbalanced
9	72	21.6	46	Yes	24	71.44	32	Yes	39	7	Yes	5	No	Altered	Compensating	Altered	Compensating
10	63	18.9	41	Yes	22	66.58	35	Yes	66	11	Yes	4	No	Altered	Compensating	Altered	Compensating
11	37	11.1	38	Yes	1	52.54	12	Yes	34	5	No	3	No	Altered	Compensating	Altered	Compensating
12	35	10.5	3	No	22	51.46	31	Yes	44	3	No	1	No	Normal	Normal	Normal	Normal
13	66	19.8	30	Yes	35	68.2	59	No	74	7	No	0	No	Altered	Compensating	Altered	Compensating
14	64	19.2	34	Yes	27	67.12	30	Yes	34	10	Yes	4	No	Altered	Compensating	Altered	Compensating
15	35	10.5	5	No	28	51.46	27	Yes	26	6	No	2	No	Normal	Normal	Altered	Normal

as sagittally imbalanced three patients. The short films diagnosed as normal five patients and as altered the other ten patients. When the diagnostic criteria for abnormal balance in short-spine films were pelvic tilt more than 5° superior to 1/3 pelvic incidence and femur inclination more than 10°, dichotomic classification in normal or abnormal in full-spine and short-spine films was matching in 14 of 15 patients. One patient classified as normal in the short-spine standing film was classified as imbalanced in the long film (Table 2, case number 2). Sensitivity of these diagnostic criteria in short-spine films for abnormal sagittal balance was calculated as 93.6 % and specificity as 100 %.

When the diagnostic criteria for abnormal balance in short-spine films were modified to include as an extra criterion lumbar lordosis out of the theoretical lumbar lordosis $\pm 9^\circ$ interval, all abnormal patients were identified, but one normal patient was classified as abnormal (Table 2, case number 15). Sensitivity of these modified diagnostic criteria (including decreased lumbar lordosis compared to expected) in short-spine films for abnormal sagittal balance was calculated as 100 % and specificity as 93.6 %.

Discussion

This study preliminarily demonstrates that an easy to obtain short-spine lateral standing radiograph can be useful as a screening method to select candidates for a more thorough evaluation with the more difficult and higher exposure whole spine radiographs.

The introduction of this method of screening would make easier, less expensive and safer systematic evaluation of sagittal imbalance in patients with back problems.

The two sets of diagnostic criteria have showed a different diagnostic behavior, allowing the clinician to select a more specific or sensitive test depending on the purpose of the evaluation in course.

The main limitation of this study is the small number of patients included in it. Further studies with a larger sample, including operated and unoperated patients should confirm these results before considering introducing the short standing radiograph as a method of evaluation of sagittal imbalance.

Conflict of interest None of the authors has any potential conflict of interest.

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