European Radiology (2019) 29:2608–2615
https://doi.org/10.1007/s00330-018-5798-z

MUSCULOSKELETAL

Psoas proximal insertion as a simple and reliable landmark for numbering lumbar vertebrae on MRI of the lumbar spine

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Received: 8 June 2018 / Revised: 7 September 2018 / Accepted: 24 September 2018 / Published online: 9 November 2018

Abstract

Objective To evaluate the value of psoas muscle proximal insertion for correct numbering of the lumbar vertebrae in MRI, in particular in case of lumbosacral transitional vertebra (LSTV).

Methods Two radiologists assessed 477 MRI scans of the lumbar spine with a sagittal localizer sequence on the whole spine for numbering vertebrae caudally from C2. Proximal insertion of the psoas was determined as the most proximal vertebra with psoas over half of its body on coronal T2 STIR sequence. The last lumbar vertebra was named considering both its number and the presence or absence of LSTV according to Castellvi classification. These same parameters were also assessed on 207 PET-CT scans of another cohort including the whole spine.

Results Proximal insertion of the psoas was L1 in 94.1% of cases: 98.5% in case of modal anatomy, 81.4% in case of LSTV, and 51.7% in case of missing or supernumerary lumbar vertebra without LSTV. There was no statistically significant difference between MRI and CT data. The inter-reader agreement for determination of psoas proximal insertion was excellent (kappa = 0.96).

Conclusion Proximal insertion of the psoas muscle is a helpful marker for correct numbering of the lumbar vertebrae in MRI and to detect a complete lumbosacral segmentation anomaly.

Key Points

- *Proximal insertion of the psoas muscle can be easily identified on a coronal T2 STIR sequence.*
- *Psoas proximal insertion on the spine almost always designates the first lumbar vertebra and is helpful to accurately number all lumbar vertebrae, especially in case of lumbosacral transitional vertebra.*
- *Conversely, when psoas muscle does not insert five lumbar bodies above the apparent lumbosacral joint, the probability of variation in the number of lumbar vertebrae is high.*

Keywords Lumbosacral region · Lumbar vertebrae · Magnetic resonance imaging · Psoas muscle

Abbreviations

HU	Hounsfield units
LSTV	Lumbosacral transitional vertebra
MRI	Magnetic resonance imaging
PACS	Picture archiving and communication system
PET-CT	Positron emission tomography-computed tomography
STIR	Short tau inversion recovery
TE	Echo time
TI	Inversion time
TR	Repetition time

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Introduction

Correct numbering of lumbar vertebrae in magnetic resonance imaging (MRI) is a daily concern in current clinical practice to ensure correct inter- and intra-disciplinary communications and to avoid inconsistency in clinical

findings or to perform wrong lumbar-level surgery [1, 2]. The typical number of presacral vertebrae in humans is considered to be 24 with seven cervical, twelve thoracic, and five lumbar vertebrae. However, previous literature has reported the possibility of both numeric variations of lumbar vertebrae and presence of a lumbosacral transitional vertebra (LSTV) [3, 4]. LSTVs are congenital vertebral anomaly of the L5–S1 junction in the spine with prevalence up to 35% [5]. The term "LSTV" is often used for either a sacralization of L5 or a lumbarization of S1 as it is challenging to decide without viewing the complete spine [6, 7]. Thus, in a recent study, it was reported that 83.9% of total 8280 patients had modal anatomy with five lumbar vertebrae without LSTV. On the other hand, 5.5% of patients were described as having complete segmentation anomaly, with a missing or a supernumerary lumbar vertebra, without LSTV [3].

The gold standard for counting the vertebrae is from the cervical spine to the last lumbar vertebra [8]. Radiologists often have to read lumbar MRI scans without having any other exam to determine the number of lumbar vertebrae. Thus, for such situations, radiologists rely on paraspinal anatomical structures whose levels do not change according to the presence or absence of any anatomical variation of the spine. Many such paraspinal anatomical landmarks and their relation to the lumbar spine were assessed in former studies. These include morphology of the S1–S2 disc, morphology of L5 and S1 bodies, number of rib pairs, aortic bifurcation, right renal artery, root of superior mesenteric artery, iliolumbar ligament, conus medullaris, and iliac crest sign. However, none of these landmarks were reported to be completely reliable for the correct numbering of lumbar vertebrae (Table 1) [9–19]. The aim of this study was to evaluate the value of psoas muscle proximal insertion site as a landmark for correct numbering of lumbar vertebrae in MRI based on coronal T2 short tau inversion recovery (STIR) sequence and in comparison with data obtained from CT scans, considered as a gold standard for determining this insertion.

Materials and methods

Patients

This study was approved by the Hospital's Institutional Review Board and all patients provided written informed consent. Over a period of 1 year, we included prospectively 477 patients who needed lumbar MRI for low back pain and/or lumbosacral radiculopathy in daily practice and who agreed to be included. The non-inclusion criteria were age under 18, pregnancy in progress, MRI contraindications, and previous history of lumbar spine surgery or spinal fracture. We also collected retrospectively 207 positron emission tomography-computed tomography (PET-CT) scans of other patients from the Hospital's picture archiving and communication system (PACS) performed between October 2015 and February 2016. The non-inclusion criteria were age under 18 and previous history of lumbar spine surgery or spinal fracture.

Image acquisition and parameters

All MRI scans were performed using Magnetom Avanto fit 1.5 T (Siemens Healthineers). All exams included a lumbar localizer sequence, four sequences on the lumbar spine, and a contiguous additional localizer sequence on cervicothoracic spine. The four sequences used on the lumbar spine were (1) sagittal T1, (2) sagittal T2, (3) axial T2, and (4) coronal T2 Short TI inversion recovery (STIR). The coronal T2 STIR sequence was performed with repetition time (TR) of 4000 ms, echo time (TE) of 55 ms, and inversion time (TI) of 160 ms; a 6-mm cutting thickness; a 2.1-mm gap; and acquisition time of 1 min 32 s. The inferior part of the head and neck coil was added for the acquisition of the additional localizer sequence on cervicothoracic spine to achieve a sufficient signal-to-noise ratio. This required patients to be installed head first in the bore of the scanner throughout the MRI exam. The acquisition time of this additional localizer sequence was about approximately 30 s.

Table 1 Value of different landmarks for numbering lumbar vertebra: literature summary

Landmark	Presumed feature in normal segmentation	Proportion of same level in normal segmentation	Stability in case of LSTV	Stability in case of complete segmentation anomaly
Conus medullaris [9, 10]	L1 body to L2–L3 disc	Extremely variable	Extremely variable	Not evaluated
Superior mesenteric artery [10]	L1 body	55.1%	20–58.8%	Not evaluated
Aortic bifurcation [11]	L4 body or L3–L4 disc	71.1%	62–65%	Not evaluated
Right renal artery [11]	L1 body or L1–L2 disc	86%	25–82%	Not evaluated
Last rib pairs [11–13]	T12	81%	50.7%	40–50%
S1-S2 disc and L5-S1 bodies [10, 12]	Type 1 or 2	53.6–98.6%	0–41%	Not evaluated
Iliolumbar ligament [14]	L5 process	95 ± 5%	25–38%	0%
Iliac crest sign [11]	Negative	96%	84.51%	0%

The PET-CT scans were performed on Biograph mCT Flow 40 and 64 (Siemens Healthineers). PET data were acquired in three-dimensional (3D) mode. Computed tomography was performed from the mid-forehead to the lower limbs, so that the entire spine was included. Patients were advised to perform normal shallow breathing during the scan. A low-dose setting (120 kVp, 100 mAs) and CT slice thickness of 3 mm was used for the acquisition. Image reconstructions used a soft filter, with the window level set at 305 Hounsfield units (HU) and its width at 40 HU and a "bone" filter with a window level at 1580 HU and its width at 480 HU.

Image analysis

The images were assessed using Syngo.via software (Siemens Healthineers).

Two radiologists independently assessed three parameters on the 477 MRI exams:

- The number of lumbar vertebrae was determined using sagittal localizer sequences of both cervicothoracic and lumbar spine. A synchronization of these sequences was made possible by using a pointer provided by the processing software, enabling us to identify the vertebrae simultaneously visible on both localizer sequences (often T11 to L2) and then to count vertebrae down from C2 to the last lumbar vertebra (Fig. 1). In agreement with former studies, we assumed that there were seven cervical and twelve thoracic vertebrae, so the last lumbar vertebra was named either L4, L5, or L6 in case of 23, 24, or 25 presacral vertebrae counts respectively [7, 20].
- The last lumbar vertebra and the lumbosacral junction was then assessed in coronal T2 STIR sequence for determining the presence of a LSTV, based on an equivalent performance of Ferguson view and coronal MRI plane for their detection [21]. We classified LSTV according to the method of Castellvi et al [4], considering only type 2 or higher, because of a lack of biomechanical significance for type 1, in agreement with former studies [15, 16, 22, 23]. (Table 2)
- We distinguished modal junction and Castellvi type 1 as "N" for "normal" and Castellvi Type 2, 3, or 4 as "C+" for "Castellvi positive." The last lumbar vertebra was designated using both the number of vertebrae and lumbosacral junction and thus named as L5C+, L6C+, L4C+ in case of LSTV with 24, 25, or 23 presacral vertebrae, or L5N, L6N, or L4N without LSTV with 24, 25, or 23 presacral vertebrae (Fig. 2).
- Finally, we assessed the psoas proximal insertion on the spine, by using the coronal T2 STIR sequence. For this assessment, we considered the main muscle fibers only, as it was not possible to determine if the thin bundles in the prolongation of main fibers were those of the psoas or belonged to the pillar of the diaphragm. The psoas proximal insertion was named as the most proximal vertebra with psoas over half of its body. For example, it was considered to be L1 if the highest fibers were seen between the upper half of the body of L1 and the lower half of the body of T12 (Fig. 3).

After comparing the data obtained by each reader for determination of the psoas proximal insertion on MRI, 16 cases were discordant and needed a second reading by both radiologists together to find a consensus and to obtain global data.

We assessed the three same parameters described above on CT images of the 207 PET-CT scans with the help of mutliplanar reconstructions. The vertebrae could be easily counted from C2 (Fig. 4).

Statistical analysis

Statistical analysis was performed using IBM® SPSS® Statistics 25. Inter-reader agreement for MRI data was obtained by Cohen's kappa method. Distribution of proximal insertion of the psoas muscle in each subgroup (L5N, L6N, L4N, L5C+, L6C+, L4C+) and determination of this insertion between MRI and CT data for each subgroup were tested using Fisher's exact test. As there were more of 20% of crosstabulation cells expected count < 5, a 1000-sample bootstrap was performed. Results were confirmed by Monte Carlo simulation (10,000 samples, confidence level of 99%). Between subgroups, proportions of insertion were compared using post hoc test with residuals (and given p values were interpreted as significant or not according to Bonferroni correction). A p value less than 0.05 was considered as statistically significant.

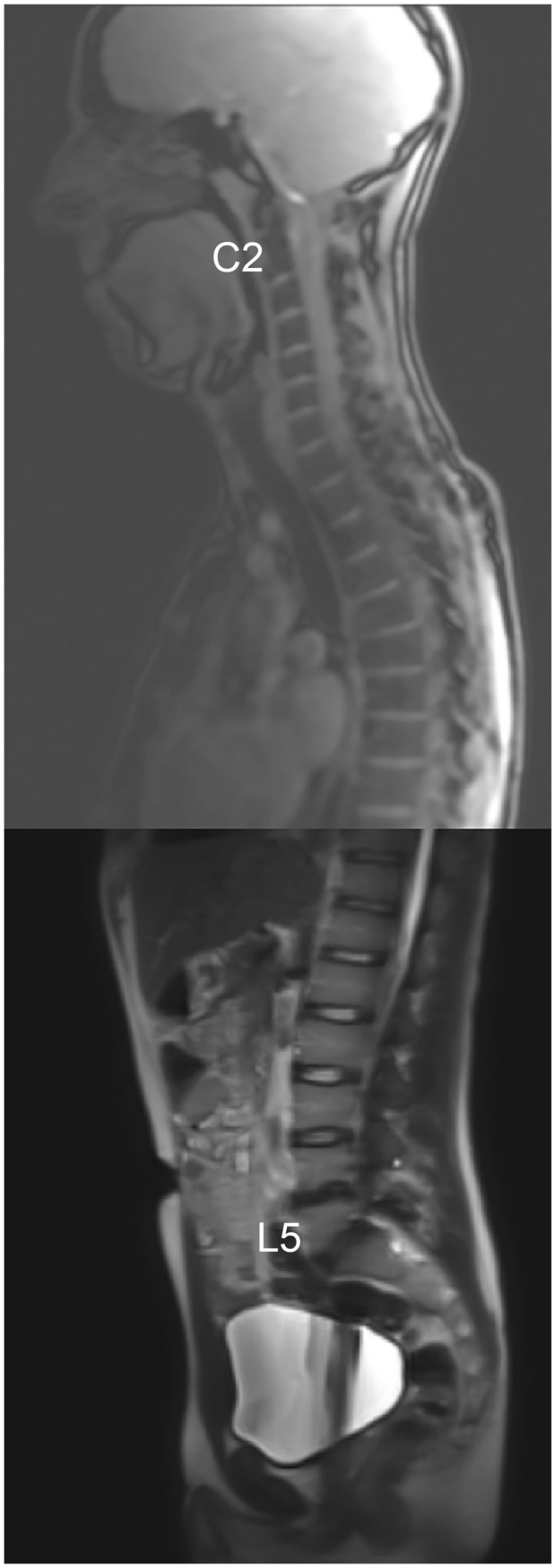
Results

MRI series assessment (Table 3)

The mean age of the 477 patients was 48 years (range 18–86 years), with 207 women and 270 men.

Out of these 477 patients, 405 (84.9%) had modal anatomy (L5N), while 43 (9.0%) had LSTV (22 L5C+, 13 L6C+, and one L4C+) and 29 (6.0%) had complete segmentation anomaly (L6N or L4N).

Overall, proximal insertion of psoas was L1 in 449 out of 477 (94.1%). The psoas proximal insertion was mostly L1 in case of L5N (399 out of 405 or 98.5%). It was often L1 in case of the presence of LSTV (overall 35 out of 43 or 81.4%), that there were 24 vertebrae (L5C+) or a supernumerary vertebra (L6C+), with rates of insertion on L1 to 88.0 and 76.5%



◀ **Fig. 1** Composing of the two sagittal localizer sequences on the spine to allow us to count vertebrae down from C2 to the last lumbar vertebra, after their synchronization and identification of the vertebrae visible on both localizer sequences

respectively. In only one case, a vertebra was missing with LSTV (L4C+), on which psoas inserted on T12.

Among the 29 patients with a complete segmentation anomaly without LSTV, 13 had supernumerary vertebrae and 16 had missing vertebrae. In the former case, proximal insertion of psoas was on L1 in two out of 13 (15.4%) while it was 13 out of 16 (81.2%) in the latter case. In case of an abnormal number of vertebrae with or without LSTV, the proximal insertion of psoas was L1 in 13 out of 17 cases with 23 presacral vertebrae (76.5%) and 15 out of 30 cases with 25 presacral vertebrae (50.0%).

The psoas proximal insertion was significantly different for the L5N, L6N, and L4C+ subgroups compared to the other subgroups.

The inter-reader agreement for the determination of the psoas proximal insertion was excellent, with a Cohen's kappa of 0.96.

PET-CT series assessment (Table 4)

The mean age of the 207 patients was 50 years (range 25–93 years), with 85 women and 122 men.

Out of these 207 patients, 172 (83.1%) had a last lumbar vertebra as L5N, 22 (10.6%) had LSTV (15 L5C+, seven L6C+, and no L4C+) and 13 (6.3%) had a L6N or L4N.

Overall, proximal insertion of psoas was L1 in 195 out of 207 (94.2%). Psoas proximal insertion was mostly L1, even in case of L5N (170 out of 172 or 98.8%). In case of the presence of LSTV, it was L1 in 18 out of 22 (81.8%), among which 14 out of 15 (93.3%) in case of L5C+ and four out of seven (57.1%) in case of L6C+.

Among the 13 patients with a complete segmentation anomaly without LSTV, six had a supernumerary vertebra, while seven had a missing vertebra, with a proximal insertion of psoas on L1 in one case (16.7%) and six cases (85.7%) respectively. In case of an abnormal number of vertebrae with or without LSTV, the proximal insertion of psoas was L1 in six out of seven cases with 23 presacral vertebrae (85.7%) and seven out of 13 cases with 25 presacral vertebrae (53.8%).

The psoas proximal insertion was significantly different for the L5N, L6N, and L6C+ subgroups compared to the other subgroups.

Psoas insertion proportion comparison

Using Fisher's exact test, no significant differences were found when testing differences in the proximal insertion of the psoas muscle between MRI and CT data in each group

Table 2 Castellvi classification of LSTV in 4 grades (A = unilateral and B = bilateral)

Grade	Uni/bilateral	Definition
0		Normal
I	A/B	Height of transverse process > 19 mm
II	A/B	Pseudarthrosis between transverse process and adjacent sacral wing
III	A/B	Complete fusion between transverse process and adjacent sacral wing
IV		Mixed: type IIA in one side and type IIIA contralateral

(L5N, L4N, L6N, L5C+, L6C+) (Table 5). The *p* value was greater than 0.05 in each situation. Thus, it can therefore be concluded that there was no difference of assessment between CT and MRI data. The L4C+ group was not tested because there was only one subject in the MRI series and no subject in the CT series.

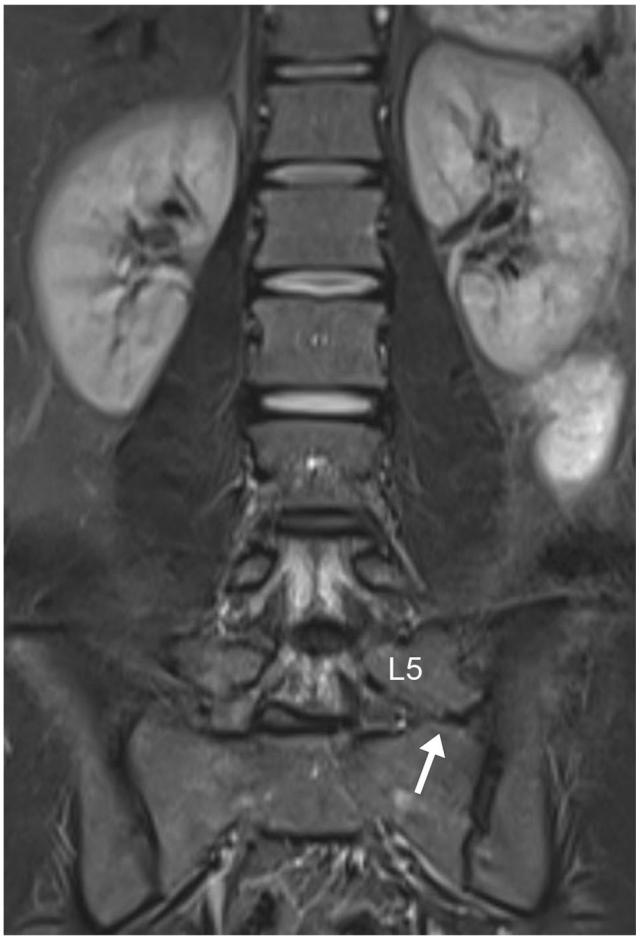


Fig. 2 Identification and classification of LSTV on the coronal T2 STIR sequence. The last lumbar vertebra is a L5C+ one in this case, with a pseudoarticulation (white arrow) between the left transverse process of L5 and sacrum (Castellvi 2A)

Discussion

This study has demonstrated that the psoas muscle insertion is a useful landmark in routine MRI practice for correctly numbering the lumbar vertebrae in comparison with the different anatomical landmarks studied in the literature.

The psoas muscle is a stable structure, with its proximal insertion always visible on lumbar MRI. This is a double long fusiform muscle placed on each side of the lumbar spine. It arises from the anterior and lower surfaces of the transverse processes of L1 to L5, and from the sides of the bodies and the corresponding intervertebral fibrocartilages of T12 to L5 [24]. It inserts down to the lesser trochanter of the femur with the iliac muscle. While the lower insertion location varies frequently, upper insertion location varies little [25].

The proximal insertion of the psoas muscle was L1 in at least 94% of all the patients in both MRI and PET-CT series. We found no statistically significant difference between data obtained with CT and coronal T2 STIR sequence on MRI, considering CT as a gold standard from the anatomical point of view (possibility of multiplanar reconstructions, thickness of slices). Coronal T2 STIR sequence is now more frequently used by different centers in routine practice because of the information it provides [26]. Moreover, the inter-reader agreement for determination of the psoas proximal insertion was excellent, with a Cohen's kappa of 0.96. These results show

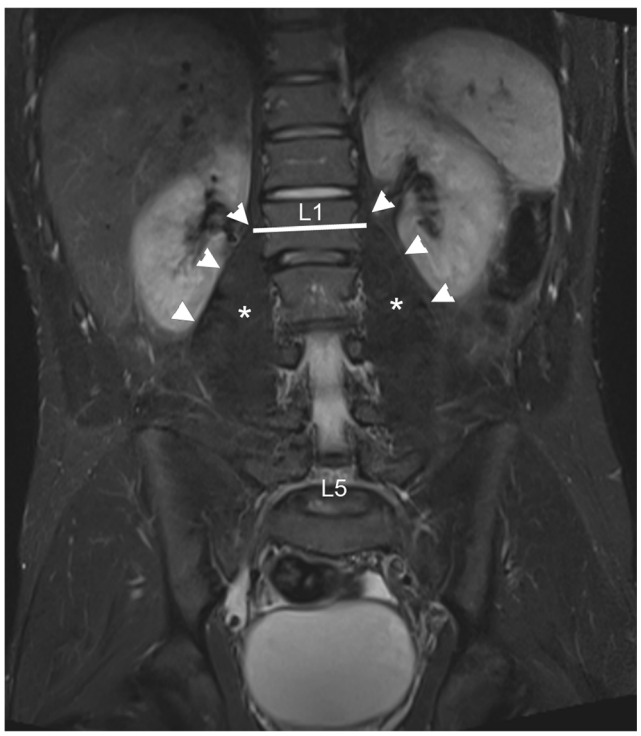


Fig. 3 Determination of the psoas muscle proximal insertion on coronal T2 STIR sequence. Proximal insertion of the psoas muscle is located on L1 in this case, the most proximal vertebra with the edges (arrowheads) of psoas muscle (asterisk) over the equator of its body (white line)

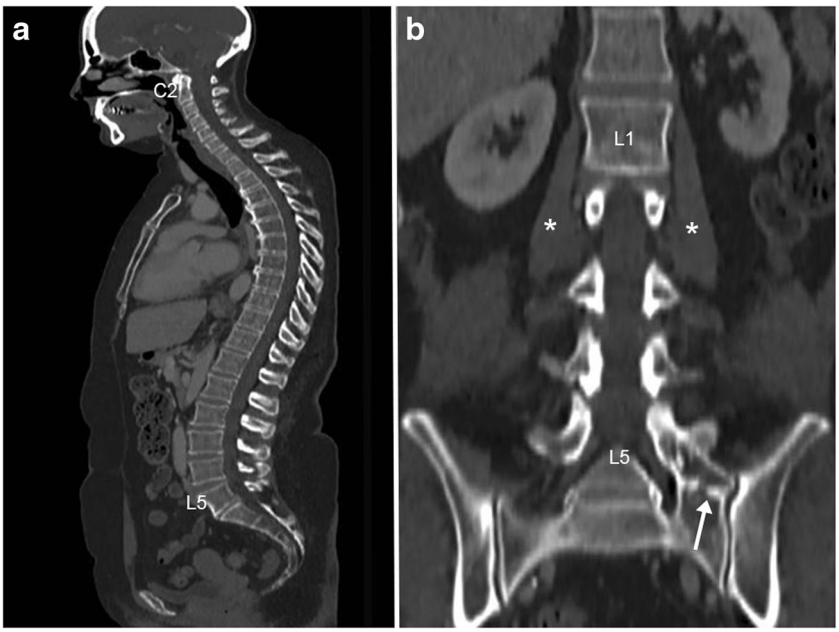


Fig. 4 Numbering of the last lumbar vertebra on sagittal reconstruction of CT images of a PET-CT scan with soft filter, counting down from C2 (**a**). Identification of a LSTV and determination of psoas muscle (asterisk) proximal insertion on coronal reconstruction (**b**). In this case, the last lumbar vertebra is a L5C+ one, with fusion (arrow) between the left transverse process of L5 and sacrum (Castellvi 3a). Proximal insertion or the psoas muscle (asterisk) is located on L1

that coronal T2 STIR sequence is reliable for determining the proximal level of the psoas. The cases in which the two readers did not agree were encountered when the insertion of the psoas was on the equator of a vertebral body. In this situation, it was challenging to conclude if the insertion was below the equator, and thus, it should keep the name of the vertebra below or rather above.

In our cohort, the rate of change from modal anatomy was similar to what was found in the literature. Our study included 84.9% of modal anatomy (L5N), 6.0% of complete segmentation anomaly, and 9.0% of LSTV, as compared to 83.9%, 5.5%, and 10.6% for each group respectively in the study of Paik et al including 8280 patients [3].

In case of modal segmentation (L5N), the insertion of the psoas muscle was very stable, almost always identified on L1 (98.5%). In the presence of a LSTV, the psoas muscle kept an insertion on L1 more than three times out of four (81.4%). This result is better than the other landmarks except iliac crest sign (Table 1), allowing to correctly number the lumbar vertebrae in 84.5% in case of LSTV (81% with sacralized L5 and 88% with lumbarized S1) [11].

In case of missing lumbar vertebra, the psoas muscle kept an insertion on L1 in 76.5% in our cohort. In this situation, psoas proximal insertion is helpful for the radiologist to suspect a dismembering vertebra, which is not five vertebral bodies above a modal lumbosacral joint. The probability of a missing vertebra must be considered as high in this situation, considering that it almost never happens in case of modal anatomy.

Supernumerary lumbar vertebra cases were distributed in groups with roughly the same size in the presence or absence of LSTV. In case of L6C+, the psoas inserted on L1 about

Table 3 Distribution of psoas muscle proximal insertion as identified in MRI series and frequency in patients. N = "normal" lumbosacral junction (modal junction and Castellvi type 1), and C+ = presence of LSTV (Castellvi type 2, 3 or 4)

Last lumbar vertebra designation	Number of cases and percentage	Psoas insertion on L1 and percentage for each subgroup	*p* value from Fisher's exact test
L5N	405 (84.9%)	399 (98.5%)	< 0.001
L6N	13 (2.7%)	2 (15.4%)	< 0.001
L4N	16 (3.3%)	13 (81.2%)	0.4194
L5C+	25 (5.2%)	22 (88.0%)	0.8768
L6C+	17 (3.5%)	13 (76.5%)	0.0766
L4C+	1 (0.2%)	0	< 0.001
Total	477 (100%)	449 (94.1%)	

Table 4 Distribution of psoas muscle proximal insertion as identified in PET-CT series and frequency in patients. N = "normal" lumbosacral junction (modal junction and Castellvi type 1), and C+ = presence of LSTV (Castellvi type 2, 3, or 4)

Last lumbar vertebra designation	Number of cases and percentage	Psoas insertion on L1 and percentage for each subgroup	*p* value from Fisher's exact test
L5N	172 (83.1%)	170 (98.8%)	< 0.001
L6N	6 (2.9%)	1 (16.7%)	< 0.001
L4N	7 (3.4%)	6 (85.7%)	0.9164
L5C+	15 (7.2%)	14 (93.3%)	0.9999
L6C+	7 (3.4%)	4 (57.1%)	0.0011
L4C+	0	0	
Total	207 (100%)	195 (94.2%)	

Table 5 Fisher's exact test to assess the differences in results obtained with MRI and PET-CT for determination of proximal insertion of the psoas muscle

Last lumbar vertebra designation	*p* value	Odds ratio	Confidence interval 95%
L5N	1	0.9968	0.7677; 1.2943
L6N	1	0.9265	0.0403; 3.3994
L4N	1	0.9492	0.2108; 4.3669
L5C+	1	0.9436	0.3378; 2.6394
L6C+	0.7364	1.3289	0.2661; 7.5813

three times out of four (76.5%). Conversely, in case of L6N, the psoas inserted on L2 in most of the cases (only 2 cases out of 13 on L1). Thus, the psoas insertion is not a reliable landmark to detect an anomaly in the number of lumbar vertebrae in this situation.

Complete segmentation anomaly of the lumbosacral junction is a recently accepted concept. There may be 23, 24, or 25 cervicothoracolumbar vertebrae. In the study, we considered in our study that there were always twelve thoracic vertebrae with a variation in the number of lumbar vertebrae. The interest of the anatomical landmarks in this situation for correct numbering of lumbar vertebrae was evaluated in few studies (Table 1) and on small samples. The iliac crest sign and the iliolumbar ligament were found to be useless in case of complete segmentation anomaly. The iliac crest sign does not make any difference between a modal anatomy and a complete segmentation anomaly [11], and the iliolumbar ligament arises from the last lumbar vertebra whatever it is [12, 14]. The number of rib pairs is variable in this situation, with 12 rib pairs between 40 and 50% [12, 13]. In case of sacralization, 13 rib pairs were found in one out of five cases for Carrino et al [12] and in nine out of 14 cases for Nakajima et al [13]. In combination with psoas proximal insertion, the determination of the last pair of ribs could improve correct identification of the L6N subjects. However, the last pair of ribs could be difficult to identify on sagittal sequence of lumbar MRI [27].

Conclusion

If a whole spine image is not available, the proximal insertion of the psoas muscle can be considered as a useful marker on coronal T2 STIR sequence during lumbar MRI protocol for radiologists to decide which the last lumbar vertebra is in case of LSTV and to detect a complete segmentation anomaly. If the psoas muscle does not insert five lumbar bodies above the lumbosacral joint, there is a high probability of variation in the number of lumbar vertebrae.

Acknowledgments The authors thank Philippe Bruyant for his help with manuscript revision.

Funding The authors state that this work has not received any funding.

Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Dr. Garetier Marc.

Conflict of interest The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

Statistics and biometry One of the authors has significant statistical expertise.

Informed consent Written informed consent was obtained from all subjects in this study.

Ethical approval Institutional Review Board approval was obtained.

Methodology
- Prospective and retrospective
- Observational
- Performed at one institution

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