Lumbosacral Transitional Vertebrae Cause Spinal Level Misconception in Surgeries for Degenerative Lumbar Spine Disorders

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Human lumbar spine usually consists of five vertebrae; however, some individuals have vertebral anomalies with four or six lumbar vertebrae because of sacralized fifth lumbar vertebra (L5 sacralization) or lumbarized first sacral vertebra (S1 lumbarization), respectively. These vertebral anomalies are called lumbosacral transitional vertebra (LSTV). Although LSTV is an asymptomatic anomaly, it is known to cause misconception in spinal counts and in spinal level at lumbar spinal surgery. The purpose of this study is to evaluate how LSTV affects the diagnosis and surgeries in lumbar spine disorders. In 550 consecutive patients who underwent lumbar spinal surgeries, a whole-spine X-ray was taken on admission to assess the true number of lumbar vertebrae. We assessed the coherence between the neurological level diagnosis and the level of spinal canal stenosis on imaging studies before and after the recognition of LSTV to clarify how recognition of LSTV affected pre-operative surgical planning. Out of 550 patients, LSTV was found in 71 (12.9%) patients: 37 cases with L5 sacralization and 34 cases with S1 lumbarization. The number of vertebrae was miscounted at the outpatient department (OPD) in 38 cases (54%): 10 L5-sacralization cases and 28 S1-lumbarization cases. Moreover, surgical spinal levels were altered from the original surgical plans at OPD in 11 cases (15%; 3 L5-sacralization and 8 S1-lumbarization cases), after recognizing the true spinal counts by the whole spine X-ray. To avoid errors in spinal level diagnosis, we should recognize the possibility of LSTV that could be assessed by a whole spine X-ray.

Keywords: Castellvi's classification; lumbosacral transitional vertebra; misconception; spinal counts; whole-spine AP X-ray
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Introduction

Human spinal column usually consists of seven cervical, twelve thoracic, five lumbar, five conjoined sacral vertebrae and coccygeus. However, some individuals have vertebral anomalies with four or six lumbar vertebrae because of sacralized fifth lumbar vertebra (L5) or lumbarized first sacral vertebra (S1), respectively (Castellvi et al. 1984). These vertebral anomalies are called lumbosacral transitional vertebra (LSTV). The frequency of LSTV is reported to be 4-35% in the general population. A sacralized L5 is often mistaken for S1 as if there are only four lumbar vertebrae, because of an anomaly of the L5 transverse process, such as enlargement and bony fusion with the sacral ala. Meanwhile, a lumbarized S1 is recognized as "L6" with pseudoarticulation or separation of the sacral ala. Although LSTV is basically asymptomatic and does not evoke degenerative processes of the lumbar spine by itself, the presence of LSTV is known to cause errors in spinal counts leading to mistakes in spinal level at lumbar spinal surgery (Wigh and Anthony 1981; Hughes and Saifuddin 2006; Konin and Walz 2010); however, there has been no detailed investigation showing the relationship between the presence of LSTV and misconception of the spinal level in diagnosis and surgeries for lumbar degenerative disorders. This report investigated the frequency of LSTV in lumbar spinal surgical cases, and discussed how the presence of LSTV affects diagnosis and surgeries of lumbar spine disorders.

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Materials and Methods

Patients

A total of 550 consecutive patients who underwent lumbar spinal surgery at Department of Orthopaedic Surgery, Tohoku Central Hospital from March 2011 through May 2012 were screened retrospectively for the study. The mean age of patients was 65 years (13-84 years) with 318 males and 232 females. The preoperative diagnosis was lumbar spinal canal stenosis (LSCS) in 272 cases, lumbar disc herniation (LDH) in 154, lumbar degenerative spondylolisthesis (LDS) in 98, lumbar spondylolysis (LS) in 19, spinal cord tumor in 3, non-union of lumbar burst fracture in 3, and tethered cord syndrome in 1.

Presurgical diagnosis

In order to screen candidate patients for decompression surgeries of the lumbar spine at the outpatient department (OPD) (Fig. 1), the neurological level diagnosis was confirmed first by physical and neurological examinations (Standaert et al. 2011). Provisional imaging studies such as X-ray and magnetic resonance imaging (MRI) of the lumbar spine were taken for further assessment. Once surgical treatment was proposed to a patient, a whole-spine anteroposterior (AP) X-ray (Fig. 2) was taken to assess the true spinal counts on admission. The level of nerve compression was confirmed by further myelography and selective radiculography when needed. The operations were planned only when the patients' neurological level diagnoses and the level of nerve compression in the imaging studies were considered to be correspondent. Lumbar decompression surgeries were planned to cover all causative spinal levels.

Study design

First, the frequency of LSTV was investigated in the 550 patients. Spinal counts and LSTV were assessed with whole-spine AP X-rays. Because congenital cervicooccipital or cervicothoracic anomalies are not considered to affect spinal counts (Wigh 1980), the spinal counts for cervical and thoracic spine were defined to be 7 and 12, respectively. LSTV was classified according to Castellvi's classification (Fig. 3, Table 1) (Castellvi et al. 1984). Type I L5 sacralization in Castellvi's classification, a simple hypertrophy of the L5 transverse process, was excluded from the study since it is considered to have no clinical significance (Paik et al. 2013).

Second, the accuracy of spinal counts at the OPD was assessed in the 71 LSTV cases, retrospectively. The spinal counts were compared between the provisional counts by lumbar X-ray and/or MRI at the OPD and the true counts by whole-spine AP X-ray on admission.

Next, an investigation was performed to determine if the preoperative recognition of LSTV led to changes in the decompression levels. The 71 LSTV patients were divided into two groups: a group of patients in which neurological level diagnosis and level of nerve compression on imaging studies at the OPD were identical ("identical group"), and a group with discrepancy ("discrepant group"). In each group, the accuracy of the spinal counts at the OPD was assessed. In patients with or without accurate spinal counts at OPD in each group, the number of patients who required an altered or additional level(s) of decompression surgery was counted to assess how the recognition of the LSTV affected the level of decompression surgery.

This study was performed with the approval of the Ethics Committee of Tohoku Central Hospital.

Results

Frequency of LSTV by Castellvi's classification

LSTV was found in 71 (12.9%) of 550 consecutive surgical cases (46 males and 25 females; mean age at surgery, 65.6 years); 37 (6.7%) had L5 sacralization, and 34 (6.2%) had S1 lumbarization (Table 2). Regarding L5 sacralization, types II and III were found in 23 and 14 cases, respectively. The numbers of patients with types I, II, III, and IV S1 lumbarization were 14, 9, 8, and 3, respectively.

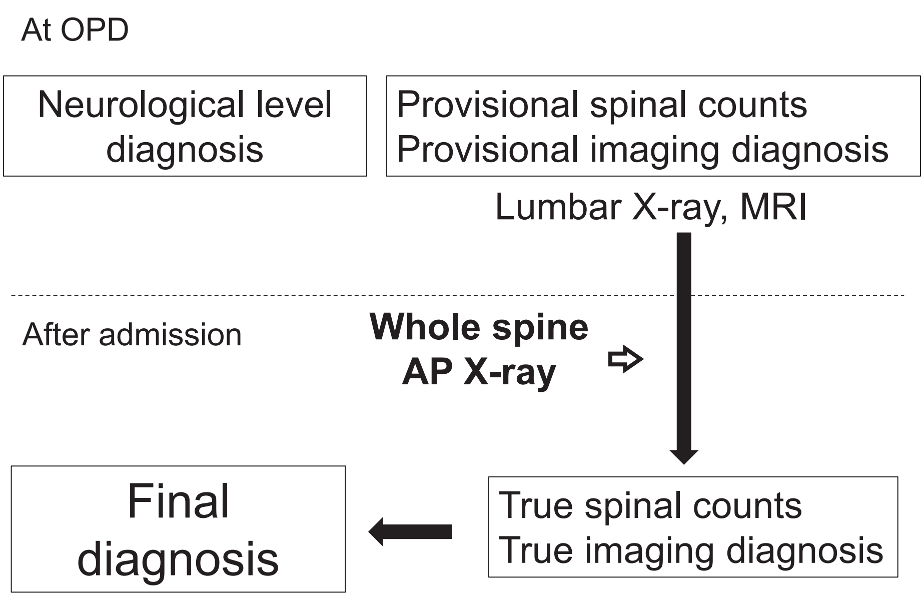

Fig. 1. Diagnostic flow-chart for lumbar spine surgery.
Provisional surgical level is determined by neurological level diagnosis, lumbar X-ray and MRI at outpatient department (OPD). The final surgical level is confirmed after considering true spinal counts with a whole spine AP X-ray.

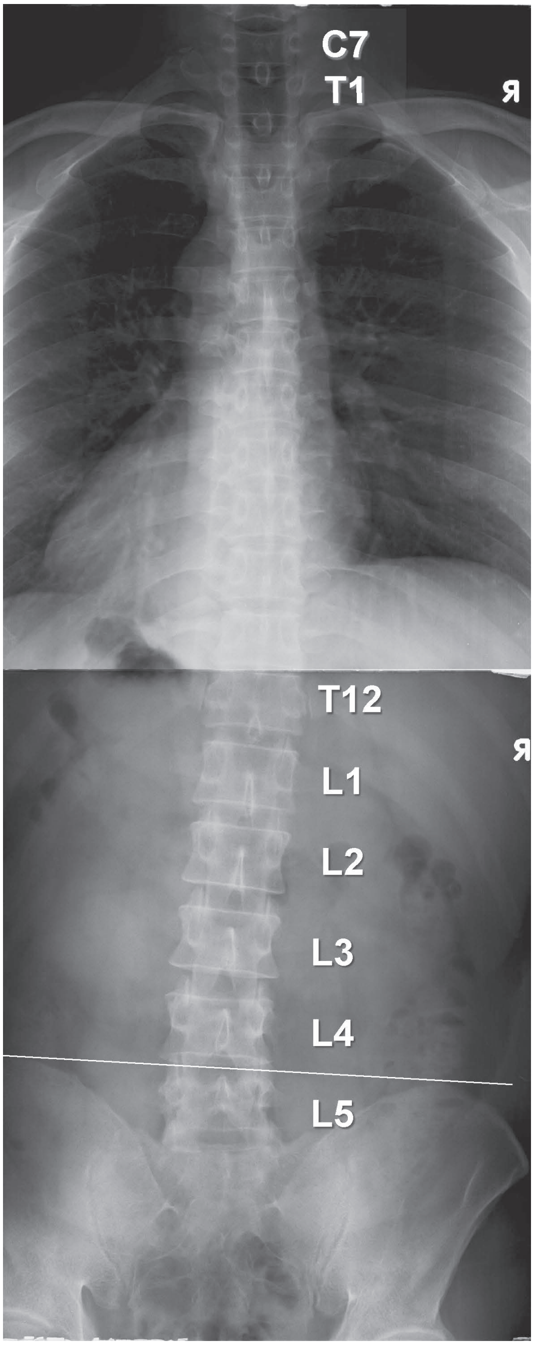

Fig. 2. A whole-spine AP X-ray.
The numbers of cervical and thoracic spines are defined as 7 and 12, respectively.

Accuracy of spinal counts at the OPD

The spinal counts at the OPD were incorrect in 38 (54%) of 71 LSTV cases. The provisional spinal counts at the OPD of type II L5 sacralization were perfectly correct in the 23 cases (Table 2). On the other hand, the number of lumbar vertebrae was inaccurately counted in most cases of type III L5 sacralization. As for S1 lumbarization, the spinal counts were inaccurate in most of type I and II cases.

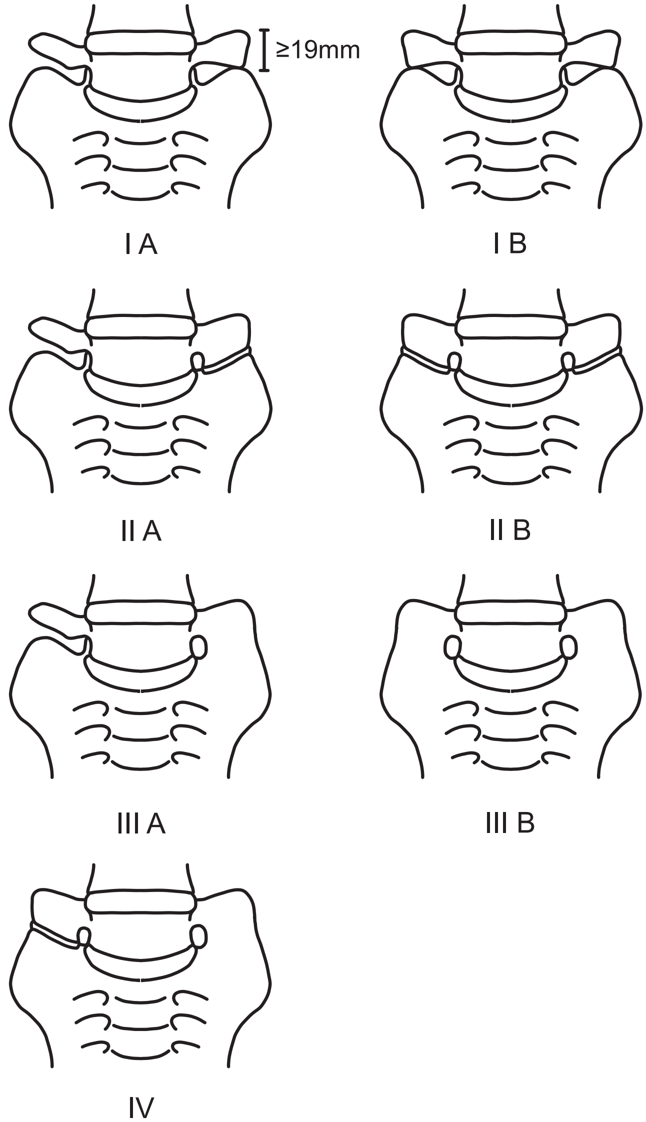

Fig. 3. Castellvi's classification for LSTV.
The precise definition of each type is shown in Table 1.

Effects of the presence of LSTV on spinal level diagnosis and surgery

Of the 71 LSTV patients, there were 57 (80%) in the identical group and 14 in the discrepant group (20%) (Fig. 4). In the identical group, 31 patients with correct spinal counts at the OPD did not need changes in the level of surgery. In the remaining 26 patients with incorrect spinal counts at the OPD, the discrepancy between the neurological and imaging diagnoses was revealed on admission. Six of them did not need changes of the surgical plan because multilevel decompression was originally planned for multilevel stenoses. Functional anomalies of the nerve root were suspected in 11 of the 26 cases. These cases presented a single-root lesion with a single-level disc herniation or spinal canal stenosis. Meanwhile, the nerve compression was found only in the adjacent level to the neurologically-suspected level. A single-level decompression of the affected

Table 1. Castellvi's classification (Castellvi et al. 1984).

Type	Definition	
0	Normal	
IA	Unilateral	Dysplastic transverse process with height ≥19mm
IB	Bilateral	
IIA	Unilateral	Incomplete lumbarization/sacralization
IIB	Bilateral	Enlarged transvers process with pseudoarthrosis with the adjacent sacral ala
IIIA	Unilateral	Complete lumbarization/sacralization
IIIB	Bilateral	Enlarged transverse process which has a complete fusion with the adjacent sacral ala
IV	Mixed	

Table 2. The demographic data of patients with LSTV.

Total number		71	
Male:Female		46:25	
Age (mean ± SD)		13-88 (65.5 ± 15.4)	
Pre-op diagnosis			
Lumbar spinal canal stenosis		60	
Lumbar disc herniation		11	
Operations			
Posterior decompression		56	
Open posterior discectomy		11	
Posterior decompression + discectomy		4	
Castellvi's classification*			
L5 sacralization	Type-II	23	(0)
	Type-III	14	(10)
S1 lumbarization	Type-I	14	(14)
	Type-II	9	(8)
	Type-III	8	(4)
	Type-IV	3	(2)

*Number in bracket: number of misconception at OPD.

nerve root shown in the imaging studies alleviated the neurological symptoms without altering the level of surgery in all of these cases. An L4 root with L5 function was found in 1 case, an L5 root with S1 root function was found in 2 cases, and an L6 root with L5 function was found in 8 cases (Table 3).

Additional decompression was required in 9 of the 26 cases. Of those, a one-level intracanal decompression was added in six cases. In the remaining three cases, intra or extraforaminal stenoses were newly found with further examinations, and they were successfully treated by additional foraminal and/or extraforaminal decompression.

In the 14 cases of the discrepant group, the spinal count at the OPD was found to be incorrect in 12 patients based on a whole-spine AP X-ray on admission. In the remaining two patients with a correct spinal count, nerve compression in another site was found and treated by additional decompression. Overall, 11 of the 71 LSTV patients needed altered or additional operations (Table 4).

Discussion

The frequency of LSTV has been reported to range from 4% to 35% in the literature (Bron et al. 2007; Konin and Walz 2010). Paik et al. (2013) reported the frequency of LSTV in 8,280 patients by Castellvi's classification, and demonstrated the overall frequency of 16%, with type II and III L5 lumbarization as the most frequent types. The similar trend was observed in the present study as shown in Table 2.

In order to achieve correct spinal counts, various landmarks on lumbar X-ray and MRI have been reported in the literature. The final rib used to be regarded as a useful landmark for the twelfth thoracic vertebra; however, individuals with sacralized L5 are known to have hypoplastic

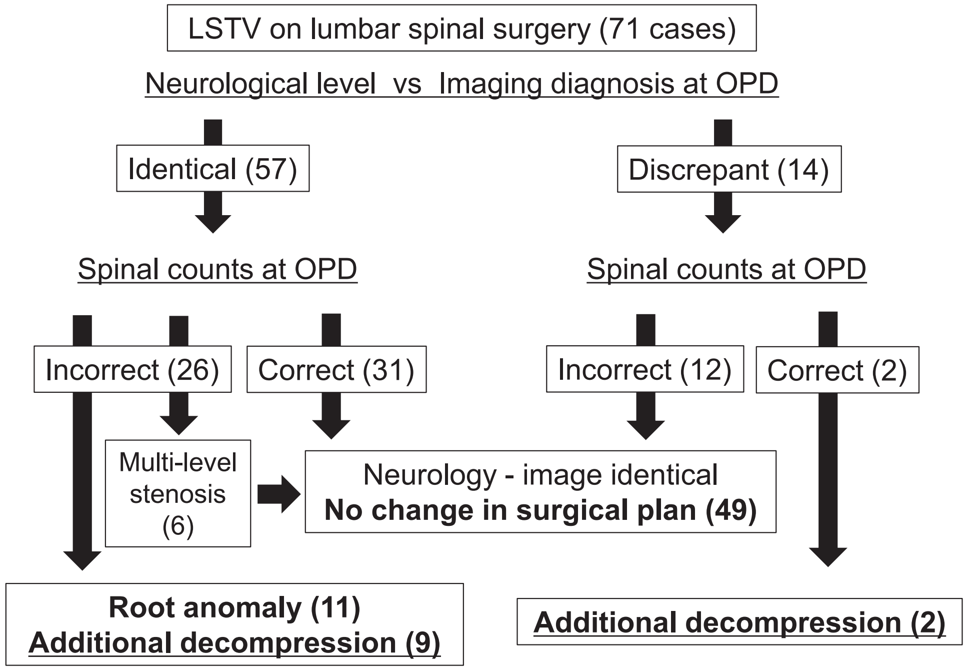

Fig. 4. The effects of LSTV in the surgical level diagnosis for lumbat spine disorders.
The recognitinon of LSTV with a whole spine X-ray revealed needs for an additional decompression and a functional anomaly of the nerve roots.

Table 3. Cases with functional anomaly of the nerve roots.

	Root anomaly	Number
L5 saclarization	L5 root containing S1 function	2
	L4 root containing L5 function	1
S1 lumbalization	L6 root containing L5 function	8

Table 4. Patients with additional or altered operative plan by recognizing the correct spinal counting by whole spine AP X-ray.

Patient #	Age	Sex	Disorder*	Type of LSTV (Castellvi)	Altered / additional operation
1	63	M	LSCS	L5 IIIB	One lower-level fenestration added
2	66	F	LSCS	L5 IIIB	One lower-level fenestration added
3	56	M	LSCS	S1 IIB	One upper-level fenestration added
4	80	F	LSCS	L5 IIIB	One lower-level fenestration added
5	58	M	LSCS	S1 IIa	One upper-level fenestration added
6	58	M	LSCS	S1 IIB	One upper-level fenestration added
7	80	M	LSCS	S1 IB	One upper-level fenestration added
8	62	M	LSCS	S1 IIA	One upper-level fenestration added
9	76	F	LSCS	S1 IIB	One upper-level total root decompression** added
10	63	M	LSCS	S1 IB	One upper-level total root decompression** added
11	71	M	LSCS	S1 IA	One upper-level lateral fenestration added

*LSCS, Lumbar spinal canal stenosis.
**Total root decompression: ipsilateral fenestration + foraminotomy + lateral fenestration.

or absent twelfth ribs frequently. Conversely, lumbar ribs are frequently present in individuals with lumbarized S1. Thus, the final rib cannot be an appropriate landmark for accurate spinal counting. The intercrestal line (Tuffier's line or Jacoby's line) is also known as a landmark for the L4/5 disc level, but it is not always on the L4/5 disc level in individuals with LSTV (Kim et al. 2003). Nicholson et al. (1988) noted that patients with LSTV have a lowered L5/S1 disc with sacralized L5 and a heightened S1/2 disc with lumbarized S1 compared to normal patients; however, these indices are also not suitable as landmarks of the spinal level since they are also seen in normal individuals. As for spinal counts by lumbar MRI, Peh et al. (1999) reported the accuracy of spinal counts in 17 LSTV cases out of 129 patients assessed only with lumbar MRI by two individual radiologists, and the accuracy rate was 82.2%. On the other hand, a sagittal cervicothoracic MR localizer was reported to be useful in assessing true spinal counts (Hahn et al. 1992). Although this image does not directly detect LSTV, true spinal counts can be achieved by recognizing the whole spine from C2 to L5. The limitations of this method are the requirement of capacity in the facility and the cost. In this regard, whole-spine AP X-ray is more cost-effective for the purpose of obtaining accurate spinal counts, compared to a sagittal cervicothoracic MR localizer. The drawback of whole-spine X-ray is the radiation exposure on the patients. In order to reduce the chances of radiation exposure, whole spine X-ray should be taken only on patients who decided to undergo lumbar spinal surgeries.

Inaccurate spinal counts can lead to serious errors in the decision about the level for lumbar spine surgery. Wigh (1979) and Malanga and Cooke (2004) reported that wrong-level operations for lumbar lesions were performed due to LSTV. The main cause of wrong-level operations in the operating room was reported to be a misconception about the spinal levels as seen on X-rays and MRIs and/or myelograms. Konin and Walz (2010) recommended a clear lumbar lateral X-ray to recognize LSTV in the operating room to match MR images and radiographs.

To date, LSTV has been reported only in relation to errors in spinal counts at operation. Meanwhile, to our knowledge, no report has ever found that LSTV can cause discrepancies in the neurological level diagnosis, as shown in the present study. Basically, spinal surgeries are planned under the assumption that the spinal levels of symptomatology, neurology, and imaging studies correspond. The misunderstanding in spinal level due to LSVT can cause confusion in choosing the decompression levels (Wigh 1979; O'Driscoll et al. 1996; Konin and Walz 2010). Especially in elderly patients, the correspondence between neurological findings and imaging studies is very important, since asymptomatic spinal canal stenosis can be frequently detected in imaging studies.

A functional anomaly of the nerve root was suspected in the present 11 LSTV cases. McCulloch and Waddell (1980), Young et al. (1983), and Chang and Nakagawa (2004) reported the functional anomaly of the nerve root with LSTV. Thus, more attention should be paid to this in LSTV cases.

In conclusion, misinterpreting LSTV can lead to mistakes in spinal counts that in turn lead to poor surgical outcomes due to errors in spinal level diagnoses and/or the inadvertent neglect of symptomatic lesions. It is important to recognize LSTV by assessing true spinal counts with a whole-spine AP X-ray in all lumbar spine surgical cases.

Conflict of Interest

The authors declare no conflict of interest.

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