Does iliolumbar ligament always originate from L5 vertebral body?

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Aims and objectives

The aims of this study were to accurately identify the origin of the iliolumbar ligament (ILL) and assess its relation with the lumbosacral junction (Fig 1).

The ILL is one of three vertebropelvic ligaments, the others being the sacrotuberous and sacrospinous. Functionally, the ILL restrains flexion, extension, axial rotation, and lateral bending of L5 on S1 [1 on page]. According to fetal dissection, it has been suggested that ILLs start forming at 11 f gestation weeks and are well developed by birth [2 on page]. It has been also suggested that ILLs have an invariable L5 origin, and that occasionally a weaker band may also coexist from L4 vertebral body [3-5 on page]. Some larger cadaver and magnetic resonance imaging (MRI) studies however have not confirmed the existence of this L4 component rather indicated that ILL would arise from the transverse processes of L5, divided into two main parts: first, a broad, flat anterior part inserting in the iliac tuberosity; and, second, a thinner fusiform, posterior part that inserts in the iliac crest [3 on page]. Konin and Walz hypothesized that if ILLs arise solely from L5, then their level of origin can serve as a marker of lumbar levels, which may enable the confident numbering of lumbosacral transitional vertebrae (LSTV) [6 on page].

LSTV are congenital anomalies of the lumbosacral spine, involving lumbarization and sacralization, first observed by Bertolotti in 1917 [7 on page]. LSTV occurs when the last lumbar vertebra shows elongation of its transverse process, with varying degrees of fusion to the first sacral segment [6 on page]. The term "LSTV" is commonly used to avoid having to decide whether the last vertebra is a sacralized L5 or a lumbarized S1, simply because it not always possible to count all the vertebrae of the entire spine. Naming a transitional vertebra "LSTV" while reading computed tomography (CT) or MRI examinations of the lumbar spine may be helpful to simplify the report process but not fully address the issue regarding vertebral numbering [8 on page].

The clinical significance of a LSTV has been frequently debated [9 on page]. This alteration may contribute to incorrect identification of a vertebral segment, leading to wrong-level spine surgery and poor correlation with clinical symptoms [10 on page]. The estimation of LSTV prevalence in the general population vary greatly, ranging from 4%-30% depending on the sample size, the population studied and on the classification criteria applied [9 on page]. Masud [11 on page] and Hsieh et al. [12 on page] reported a prevalence of 27% and 5.9%, respectively, and Delport [9 on page] observed a rate of 30%, based on articulation or fusion of at least one transverse process and presence of an intervertebral disc caudal to the transitional segment [13 on page].
According to Castelvi et al. LSTV can be classified into four types [6 on page 13]. Type I includes unilateral (Ia) or bilateral (Ib) dysplastic transverse processes, measuring at least 19mm in width (craniocaudal dimension). Type II exhibits in complete unilateral (IIa) or bilateral (IIb) lumbarization / sacralization with an enlarged transverse process that has a diarthrodial joint between itself and the sacrum. Type III LSTV describes unilateral (IIIa) or bilateral (IIIb) lumbarization / sacralization with complete osseous fusion of the transverse process (es) to the sacrum. Type IV involves a unilateral type II transition with a type III on the contralateral side [14 on page 22] (Fig 2A, Fig 2B).

Nevertheless a LSTV can be sensitively identified and characterized, based on abnormal morphology of the lumbosacral junction and on the relationship between the transitional segment and the level above or below, this classification system does not provide relevant information to accurate number of the involved segment and no standard method is established for this purpose [6 on page 13, 14 on page 22]. Techniques that have been used include the addition of cervicothoracic localizer scans and determining lumbar levels by identification of the right renal artery, both techniques however, prone to substantial error [6 on page 13].

The true nature of the lower vertebral segmentation can only be established on imaging methods including the thoracolumbar junction allowing correct identification of the L1 vertebral body [15 on page 23]. Once this has been correctly established, the LSTV level can be confirmed [16 on page 23] (Fig 3, Fig 4, Fig 5).

In practice, an operation performed at an erroneous level can be avoided by designating the LSTV as either L5 or S1 using the accurately identify of the origin of ILL and its relation with the lumbosacral junction. Considering this, the current study have applied CT images of positron emission computed tomography (PET-CT) covering the entire vertebral column to accurately identify the origin of ILL and its relation with the lumbosacral junction, to qualitatively assess the variation present at the lumbosacral junction in order to identify individuals with and without LSTV and its relationship with the origin of ILL, and to perform correct vertebral numbering.
**Fig. 1**: Fig. 1 CT of lumbar spine in 61-year-old woman. Axial image at level of lumbosacral junction shows bilateral iliolumbar ligament (arrow head).

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**Fig. 2:** Fig. 2 CT of lumbar spine in 61-year-old woman. A, Coronal MPR through Castellvi type IIb (bilateral pseudarthrosis) transitional vertebra shows enlargement of transverse process, extending down to sacral ala. B, Coronal MPR with ILL originating at tip of lumbosacral transitional vertebrae transverse process and inserting at iliac tuberosity (arrow head).

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Fig. 3: Fig. 3 CT including the thoracolumbar junction in 77-year-old man. Axial image at level of lumbosacral junction shows bilateral iliolumbar ligament (arrow head).

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Fig. 4: Fig. 4 CT including the thoracolumbar junction in 77-year-old man. B, 3D Curved-MPR through Castellvi type IIIa transitional vertebra. C, Coronal MPR evidences ILL originating at tip of LSTV transverse process (arrow).

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**Fig. 5**: Fig. 5 CT including the thoracolumbar junction in 77-year-old man. CT through the entire spine. Note the osseous fusion of the right transverse process of LSTV to the sacrum (arrow) and vertebral numbering.

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Methods and materials

In order to accurately count all the vertebral bodies and assess the origin of the ILL of a given individual, one can perform full spine MRI or CT scanning with inherent pros and cons on both techniques. Full spine MRI would be a very safe way to count all vertebral bodies because of the lack of ionizing radiation, with the inconvenience of long scanning time and high cost. Full spine CT evaluation has the inconvenience of unnecessary radiation exposure with the advantage of being a very fast way to scan and count all the vertebrae. Moreover it would be difficult to obtain ethics committee approval to perform full spine CT scans on healthy subjects for the simple purpose of vertebral bodies counting. For those negative reasons, we have decided to review CT images from whole body PET-CT studies, which in our institution are performed mainly for malignant tumors workup to perform our investigation.

We have reviewed 100 whole body PET-CT studies performed from May 2013 to September 2013 on adult patients (older than 18 years). Patients were excluded if there was an important history of trauma, fractures, infection, vertebral metastasis causing fractures or gross vertebral destruction, or previous lumbar spine surgery, disabling the proper evaluation and vertebral counting. All patients were scanned in an Optima PET/CT 560 scanner, with slice thickness of 0,6 mm, field of view 70,0 cm, 120kV, 280 mA (average), pitch of 1,375:1 and pixel size of 0,13 mm. From our knowledge this paper is the pioneer using PET-CT images of the entire body.

Data collection consisted of subject's age at the time of imaging, gender, number of cervical, thoracic and lumbar vertebral bodies, as well as rib numbering. Further structural changes, such as the presence of rudimentary ribs and cervical ribs were also computed.

The presence of an LSTV was determined manually by evaluating the craniocaudal width of the transverse process, with a threshold of greater than 19 mm according to Castelvi’s system. Once detected a LSTV, it was classified according to the system proposed by Castellvi, on types IA, IB, IIA, IIB, IIIA, IIIB e IV (Fig 6).

All axial and coronal images through the lumbosacral junction were examined to identify the ILLs. These appeared as either a single or a double hypodense band arising from the transverse process and extending to the posteromedial aspect of the iliac crest. The ILL was characterized as unilateral or bilateral in each case. In the presence of a transition vertebra, the origin of the ILL was assessed if this originated in the very transitional vertebra, or in the above or bellow vertebral body. In addition, the position of the right renal artery (RRA) in relation to the L1-L2 disk space was noted on axial and coronal images (Fig 7). Two radiologist residents performed all measurements. All cases with
spinal abnormalities, as well as all cases with the presence of transitional vertebra were reviewed jointly by an expert neuroradiologist.
**Fig. 6:** CT of lumbar spine in 72-year-old man. Coronal MPR shows bilateral ILL (arrow) originating at Castellvi type Ib transitional vertebra.

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**Fig. 7**: CT of lumbar spine in 72-year-old man. 3D MPR Volume Rendering evidences right renal artery origin at the level of L1-L2 (arrow) and both ILL inserting at iliac.

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Results

The 100 patients in the study group consisted of 46 females and 54 males, with a mean age of 59.6 years (range, 19-89 years). The great majority of the patients (92%) presented normal lumbosacral segmentation and 8% had transitional lumbosacral junctions. Two main groups were found: the larger composed of patients with typical lumbosacral junction (92 patients - group 1) and a smaller composed of patients with transitional junction (8 patients - group 2). Based on Castelvi’s system, among those 8 patients from group 2, we have found, 1 patient with type Ia morphology, 2 with type Ib, 3 with type IIb, 1 with type IIIa and 1 with type IIIb.

All patients from group 1 had seven cervical, twelve thoracic and five lumbar vertebral bodies and twelve pair of normal ribs. All patients from group 2 had seven cervical and 12 thoracic vertebrae bodies. Based on the number of lumbar vertebral bodies individuals from group 2 were divided into 2 subgroups. Subgroup 2a, composed of 5 patients with four vertebral bodies and one LSTV and subgroup 2b, composed of 3 patients with five lumbar vertebral bodies and one LSTV (six vertebral bodies bellow the last thoracic rib). In subgroup 2a, 5 patients had twelve pairs of ribs, with 1 one these patients with a pair of hypoplastic small ribs arising from the twelfth thoracic vertebral body. In subgroup 2b, 1 patient had twelve pairs of ribs, 1 patient had thirteen pairs of ribs, the last pair, hypoplastic, arising from the first lumbar vertebral body and 1 patient with twelve ribs on the right side and 13 ribs on the left side, this one hypoplastic, arising from the first lumbar vertebral body.

ILL was found in all individuals, bilaterally in 99 individuals and unilateral in only one individual (from group 1). All individuals from group 1 had ILLs arising from L5 vertebral body. All individuals from group 2a had ILLs arising from the LSTV (fifth vertebral body bellow the last thoracic rib) and in one individual also arising from L4 (small bands). The 3 individuals from subgroup 2b had different ILL origins. The individual with twelve pairs of ribs had ILL arising from LSTV. The individual with twelve ribs in one side and thirteen on the other side had ILL arising from L5. And finally the individual with thirteen pairs of ribs had ILL arising from L5.

RRA was identified in all subjects, 86% located at L1/L2 level, 7% above and 7% below this level.
Fig. 8: CT of lumbar spine in 65-year-old woman. Coronal MPR image at level of lumbosacral junction shows iliolumbar ligament (arrow head) originating at transverse process of LSTV and L4, bilaterally.

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Conclusion

Correct identification of a LSTV on imaging studies is essential because of potential clinical implications. Inaccurate identification may lead to surgical and procedural errors and poor correlation with clinical symptoms [6]. Moreover increased prevalence of disc protrusion or extrusion in the disc above LSTV has been found in patients with low back pain [19]. One of the techniques that can be used to correctly number an LSTV is locating the iliolumbar ligament, which hypothetically arises solely from L5 [6].

However the true nature of the lower vertebral segmentation can be established only on imaging studies that include the thoracolumbar junction so that hypoplastic true ribs may be differentiated from large transverse processes, thus allowing correct identification of the L1 vertebral body. Once this has been correctly established, the LSTV level can be confirmed [3, 16].

Radiographs of the entire spine may allow the radiologist not only to count from C2 inferiorly but also to differentiate hypoplastic ribs from lumbar transverse processes, therefore enabling accurate counting the number of thoracic segments and correct identification of L1 vertebral body. Nonetheless, ILLs can never be imaged on plain films and more over, rare are the cases in which plain films of the entire spine of a given patient are available nowadays. Currently, given its superior spatial resolution, CT is considered the best imaging technique for characterization of LSTV [6] (Fig 9 and Fig 10).

Cancer patients, who are submitted to whole body PET-CT for cancer workup, commonly have their entire spine evaluated. With the images of the whole spine one is capable to identify with certainty the number of vertebrae in each segment, ILL identification, as well as rib counting, making it possible to accurately number the vertebrae as well as identify transitional vertebrae. In our study, ILL was found in all individuals, which demonstrates that CT images from a PET examination are useful for identifying them. PET-CT imaging proved to be useful and can be applied to identify the ILL, since this was identified in our entire group of subjects, bilaterally in 99 and unilaterally in only one individual. From our knowledge this the first time this method has been used for this purpose.

LSTVs are common in the general population, with a reported prevalence ranging of 4%-30% [9]. The 8% LTSV prevalence in our study was similar and consistent with other studies of prevalence in the general population. This percentage of transitional vertebra was similar to the findings of Hsieh et al, who found a total of 6.5% of transitional vertebra in 786 lumbar series [12]. Paik [8] et al, applying MRI, found 10,6% of prevalence of LSTV. Using different methodology, some other authors have found higher prevalence. Masud [11] reported a prevalence of 27% in 100 radiographs of patients presenting with low
backache, while Delport et al [9], in his study of 300 consecutive lumbar spine patients with low back pain, found 30% of patients with a transitional vertebrae. Finally, Apazidis et al, have stated that the prevalence of LSTV available in the literature ranges between 4% and 36%, with a mean of 12.3%. According to them most those studies are based on individuals who suffer from low back pain, and thoroughly classification of LSTV among those studies are scarce and unclear [13].

In 1984 Castellvi et al, proposed a LSTV classification system, based on the conventional radiographic appearance [6]. In our data, according to their classification, from 8 patients with LSTV, the most prevalent types were type Ib and IIb, with 2 and 3 patients respectively (Fig 11). Analyzing 769 MRI examinations, Quinlan et al, have found 35 patients with LSTV, and from those patients 33% had type II and 77% type IIb [11]. Delport et al, studying plain films of 300 consecutive lumbar spines, grouped patients who had type II and I as incomplete LSTV, and those with type III and IV as complete LSTV. Thus, 45% of patients with LSTV (total of 90) were in the group of incomplete vertebrae (type I or II of Castellvi) [9]. Paik et al, after studying over than 8000 MRI scans, have found that 877 (10.6%) patients had LSTV of types II, III, or IV. Of this, 57% had type II (39% type IIa and 18% type IIb) and 34% had type III of Castellvi [8].

Castellvi states that type I LSTVs are of no clinical significance and are a "forme fruste" and therefore have no relation to back pain. There may be an association of such iliolumbar ligament morphology with broadened long transverse processes (type I) [6], but others studies are necessary to prove it. It is established in literature that type II LSTV has an increased number of disc prolapses at the level above the transition [16].

In our group of individuals counting the cervical and thoracic vertebrae did not play an important role since all of them had typical cervical and thoracic vertebrae counting. Individuals from group 1 and 2a had twelve pair of ribs (97% of the individuals).

Some anatomic and MRI studies have indicated that the iliolumbar ligament (ILL) arises almost exclusively from the L5 transverse process, however these studies are limited by relatively small numbers of subjects [3]. Starting from this principle L5 can serve as a marker of lumbar levels, which may enable the confident numbering of LSTV.

L5 vertebral body was the origin of the ILL in 94% of the individuals in our study, ninety-two individuals from group 1 and two individuals from group 2b. But if we arbitrarily name as "L5" all LSTV from individuals from group 2a, hence these were the fifth vertebral body bellow the last thoracic vertebral body, we have found L5 as origin of ILLs in 99% of the individuals. We shall not forget, however, that L5 only represented the last lumbar vertebral body in the individuals from groups 1 and 2a, but not in those from group 2b.
Our study demonstrates that L5 was almost always the origin ILL (99% of the individuals). L5 vertebral body represented the last lumbar vertebral level in 97% of the patients (encompassing individuals group 1 and 2a). ILL can be accurately used as a marker to identify L5 in individuals with typical lumbar segmentation. We have found 97% agreement rate between L5 vertebral body being the last lumbar level and the origin ILL altogether.

The RRA was identified in all patients. In 86 was the RRA at the level of L1-L2 disk space. It was above this level in 7 patients and under in 7. Hughes et al, found that the RRA was identified on the sagittal MRI images in 456 of the 500 patients, and was not seen in 44 cases. The RRA was identified adjacent to the L1-2 disk in only 73.5% of cases. It was not seen in 8.5% of the cases and was at the mid vertebral body level or closer to other disk spaces in 17.5% of cases [3]. In literature it is proposed that the use of anatomic markers, including right renal artery may be used to identify lumbar levels on sagittal MRI, because it usually lies closest to the L1-2 disk space [17, 18]. However, this method also appears insensitive in our investigation. Although the RRA is commonly seen to lie adjacent to the L1-2 disk, this criterion cannot be used in approximately 25% of cases, either because it is not imaged or is present at another location [3, 17].
**Fig. 9:** Normal lumbosacral junction in a 61-year-old woman. Axial view of ILL originating at tip of L5 transverse process.

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**Fig. 10:** Normal lumbosacral junction in a 61-year-old woman. Coronal MPR view showing ILL bilateral.

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**Fig. 11:** CT of lumbar spine in 68-year-old woman. Coronal MPR image at level of lumbosacral junction shows bilateral iliolumbar ligament (arrow head) originating at Castellvi type IIa (unilateral pseudarthrosis) transitional vertebra.

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