Radiographic evaluation of ventral instability in lumbar spondylolisthesis: do we need extension radiographs in routine exams?

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Abstract

Purpose To determine the usefulness of acquiring extension radiographs for the evaluation of the degree of spondylolisthesis.

Methods Routine radiographs of the lumbar spine were retrospectively evaluated in 87 patients (mean-age 63, range 32–86) by two independent radiologists. All patients received radiographs in standing neutral, flexion and extension position. Vertebral body depth, sagittal translational displacement and lordosis angle were measured and slip percentage (SP) was calculated on standing neutral, flexion and extension radiographs. Statistical analysis was performed with a two-sided *t* test. Inter- and intraobserver reliability was assessed using the kappa-coefficient.

Results There was no statistically significant SP-difference between neutral standing and extension images. Ventral instability was diagnosed in 25–34 % (cut-off >8 % SP-difference) for neutral versus flexion comparison. The detection rate of flexion–extension radiographs representing the extremes of motion was lower with 15–22 %. Inter- and intraobserver reliability was good to excellent.

Conclusion Slip percentage in routine standing extension radiography ultimately does not differ from that obtained in a static neutral standing view. Extension radiography may

therefore be omitted in a routine work-up of ventral instability in lumbar spondylolisthesis.

Keywords Radiography · Back pain · Spondylolisthesis · Vertebral instability

Introduction

Low back pain is a common condition with a lifetime prevalence of up to 84 % of the general population [1]. At a given time 23 % of the population suffers from chronic low back pain [1]. In many cases it remains difficult, if not impossible, to determine the exact cause of back pain, but among various other conditions spondylolisthesis with lumbar intervertebral instability can be an important factor [2].

While spinal stability can be defined as a limited relative displacement of the vertebrae under physiological conditions [3], the definition of instability is still under considerable debate [4].

Various techniques have been developed over the past decades to evaluate the presence of spinal instability both clinically and radiologically. The most widely used approach is lumbar flexion–extension radiography in the sagittal plane [5–7]. Although there have been studies calling reproducibility of such images into question [8–10], many surgeons base their decision for surgical treatment on this method [11].

There have been many reports on the ideal patient position in which lateral radiographs are best to be taken to maximize diagnostic efficacy [7, 12–18], however, no study evaluated whether it is necessary to acquire both positions: extension and flexion X-ray in addition to neutral standing images.

The aim of the present study was therefore to determine the degree of spondylolisthesis and additional ventral

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translation on neutral, flexion and extension radiographs in a standing position under the hypothesis that in a routine clinical work-up in patients with manifest spondylolisthesis images in a neutral standing position and in flexion are sufficient for the evaluation of ventral instability.

Materials and methods

Patient collective

We retrospectively evaluated routine radiographs of the lumbar spine of 87 patients (59 w, 28 m, mean-age 63, range 32–86) acquired between April 2011 and April 2012 for the evaluation of chronic low back pain. Inclusion criteria were the presence of low back pain as well as ventral spondylolisthesis on plain lateral films in the neutral standing position. Patients were excluded from the study if a severe scoliosis was present or if they had previously undergone lumbar surgery. Image quality regarding adequate lateral patient positioning was evaluated in consensus by two radiologists prior to measurements.

Radiographic technique

Anterior–posterior and true lateral neutral radiographs as well as standing flexion and extension images of the lumbar spine were obtained in all patients. Images were acquired on 35/43 cm digital X-ray cassettes with a film focus distance of 1.15 m and 85 kV.

All examinations were part of a routine clinical work-up for low back pain and no additional images were acquired for this study.

Radiographic evaluation

Images were retrospectively analyzed by two independent, blinded, experienced radiologists using the measurement technique proposed by Dupuis et al. [6]. The first examiner repeated measurements after 4–6 weeks.

The following parameters were assessed individually for each image: vertebral body depth (VBD), absolute values of sagittal translational displacement (TD), as well as the lordosis angle (LA).

Data analysis

Slip percentage (SP) was calculated using VBD and TD for all images. The respective SP value of neutral lateral standing images was then compared to the dynamic flexion–extension images. Vertebral segments were regarded as unstable if the SP-difference exceeded 8 %.

All measurements were performed using the IMPAX EE Software (Agfa HealthCare, Germany).

Normal distribution of the data was evaluated using QQ plots. Inter- and intraobserver reliability was analyzed using the approach of Bland and Altman [19]. The data were then entered into a two-sided *t* test for dependent values for statistical analysis. Apart from comparison of the measured values themselves, we analyzed the detection rate of vertebral instability (cut-off SP >8 %) of both examiners using the kappa-coefficient.

Results

All patients presented with low back pain warranting routine radiographic examination of the lumbar spine. Spondylolisthesis was present to a different degree in all cases in the neutral standing position with the level L4–5 being affected in the majority of cases ($n = 48$), followed by L5–S1 in 23, L3–4 in 11, L2–3 in 4 and S1–2 in 1 case. 92 % showed a grade 1 olisthesis according to Meyerding on plain radiography. The remaining 8 % presented with grade 2 olisthesis.

Intra- and interobserver agreement on the presence of instability was good to excellent, with an intra- and inter-rater reliability of $K = 0.92$ and $K = 0.81$ (kappa-coefficient), respectively for neutral standing versus flexion comparison as well as $K = 0.82$ and $K = 0.70$ for standing flexion–extension comparison.

When looking at the measurement results themselves intra- and interobserver reliability were also within previously described boundaries [20]. Figure 1 shows exemplary Bland-Altman-plots for TD and LA. As is to be expected the limits of agreement are wider for interobserver comparison, but there is no systematic measurement error between the two radiologists.

Measurement results of LA and calculated values for SP, as well as the results of the statistical analysis are summarized in Tables 1 and 2.

SP differed significantly between the neutral position and flexion, as well as between flexion and extension ($p < 0.001$), while there was no statistically significant difference between SP as measured in the neutral position and extension images.

Ventral vertebral translation was highest in standing flexion ($SP\ 21.98 \pm 6.85\ %$) and lowest in the neutral standing position ($SP\ 16.96 \pm 7.48\ %$). SP in extension images was slightly higher ($SP\ 17.25 \pm 7.28\ %$) than in neutral standing images, however, this was not statistically significant.

The largest difference of the LA, representing the extremes of motion, was found in standing flexion–extension images. Although motion between neutral and

Fig. 1 Bland-Altman plots for comparison of intraobserver (a, c) and interobserver (b, d) agreement between measurements of listhesis (a, b) and lordosis angle (c, d)

extension images was rather small ($-2.52 \pm 4.72^\circ$) LA changes were still statistically significant.

Using a cut-off of $>8\%$ to diagnose ventral translational instability, 25–34 % of segments were rated to be unstable when comparing neutral and flexion images. Interestingly, the detection rate of flexion–extension radiographs representing the extremes of motion was lower (15–22 %).

Discussion

Biomechanical features of the lumbar spine are difficult to assess on a clinical routine basis and the diagnosis is commonly based on imaging findings [21]. No definite agreement on the optimum approach to evaluate segmental instability has been reached, with standing flexion–extension images being the most widely used [4, 5].

In our study of 87 symptomatic patients with lumbar spondylolisthesis suffering from low back pain, we investigated the degree of olisthesis on lateral neutral, extension and flexion images acquired in the standing position to determine the usefulness of these different positions in a clinical routine work-up. In contrast to sagittal CT or MRI views, there can be inherent measurement errors on radiography due to imperfect patient positioning in daily routine. However, measurements were performed with widely accepted and validated techniques on true lateral views and yielded good to excellent values for inter- and intraobserver reliability.

The overall range of motion of the lumbar spine between the different positions was defined by the lordosis angle (LA), representing the sum of all angulatory changes between spinal segments L1–S1 [22]. As is to be expected we observed the largest LA-difference between flexion and

Table 1 Mean slip percentage and lordosis angle

	Observer 1				Observer 2	
	Measurement 1		Measurement 2			
	Mean $\pm$ SD	N	Mean $\pm$ SD	N	Mean $\pm$ SD	N
Slip percentage (%)						
Neutral standing	16.96 $\pm$ 7.48	87	16.86 $\pm$ 7.48	87	17.50 $\pm$ 7.40	87
Flexion	21.98 $\pm$ 6.85	87	21.99 $\pm$ 6.98	87	21.80 $\pm$ 6.86	87
Extension	17.25 $\pm$ 7.28	87	17.24 $\pm$ 7.22	87	17.83 $\pm$ 7.24	87
Lordosis angle (°)						
Neutral standing	54.19 $\pm$ 13.49	87	54.35 $\pm$ 13.40	87	55.15 $\pm$ 12.80	87
Flexion	33.51 $\pm$ 18.64	87	32.94 $\pm$ 18.60	87	34.37 $\pm$ 18.80	87
Extension	56.71 $\pm$ 13.00	87	57.19 $\pm$ 12.92	87	58.52 $\pm$ 13.43	87

SD standard deviation

Table 2 Results of *t* test for slip percentage and lordosis angle

	Observer 1				Observer 2	
	Measurement 1		Measurement 2			
	Mean $\pm$ SD	<i>p</i>	Mean $\pm$ SD	<i>p</i>	Mean $\pm$ SD	<i>p</i>
Slip percentage (%)						
NS–Flex	−5.01 $\pm$ 4.36	<0.001	−5.13 $\pm$ 4.30	<0.001	−4.31 $\pm$ 3.91	<0.001
NS–Ext	−0.28 $\pm$ 2.24	0.24	−0.38 $\pm$ 2.15	0.105	−0.33 $\pm$ 2.51	0.225
Flex–Ext	4.72 $\pm$ 4.02	<0.001	4.78 $\pm$ 3.79	<0.001	3.98 $\pm$ 3.32	<0.001
Lordosis angle (°)						
NS–Flex	20.68 $\pm$ 14.29	<0.001	21.40 $\pm$ 14.46	<0.001	20.78 $\pm$ 15.41	<0.001
NS–Ext	−2.52 $\pm$ 4.72	<0.001	−2.84 $\pm$ 4.67	<0.001	−3.38 $\pm$ 5.47	<0.001
Flex–Ext	−23.20 $\pm$ 15.33	<0.001	−24.24 $\pm$ 15.52	<0.001	−24.15 $\pm$ 16.09	<0.001

NS neutral standing, Flex flexion, Ext extension, SD standard deviation

Bold values indicate statistical significance ($p < 0.001$)

extension. LA differed significantly between all three positions, indicating good patient cooperation, i.e., adequate performance of inclination and reclination.

In contrast to the significant LA-difference, we found no difference for SP when comparing neutral and extension images, while SP differed significantly between flexion and neutral, as well as flexion and extension. When looking at the calculated SP values themselves, extension did not lead to reposition of the ventral slip present in the neutral position.

The definition of anterior–posterior instability using a cut-off of $>8\%$ SP-difference is widely accepted in literature [17, 23, 24]. Using flexion radiographs in addition to a neutral standing view, our observed instability of 25–34 % was in line with previously reported values of instability [17, 25, 26]. Extension images did not add further information concerning ventral instability. In fact,

when comparing the two “extremes” of motion, namely flexion and extension views, the detection rate was even lower (15–22 %), which might be explained by slightly higher SP values in extension than in the neutral position. This observation was consistent between different measurements and different observers.

There are some influencing factors of intervertebral motion that have to be considered. Flexion–extension radiographs in the standing position are dependent on patient cooperation, which has challenged the relevance of such images in the evaluation of vertebral instability in the view of some authors [27].

An important part of the stabilizing system of the spine is muscle tension, which can compensate a loss of intervertebral stability to a certain extent [28]. It is well-known that abnormal translation is reduced in a standing position compared to a lateral decubitus position due to

heightened muscle tone when standing [17], although sagittal balance allows for a comparatively low muscle tone in the neutral position compared to flexion or extension. Back pain is also a contributing factor leading to significantly reduced intervertebral movement in dynamic examinations [17, 29].

As patient cooperation in our study was considered to be adequate on the basis of an overall significant LA-difference, the lack of a corresponding SP-difference between neutral and extension images might therefore be explained by heightened muscle tone in the respective spinal segment limiting intervertebral motion.

Especially in view of rather high-radiation doses of lumbar spinal radiographs (2.2 mSv for a standard AP-view and 1.5 mSv for lateral images) [30] the number of images should be limited to a minimum necessary for proper diagnostic purposes.

As sagittal spinopelvic parameters measured on neutral standing radiographs, like the pelvic tilt, slope and incidence, as well as the spinal sagittal balance have been recognized as being important for surgical planning of lumbar fusion, neutral standing images are part of routine examinations [5, 31].

Standing flexion images can then be acquired to determine the extent of ventral translational shift. It can be advantageous to additionally compare SP in standing flexion to measurements taken in the supine recumbent position (i.e., CT or MRI) [20].

Extension views, however, should be omitted in a routine work-up for the evaluation of ventral instability in spondylolisthesis, since the slip percentage does ultimately not differ from that in the neutral standing position and since radiation dose should be kept as low as reasonably achievable.

Conflict of interest All authors report that there are no disclosures relevant to this publication.

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