

Anatomic Variants and Radiographic Predictors of Lumbosacral Transitional Vertebrae

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INTRODUCTION: Accurate vertebral identification is critical for safe spinal surgery, yet variations in vertebral number and anatomy can cause wrong-level procedures. While most humans have 7 cervical, 12 thoracic, and 5 lumbar vertebrae, deviations occur. Differences in rib length and transitional vertebrae further complicate numbering. This study aimed to determine the prevalence of vertebral variants, evaluate sagittal alignment, and measure 11th/12th rib lengths in patients without deformities. Identifying radiographic markers on standard imaging may improve recognition of transitional segments, enhance numbering accuracy, and reduce surgical error. These findings are relevant to surgeons, radiologists, and other specialists. Prior reports describe 11–13 thoracic vertebrae, with or without transitional segments, and occasional lumbar count variations. Variability in reporting and rib length underscores the need for systematic radiographic assessment to reduce errors and improve outcomes.

METHODS: This retrospective IRB-approved study (consent waived) included adults (≥ 18) who underwent AP and lateral EOS spine scans (Jan 2019–May 2021). Exclusion criteria: prior spine surgery, deformities, scoliosis $>20^\circ$, congenital fusion, or poor-quality imaging. Demographics (age, sex, race, ethnicity) were collected. Radiographic measures included thoracic/lumbar segment count, transitional vertebra presence, rib lengths, pelvic parameters, lumbosacral–femoral head distance, L5 encasement, and intercrestal line position. Segment counts were made C1–S1; rib lengths from pedicle to tip; lumbosacral distance from S1 endplate to femoral head centers. L5 encasement within the pelvis was scored as 0 (less than half below the iliac crest apex), 1 (\geq half below apex), or 2 (entire vertebra below apex). Continuous data were summarized as mean \pm SD and categorical as counts/percentages; significance was set at $P < 0.05$.

RESULTS SECTION: A total of 850 patients were included (mean age: 50 ± 11 years, 48.9% female). Most were non-Hispanic/Latino (87%) and White (77%). All patients had 7 cervical vertebrae, and 99% had 5 lumbar vertebrae. Variants included 11 thoracic vertebrae in 4% ($n=31$) and 13 thoracic vertebrae in 0.8% ($n=7$). Of those with 11 thoracic vertebrae, 74% had a transitional segment. Variants in lumbar count were rare (4 lumbar vertebrae, 0.4%; 6 lumbar vertebrae, 0.8%). Overall, 36% of patients ($n=304$) had a transitional vertebra. An intercrestal line through L5 was observed in 46% of patients. The 11th rib averaged 15.8 ± 1.9 cm in length, measuring ≥ 11 cm in 99% of patients, while the 12th rib averaged 9.5 ± 2.4 cm and was ≤ 15 cm in 99%. Patients with a transitional vertebra demonstrated higher pelvic incidence ($56.3 \pm 14.4^\circ$ vs. $50.2 \pm 11.5^\circ$, $P < 0.001$), pelvic tilt ($17.2 \pm 8.6^\circ$ vs. $15.5 \pm 7.9^\circ$, $P = 0.006$), and sacral slope ($39.1 \pm 11.8^\circ$ vs. $34.7 \pm 9.5^\circ$, $P < 0.001$). The lumbosacral joint-to-femoral head distance was shorter in men (10.2 ± 1.0 cm vs. 10.6 ± 0.8 cm, $P < 0.001$) and women (10.4 ± 0.9 cm vs. 10.7 ± 0.8 cm, $P = 0.001$) with a transitional vertebra. The L5 encapsulation score was greater in the transitional group (1.30 ± 0.72 vs. 1.13 ± 0.61 , $P = 0.001$). Fifty-one patients with L5 fully below the iliac crest had a transitional vertebra.

DISCUSSION: Transitional vertebrae are common and predictable with reproducible radiographic markers, including rib length, lumbosacral pelvic distance, spinopelvic alignment, and L5-pelvis relationship. These features support multiple strategies for accurate vertebral counting on standard radiographs, even without advanced imaging. Although EOS allowed precise counts here, it is costly and less accessible. Emphasizing markers visible on AP lumbar films offers practical means to reduce wrong-level surgery. Limitations include variability in imaging and anatomy, sometimes requiring confirmatory advanced imaging.

SIGNIFICANCE/CLINICAL RELEVANCE: Accurate identification of transitional vertebrae is clinically significant, as failure to recognize these anatomic variants can lead to errors in vertebral counting and increase the risk of wrong-level spinal surgery or procedures. Together, thoracic segment number, rib length, lumbosacral pelvic distance, pelvic parameters, and the degree of L5 encapsulation represent practical and reproducible radiographic markers that can be assessed on routine imaging, including standard lumbar radiographs. Incorporating these features into clinical practice provides a reliable framework for identifying transitional segments, thereby improving diagnostic accuracy and enhancing patient safety.

IMAGES AND TABLES:

Table 1. Prevalence of Vertebral Variations and Associated Radiographic Parameters

Parameter	Overall (n=850)	With Transitional Vertebra (n=304)	Without Transitional Vertebra (n=546)	P Value
Thoracic count	11 vertebrae: 4% (n=31) 13 vertebrae: 0.8% (n=7)	74% of 11T cases transitional (n=23)	—	—
Lumbar count	5 vertebrae: 99% 4 vertebrae: 0.4% 6 vertebrae: 0.8%	—	—	—
Any transitional vertebra	36% (n=304)	—	—	—
Rib length (cm)	11th: 15.8 ± 1.9 (≥ 11 cm in 99%) 12th: 9.5 ± 2.4 (≤ 15 cm in 99%)	—	—	—
Pelvic incidence ($^\circ$)	—	56.3 ± 14.4	50.2 ± 11.5	< 0.001
Pelvic tilt ($^\circ$)	—	17.2 ± 8.6	15.5 ± 7.9	0.006
Sacral slope ($^\circ$)	—	39.1 ± 11.8	34.7 ± 9.5	< 0.001
Lumbosacral–femoral head distance (cm)	—	Men: 10.2 ± 1.0 Women: 10.4 ± 0.9	Men: 10.6 ± 0.8 Women: 10.7 ± 0.8	$< 0.001 / 0.001$
L5 encapsulation score	—	1.30 ± 0.72	1.13 ± 0.61	0.001

Prevalence of vertebral number variations and associated radiographic parameters in 850 patients undergoing EOS spine imaging. Continuous variables are expressed as mean \pm standard deviation. Categorical variables are expressed as counts and percentages. Comparisons between patients with and without transitional vertebrae were analyzed using t-tests and are reported with corresponding P values.