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Sagittal alignment in lumbar spinal canal stenosis

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Abstract

Objective: To evaluate the impact of lumbar canal stenosis on the sagittal balance of patients by studying the parameters of sagittal alignment.

Methods: This single-centre prospective study, conducted from January 2020 to January 2022, included 47 patients presenting with lumbar canal stenosis confirmed by MRI and documented spinal balance assessed by full spine X-ray in standing profile. Patients with lumbo-radicular pain post-lumbar arthrodesis surgery were also included. The sagittal alignment parameters assessed were pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), L4-S1 lordosis (LL4-S1), PI-LL mismatch, thoracic kyphosis (TK), sagittal vertical axis (SVA), and TPA.

Results: The mean pelvic incidence (PI) was 60.97° (SD 13.93°), with Class IV incidence in 36.2% of cases. Pelvic tilt (PT) averaged 18.65° (SD 10.91°), with values <10° in 19%, 10-25° in 53%, and >25° in 28% of patients. Sacral slope (SS) was 42.87° (SD 8.49°), with 53.2% in the 35-45° range. The measured lumbar lordosis (LL) was 46.10° (SD 17.84°), significantly lower than the theoretical LL (p=0.001). L4-S1 lordosis averaged 38.85° (SD 15.34°), also less than the theoretical value (p=0.017). PI-LL mismatch >10° was present in 60% of cases. Thoracic kyphosis (TK) averaged 14.57° (SD 11.29°), and sagittal vertical axis (SVA) was >5 cm in 81% of patients. T1 pelvic angle (TPA) was <20° in 57.4%.

Conclusion: The analysis revealed that lumbar canal stenosis significantly affected spinal architecture, primarily through the loss of lumbar lordosis, and had a notable impact on thoracic kyphosis. Therapeutic approaches should not only focus on root decompression but also on restoring lumbar lordosis, with careful consideration of the arthrodesis level.

Keywords
lumbar canal stenosis, lumbar lordosis, pelvic incidence, pelvic tilt, sagittal balance

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Introduction

Lumbar spinal canal stenosis is one of the most degenerative spine diseases. It's the most common cause of spine surgery for people over 65 years old (4,14). Lumbar spine canal stenosis is characterized by morphological changes of the intervertebral disc, the ligamentum flavum and the facet joints. The result of these changes is the reduction of the useful diameter of the vertebral canal thus causing spine and neurogenic pain (12). Apart from neurological damage, the modifications caused by stenosis have an impact on spinal architecture.

The biomechanical organization of the spine includes the sagittal spinal alignment defined as harmonious succession sagittal spinal curvatures. (5)

There is a strong statistical link between sagittal alignment and pre or post operative quality of life (15). Spinal imbalance induces spinal pain, a source of functional disability well evaluated by the ODI (6). Maintaining or restoring optimal spinal alignment is one of the major therapeutic goals in spinal stenosis.

Lumbar canal stenosis poses the problem of the evaluation of its impact on the lumbar spinal architecture but also far from the initial lumbar site.

The aim of this study was to evaluate the impact of lumbar canal stenosis on the sagittal balance of patients by studying the parameters of sagittal alignment.

Material and method

This was a single-center prospective study carried out from January 2020 to January 2022. The inclusion criteria grouped together patients seen in neurosurgery consultation for stenosis of the lumbar canal documented by an MRI, patients whose spinal balance was documented by a full spine X-ray in standing profile as well as patients operated for lumbar canal stenosis with an arthrodesis and presenting with lumboradicular pain. According to these inclusion criteria, the sample for this study was 47 patients, M= 21, F= 26. The data was collected on a survey form guaranteeing the anonymity of the patients. It included patients sociodemographic characteristics (age, gender, occupation). The sagittal and global alignment parameters studied were pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), L1-S1 lumbar lordosis (LL), L4-S1 lordosis (LL4-S1), PI minus LL (PI-LL), thoracic kyphosis (TK), sagittal vertical axis (SVA) and TPA.

The data was analyzed using IBM SPSS 26 software. For quantitative variables, the numbers and percentages were calculated. For the qualitative variables we calculated the followed by the standard deviations and the extremes. We used Khi^2 test or the exact test of fisher to cross two qualitative variables. The difference between the measured values and the theoretical values were analyzed by the T-student test. The significance threshold was set at 5% ($p \leq 0.05$).

Results

The mean PI was of 60.97° (minus=35°, maximum=90.6°, SD=13,93°). Class IV incidence was mostly seen (36,2%). The PT was in value 18.65°+/-10.91°. Its distribution showed extreme between 1° to 45.10°. PT was less than 10 in 19%, between 10° to 25° in 53% and over than 25° in 28%. The SS was of 42,87°+/- 8.49. SS was small (less than 35°) in 17%, middle (between 35° to 45°) in 53.2% and over 45° in 29.8%. the measured LL was 46.10°+/-17.84° (13° to 94.3°). The measured LL was 21.4°±15.41° in women and 18.30°±16.70° in men (P=0.662). The theoretical LL was 67.15°±7.46° (55° to 85.6°). This LL was 68.01°±7.03° in women and 65.98°±8.02° in men (p=0.362). The theoretical LL was greater than measured LL (p=0.001). The L4-S1 lordosis was measured to 38.85°±15.34° (2.30° to 77.40°) and this lordosis was less than the theoretical one, 44.76±4.97° (p=0.017). The loss of lumbar lordosis is summarized in the table 1. PI-LL was 20.12°±16.07° (0.6° to 59.6°). PI-LL up to 10° (PI-LL>10°) was seen in 60 % of cases. The thoracic kyphosis (TK) was 14.57°±11.29° (0.8° to 50.4°). TK was less than 45° in 93.6% of cases, up to 45° in one case and equal to 45° in two cases (4.3%). The SVA was 16.01±14.12 cm (0.1 to 69.4°). It was greater than 5 cm in 81% and lower than 5 cm in 19%.

The Pelvic angle of T1 was 17.97°±11.59° (0.3 to 46.4°). TPA was less than 20° in 57.4% of cases. The Table 2 summarizes the characteristics of all patients in this cohort.

Table 1. Assessment of loss of lordosis according to theoretical L1-S1 lordosis.

	Number	%
Lost of lordosis>30°	16	34.04
Lost of lordosis beetwen 20° and 30°	11	23.41
Lost of lordosis between 10° to 20°	05	10.63
No lost of lordosis	15	31.92

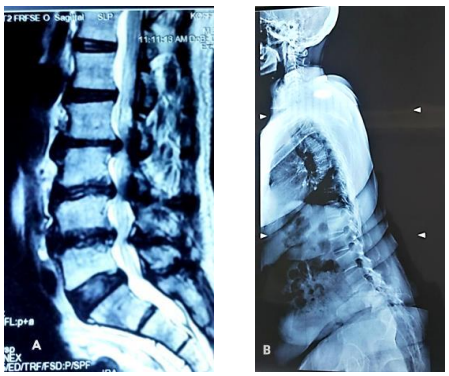

Figure 1. Sagittal MRI with L1-S1 spinal canal stenosis (A**)** with important degenerative changes in spine architecture on full spine radiography in standing profile (**B**).

Discussion

Lumbar canal stenosis is a common degenerative disease which causes significant pain and functional disability (2,3). This condition is responsible for spinal structural and architectural modifications. Evaluating its impact on spinal alignment is needed to establish spinal and pelvic parameters of the target population. Savadogo et al defined LL of subsaharians Africans according to pelvic parameters (12).

Table 2. Summary of the study patient characteristics.

N°	Age/sex	PI	PT	SS	LL1-S1	TLL1-S1	LL4-S1	TK	SVA	TPA	PI-LL	LL1-S1-TL1-S1
1	64/F	78°	36°	42	25°	83°	11°	3°	61	46.4°	53°	-58°
2	39/F	35°	1°	36	59°	55°	42°	22.7°	9.4	7.4°	-24°	4°
3	17/F	60°	3°	57	85°	65°	40°	12.2°	21	9.1°	-25°	20°
4	58/F	52°	26°	26°	13°	62°	49°	6.7°	26	32.9°	39°	-49°
5	34/F	58°	8°	50°	73°	63°	60°	28,9°	25	3.3°	-15°	10°
6	23/F	61.8°	11.1°	50.7°	57.2°	66.8°	51°	18.1°	17	1.5°	4.6°	-9.6°
7	63/F	82°	45.1°	36.9°	49.1°	77°	12.1°	8.1°	24	44.6°	32.9°	-27.9°
8	55/M	42.6°	12.4°	30.2°	55.1°	57.6°	22.4°	6.9°	18	12.9°	-12.5°	-2.5°
9	57/F	47.9°	11.5°	36.4°	49.5°	62.9°	48.7°	8.2°	17	0.3°	-4.2°	-13.4°
10	48/M	37.1°	7.4°	29.7°	48.5°	57.1°	37.5°	4.5°	6.8	0.9°	-11.4°	-8.6°
11	53/F	85.9°	33.8°	52°	55.7°	80.9°	51.9°	11.8°	11	24.9°	30.2°	-25.2°
12	22/F	63.4°	18.4°	45°	94.3°	68.4°	55.1°	9.3°	14	9.7°	-30.9°	25.9°
13	74/M	48°	7°	41°	34°	58°	29°	2.9°	15	13.3°	14°	-24°
14	40/F	72°	15°	57°	79°	72°	65°	23.3°	12	7.6°	-7°	7°
15	48/F	44.2°	4.4°	48.6°	54.2°	59.2°	31.5°	9.9°	16	7.8°	-10°	-5°
16	40/F	53.7°	10.9°	42.8°	21.5°	63.7°	2.3°	23°	28	20.6°	32.2°	-42.2°
17	34/F	58.7°	17.7°	41.2°	57.6°	63	27.6°	13.8°	0.2	12.6°	1.1°	-5.4°
18	42/M	43.1°	12.6°	30.06°	44.4°	58.1°	36.6°	18.1°	0.4	9.3°	-1.3°	-13.7°
19	39/M	53.6°	8.6°	45°	66.1°	63.6°	43.5°	18.7°	15	1°	-12.5°	2.5°
20	57/F	54.1°	12.1°	42°	24.1°	64.1°	42.9°	18°	11	15.3°	30°	-40°
21	55/M	77.4°	22°	55.4°	68°	77.4°	65°	30.4°	8.2	14.2	9.4°	-9.4°
22	63/F	58.4°	46.1°	46.2°	40.4°	63.4°	35.4°	9.4°	20	16.9°	18.4°	-23°
23	50/M	90.6°	26.2°	64.4°	65.2°	85.6°	61.5°	0.8°	4.3	21.2°	25.4°	-20.4°
24	60/F	73°	34°	39°	57.2°	73°	20.3°	41.7°	43	43.1°	15.8°	-15.8°
25	48/M	44.2°	4.4°	39.8°	54.2°	59.2°	31.5°	10.1°	16	7.8°	-10°	-5°
26	38/M	58.4°	13.4°	45°	56.5°	63.4°	36°	19.8°	1.1	9.2°	1.9°	-7.1°
27	52/M	64.8°	21.6°	43.2°	53.8°	69.8°	28.4°	16.9°	37	29.4°	9°	-16°
28	44/F	70.4°	28.7°	41.7°	50.4°	70.4°	33°	21°	0.7	20.6°	20°	-20°
29	63/F	46.9°	11.6°	35.3°	55.7°	61.9°	42.7°	2.8°	20	13.4°	-8.8°	-6.2°
30	58/M	60.3°	16.3°	44°	40.3°	65.3°	34.3°	6.3°	28	21.9°	20°	-25°
31	73/F	66°	23.1°	42.9°	19.5°	71°	28.3°	19.6°	10	23°	46.5°	-51.5°

The PI distribution showed large PI in 15.90%, a middle PI in 65.90% and a low grade PI in 18.20%. They concluded that the expected LL of Subsaharian Africans was in fact mostly middle (12). PI distribution was identical in our sample with middle grade PI in 49%. Lim et al (10) evaluated spinopelvic alignment between degenerative spondylolisthesis (SPDL) and lumbar canal stenosis (SCL) on a sample of 142 patients. PI was 56.10 +/-10 in SPDL and 49.60 +/-12 in SCL. According to them SCL spinopelvic alignment was relatively well compensated by a pelvic retroversion. We can concluded that the possibility of pelvic retroversion is more important in SCL even when the PI was lower than in SPDL. In fact we observed that, the sagittal misalignment was compensated by a pelvic retroversion in 28% of patients of our cohort. We had also 19% of pelvic anteversion. They was no difference in pelvic adaptation between men and women (p=0.522).

The global L1-S1 lordosis stayed low according to PI. The theoretical L1-S1 lordosis was significantly superior to the measured one (p<0.005) in 87.2%. Thus the stenosis had a strong impact on the lumbar lordosis leading to a loss of it in the majority of patients (8,9).

Frequently it existed a transition from lordosis to kyphosis (2,3,11). Apart from absolute values of lumbar lordosis the measured LL was statistically

inadapted to PI in 60% thus testifying to this loss of lumbar lordosis. We noted also a statistically significant loss of adequacy between the segmental L4-S1 lordosis and the global lordosis L1-S1 (p=0.017). Distal lordosis was no longer synchronous with overall lumbar lordosis and therefore with other pelvic parameters. This state led to a forward shift of the head far from the axis of pelvis thus attested in our series by the lengthening of the SVA indicating severe anterior imbalance. We thus found 81% of patients having an imbalance according to SVA. This percentage was reduced to 42.6 when we use the T1 slope (TPA) ignoring the bias induced by pelvic retroversion. The TPA was 17.9°+/- 11.6° in lumbar canal stenosis. Hasegawa et al found 17.6° in degenerative spondylolisthesis and 35.6° lumbar canal stenosis with degenerative scoliosis (7). Despite the average value of the TPA, we noticed a global imbalance in 42.6% (TPA>20°).

One of the affected alignment parameters was thoracic kyphosis (1). In our series there was a loss of thoracic kyphosis in 93.6%. Overall, 95.7% were unbalanced at the thoracic spinal level, reflecting an adaptation phenomenon.

Conclusion

The analysis of the different parameters revealed that stenosis of the lumbar canal had a strong impact on spinal architecture. The key point of this impact seemed to be the loss of lumbar lordosis and this stenosis had a significant impact on the thoracic kyphosis.

The pain observed in this pathology was not only linked to the radicular compressive phenomenon but to the cascade of events aimed at rebalancing the spine. The spinal imbalance was global in the majority of cases. Therapeutic treatment in addition to root release should aim to restore lumbar lordosis with the problem of choosing the level of arthrodesis.

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