

Use of the Thoracolumbar Facet Transition as a Method of Identifying the T12 Segment

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Abstract

Purpose: Evaluate the reliability of the change from the flat, posterolaterally oriented facets of the thoracic segments to the curved, posteromedially oriented facets of the lumbar spine, the “facet transition”, as a marker for the T12 segment and determine if variations in rib number are associated with lumbosacral transitional segments.

Materials and methods: 244 patients underwent whole spine CT examinations and the positions of the thoracolumbar facet transition, type of thoracolumbar facet transition (gradual or abrupt), position of the lowest thoracic ribs, and presence or absence of lumbosacral transitional anatomy were recorded. A Fisher Exact Test was used to determine if there was an association between a variant number of ribs and transitional anatomy at the lumbosacral junction.

Results: The thoracolumbar facet transition was located at the eighteenth segment in 50/244 (20%), nineteenth segment in 184/244 (75%), and twentieth segment in 10/244 (4%) of cases. The thoracolumbar facet transition was abrupt in 227/244 (93%). The lowest set of ribs was observed at the nineteenth segment in 225/244 (92%), twentieth segment in 11/244 (5%), and eighteenth segment in 8/244 (3%). The lowest fully-formed intervertebral disc was located between the twenty-third and twenty-fourth segments in 9/244 (4%), twenty-fourth and twenty-fifth segments in 216/244 (88%), and twenty-fifth and twenty-sixth segments in 19/244 (8%). Coexistent lumbosacral transitional anatomy was seen in 5/7 (71%) with eleven, 8/11 (73%) with thirteen, and 24/234 (10%) with twelve ribs. There was an association between variant numbers of ribs and coexistent lumbosacral transitional anatomy ($p < 0.5$).

Conclusion: The thoracolumbar facet transition is not a reliable method of identifying the T12 segment. There are no known landmarks that reliably identify the lumbar segments. Accurate numbering of the lumbar spine requires counting caudally from C2.

Keywords: Spine segmental numbering; Thoracolumbar facet transition; Spine imaging; Wrong level; Surgery

Introduction

Accurate numbering of the lumbar segments is important in order to prevent wrong level spine surgeries and procedures [1-3]. The lumbar spine is most commonly imaged with a field of view that included one or two of the caudad thoracic segments, the lumbar segments, and the upper sacral segments. As a result, a set of assumptions is generally made when applying a numbering strategy to the lumbosacral segments. The lowest set of floating ribs is generally assumed to arise from the T12 segment and the lowest fully-formed intervertebral disc is generally assumed to be L5-S1.

To date, no single technique has proven reliable in identifying any particular lower thoracic, lumbar, or sacral segment on the basis of regional anatomy. Some of the techniques investigated include: the location of the aortic bifurcation [4], right renal artery [5-7], confluence of the inferior vena cava [8], conus medullaris [5,9,10], and the position of the iliolumbar ligaments [11]. While some of these techniques properly identify lumbar segments in the majority of cases, none of these techniques has proven to be reliable in all cases.

To date, little has been written about the characteristics of the thoracolumbar facet transition. In the thoracic spine, the surfaces of the superior articular facets are flat and oriented posterolaterally (Figure 1). The surfaces of the superior articular facets in the lumbar spine are curved and oriented posteromedially (Figure 2). The transition from the thoracic-type to lumbar-type facet orientations has been described as abrupt, occurring at one segment, or gradual, occurring over multiple segments.

Singer and colleagues described a sudden facet transition in 46% of cases, occurring most often at T12. In 54% of cases, a gradual facet

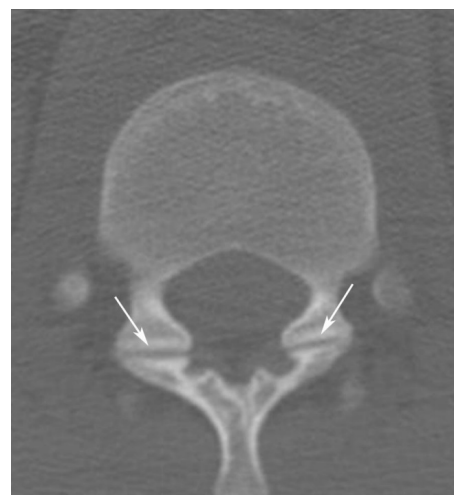


Figure 1: Axial CT image demonstrates the typical near coronal orientation of the thoracic facets (arrows).

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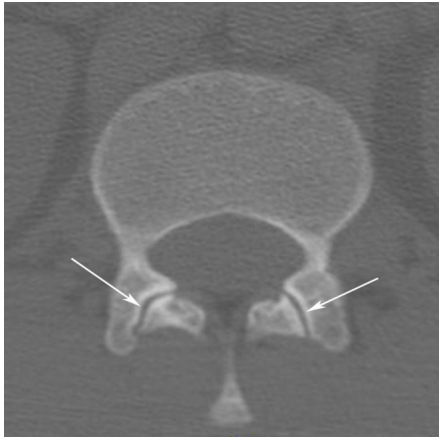


Figure 2: Axial CT image demonstrates the typical sagittal orientation of the lumbar facets (arrows).

transition was observed over two adjacent segments, typically at T11 and T12 [12]. Shinohara reported that the thoracolumbar facet transition was abrupt in about two thirds of cases and tended to occur at T12. The facet transition was gradual in one third of cases, with a tendency to occur over two successive levels [13]. Patel et al. observed an abrupt facet transition in 94% of cases, most commonly located at T12 and less commonly at T11 [14].

In the current study, we evaluated the characteristics of the thoracolumbar facet transition and sought to determine the reliability of this transition in identifying the T12 segment. Commonly used markers for segmental numbering were also evaluated, including the position of the lowest set of floating ribs and the lowest fully-formed intervertebral disc.

Materials and Methods

We retrospectively reviewed the images of 262 consecutive adults who had received cervical, thoracic, and lumbar spine CT examinations at our institution between January, 2009 and December, 2011. Exclusion criteria consisted of any factor that would interfere with evaluation of facet orientation and accurate segmental numbering, such as: severe artifacts, displaced fractures, severe spinal deformity, congenital segmentation anomalies, or surgical fusion. The most common indications for the CT examinations reviewed included trauma, pre- and post-surgical spine evaluations, and scoliosis.

All CT examinations were performed on 64 detector GE LightSpeed VCT scanners and the images were reviewed with the Philips Intellispace PACS and Philips Intellispace Portal (Koninklijke, Philips N.V., 2014). In each case, the vertebral segments were numbered from craniad to caudad with the assumption of seven cervical and twelve thoracic segments [15]. The position of the thoracolumbar facet transition, type of thoracolumbar facet transition (gradual or abrupt), position of the caudal-most thoracic ribs, position of the lowest fully-formed intervertebral disc, and presence or absence of lumbosacral transitional anatomy were recorded.

Each CT examination was independently reviewed by a board certified, fellowship trained, staff neuroradiologist holding a Certificate of Added Qualification in Neuroradiology from the American Board of Radiology and an upper level radiology resident. Inter-rater reliability was quantified with the use of the Kappa coefficient.

The thoracolumbar facet transition was defined as the segment

or segments in which the facets change in orientation from the near coronal orientation typical of the thoracic segments (Figure 1) to the more sagittal orientation that is typical of the lumbar segments (Figure 2). Facet transitions were recorded as “abrupt” if the transition occurred at one segment. Facet transitions were recorded as “gradual” if they occurred over more than one segment. The orientation of the zygapophyseal joint with respect to the mid-sagittal line was used to determine facet angulation. Superior articular facets angled 0-90 degrees were considered to be posterolaterally or posteriorly oriented. Inferior articular facets with angles greater than 90 degrees were considered to be anterolaterally oriented. The shape of the facet (i.e. flat or curved) was not considered due to the considerable morphologic variation that has been reported previously [16].

The position of the caudal most ribs was determined with the use of criteria adapted from Wigh [17] and Carrino, et al. [18]. A rib was defined as a bony structure that slopes from superomedial to inferolateral and maintains a central articulation with the vertebral body. A transverse process was defined as a horizontal bony process that does not centrally articulate with the vertebral body.

In order to determine if variations in rib number are associated with lumbosacral transitional anatomy, the presence or absence of lumbosacral transitional anatomy, as defined by the Castellvi et al. [19] system, was recorded for each patient. Lumbosacral transitional anatomy was not further categorized. A two-tailed Fisher Exact Test was used to determine if there was an association between a variant number of ribs and transitional anatomy at the lumbosacral junction. A p-value of less than 0.05 was considered to be statistically significant.

This study was conducted under institutional review board approval (reference number pro-00000525). The study was Health Insurance Portability and Accountability Act compliant. Descriptive and inferential statistics were calculated with the use of StatPlus: mac 2009 5.8.3.8.

Results

The final sample consisted of 244 cases. A total of 18 cases were excluded. The most common reasons for exclusion were: severe fractures (n=3), severe congenital fusion anomalies (n=3), and the presence of surgical hardware with segmental fusion (n=2). The patient sample was 63% male and 37% female with an age range of 16-87 years (mean age=34 years).

There was perfect agreement amongst the raters (Kappa=1.0). The thoracolumbar facet transition was abrupt in 227/244 (93%) cases and gradual in 17/244 (7%) cases. The facet transition was located at the eighteenth segment in 50/244 (20%) of cases, the nineteenth segment in 184/244 (75%) of cases, and twentieth segment in 10/244 (4%) of cases.

The lowest set of ribs was observed at the nineteenth segment in 225/244 (92%), twentieth segment in 11/244 (5%), and eighteenth segment in 8/244 cases. The lowest fully-formed intervertebral disc was located between the twenty-third and twenty-fourth segments in 9/244 (4%), twenty-fourth and twenty-fifth segments in 216/244 (88%), and twenty-fifth and twenty-sixth segments in 19/244 (8%).

Twelve sets of ribs were most commonly observed, with the caudal-most set of ribs associated with the nineteenth vertebral segment in 225/244 (92%) of cases. Thirteen sets of ribs were observed in 11/244 (5%) of cases and eleven sets of ribs were observed in 8/244 (3%) of cases, with the caudal-most ribs associated with the twentieth and eighteenth vertebrae, respectively. Cervical ribs were present at C7 in one patient that were not included in the total rib count.

Transitional lumbosacral anatomy was observed in 37/244 (15%) of the sample. In those patients with eleven sets of ribs, 5/7 (71%) had transitional anatomy at the lumbosacral junction. There was an association between variant numbers of ribs (i.e. 11 and 13 ribs) and coexistent lumbosacral transitional anatomy ($p < 0.05$).

In 216/244 (89%) of cases, there were 24 presacral segments. 9/244 patients (4%) were found to have 23 presacral segments. 19/244 patients (8%) were found to have 25 presacral segments.

Discussion

The incidence of wrong level spine surgeries and wrong level surgical exposures has been reported to be between 0.032% and 15% of cases [1,19-23]. A recently published survey of spine surgeons revealed the 36% of the respondents admitted to performing wrong-level surgery at some point in their career [24]. Most of the reported errors were attributed to a failure to recognize unconventional spinal anatomy (e.g. supernumerary segments, eleven ribs, thirteen ribs), suboptimal intraoperative x-rays, miscounting, using poor references when counting, and failure to re-localize after exposure. Interestingly, a number of the errors were attributed to faulty methods of counting, such as counting down from the lowest set of ribs or counting up from the sacrum, or miscommunication (e.g. radiologist counting down from the ribs and surgeon counting up from the sacrum).

Accurate segmental numbering and identification of lumbosacral transitional anatomy is an important part of image interpretation when there is a realistic possibility of surgical or procedural intervention. Routine CT, MR, and plain film examinations of the lumbar spine are frequently interpreted without the availability of cervicothoracic spine imaging. Establishing anatomic landmarks that reliably identify vertebral segments is clearly in the interest of the radiologist or surgeon interpreting imaging studies. Several anatomic structures have been evaluated in this regard, including structures intrinsic and extrinsic to the spine [4-11]. In addition, a variety of measurement techniques and morphologic features have been described that assist in identifying certain vertebral segments and transitional segments [17,18,25-28]. To date, none of the techniques studied provide for the 100% certainty that is required.

In the current study, we examined the location of the thoracolumbar facet transition as a potential method of identifying the T12 segment. We observed an abrupt facet transition in 93% of cases, closely approximating the results reported by Patel et al. [14]. Likewise, the thoracolumbar facet transition was located at segment nineteen in only three quarters of the cases in our sample. The variation in the location of the thoracolumbar facet transition precludes its use as a reliable landmark for the T12 segment.

We observed considerable variability in the number of rib-bearing vertebral segments. Variation in the position of the caudal most rib-bearing segment can present a significant problem when attempting to accurately number the lumbar segments. The lowest set of ribs of ribs allowed the identification of the T12 segment in 92% of cases in our sample. While identification of the lowest set of ribs and lowest fully formed intervertebral disc are more reliable methods of identifying certain vertebral segments, the error rates associated with using these techniques are not considered acceptable for routine clinical practice.

The lack of reliable intrinsic or extrinsic landmarks for the correct identification of the lumbar segments in routine lumbar spine imaging has led some authors to suggest various counting techniques, including rapid whole spine localizer sequences [29-31], use of whole spine radiographs [18], intraoperative fluoroscopic or CT imaging [19,20,32,33], and the addition of coronal localizer sequences of the

lumbosacral spine [18].

With modern MRI scanners, it is possible to obtain rapid whole spine localizer images in the sagittal and coronal planes, allowing reliable segmental numbering and adequate characterization of lumbosacral transitional anatomy with minimal additional scanner time required. In the case of CT, the use of AP or lateral scanograms that include the cervicothoracic segments or cervicothoracic plain films would assist in segmental numbering.

We are in general agreement with the reporting approach described by Carrino et al. [18], in which there is a description of the numbering approach, categorization of transitional anatomy, and explicit reference to the location of the caudal most fully formed intervertebral disc. Alternatively, a description of the location of a caudal most partially formed intervertebral disc can also assist in intraoperative or procedural localization with fluoroscopy.

This study has a number of limitations, foremost of which are the inherent limitations of the retrospective nature of the data collection. Our final sample was predominantly male, owing to the high volume trauma service at our institution. The final sample included a slight preponderance of causes related to trauma, pre- and post-surgical spine evaluations, and scoliosis. We do not believe that this introduced a significant bias considering that the frequency statistics we reported were not dissimilar to those previously reported.

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