The association of lumbosacral transitional vertebrae with low back pain and lumbar degenerative findings in MRI - a large cohort study

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Abstract

Study design: A cross-sectional study of the Northern Finland Birth Cohort 1966 (NFBC1966).

Objective: To evaluate the association of lumbosacral transitional vertebrae (LSTV) with low back pain (LBP) and associated degenerative findings using MR imaging.

Summary of background data: LSTV is a common finding with a prevalence of 10% to 29%. LSTV causes biomechanical alterations leading to accelerated lumbar degeneration. However, its association with degenerative findings on MRI and LBP is unclear.

Methods: 1468 lumbar spine MRI scans from the NFBC1966 acquired at a mean age of 47 years were assessed for the presence of LSTV and degenerative changes. Castellvi classification was utilized to identify LSTV anatomy. Additionally, 100 controls without LSTV were collected. Self-reported LBP with a duration of >30 days in the past year was deemed clinically relevant. For the statistical analyses, chi square test, independent samples t-test and multinomial logistic regression analyses were used.

Results: LSTV was found in 310 (21.1%) subjects. After adjusting for age, sex and disc degeneration (DD) sum, subjects with Castellvi type III reported prolonged LBP significantly more frequently than the controls (OR=8.9, p=0.001). We observed a higher prevalence of facet degeneration (FD) at all levels from L3/L4 to L5/S1 in type I, and L3/L4 to L4/L5 in types II-IV. DD was more prevalent at L4/L5 in types II-IV. Disc protrusion/extrusion occurred more frequently at L3/L4 and L4/L5 in type II, and at L3/L4 in type III. Castellvi type II had a higher prevalence of type 1 Modic changes at all levels from L3/L4 to L5/S1, and type IV had a higher prevalence of any Modic changes at L4/L5.

Conclusion: LSTVs were a common finding within this study, and Castellvi type III LSTVs were associated with LBP. Degenerative findings were associated with LSTV anatomy and occurred more commonly above the transitional level.

Key words (10-15): Castellvi, disc degeneration, facet joint, foraminal stenosis, low back pain, lumbar central canal stenosis, lumbosacral, Modic changes, MRI, prevalence, protrusion, transitional vertebra

Level of evidence: 3

Mini Abstract: This study evaluated the association of lumbosacral transitional vertebrae (LSTV) with low back pain (LBP) and degenerative findings from the Northern Finland Birth Cohort using MRI. Castellvi type III LSTVs were associated with LBP, and degenerative findings were associated with LSTV anatomy and occurred more commonly above the transitional level.

Key points:

1. LSTV is a common finding in the general population.
2. Castellvi type III LSTVs seem to be associated with prolonged low back pain.
3. Degenerative findings seen on MRI are associated with LSTV anatomy and occur more commonly above the transitional level.

Introduction

Lumbosacral transitional vertebra (LSTV) is a common spinal anomaly. In LSTV, the transverse process of the lowest lumbar vertebra is enlarged and can form either a pseudo-articulation or a complete osseus fusion with the adjacent ala of the sacrum [1]. Ordinarily, the presence of LSTV is evaluated on conventional radiographs applying the classic Castellvi classification [2]. In large-scale studies, LSTV is a frequent finding with a reported prevalence ranging from 9.9% to 28.6% [3-6]. The association of LSTV with low back pain (LBP) is known eponymously as Bertolotti syndrome [7]. However, the clinical significance of LSTV is equivocal. LSTV affects biomechanical properties of the lumbar spine, which predisposes the superjacent disc to premature degeneration [8, 9]. Although the relevance of disc degeneration (DD) to LBP is debated and DD is associated with so-called normal aging [10], DD has been demonstrated to be more prevalent in adults with LBP [11]. Nevertheless, results are controversial regarding the effect of LSTV on LBP; for instance, in a series of 4000 patients, no relationship between LBP and LSTV was found [12], but in a more recent study with 4636 participants, Castellvi types II and IV were found to be strongly associated with LBP [3].

Previous studies utilizing magnetic resonance imaging (MRI) have further elucidated the associated findings of LSTV. Extraforaminal nerve compression at the transitional level can occur with a prevalence of 13% and can be symptomatic in up to 70% of patients [13]. Farshad-Amacker et al. found that the subjects with LSTV had a higher prevalence of annular tears and large disc herniations at the superjacent level compared to the non-LSTV control group. Furthermore, Modic changes (MC) were more prevalent at the superjacent level among subjects with LSTV, whereas MC were observed at the transitional level more frequently among subjects without LSTV [14].

Given the significant prevalence of both LSTV and LBP, we found it prudent to study the association between these two variables using lumbar spine MRI from a large Northern Finland Birth Cohort of the general population. We also sought out to further evaluate the association between LSTV and degenerative findings visible on MRI.

Materials and Methods

Study population

Institutional review board approval was obtained and the requirement for informed consent was waived for this study. Northern Finland Birth Cohort 1966 (NFBC1966) is a large prospective population-based birth cohort study with an initial coverage of 96% of births in Northern Finland between January 1st and December 31st, 1966 (n=12 231) [15]. A major follow-up study was conducted in 2012 with study population age of 46 years. A subset of cohort subjects were invited to undergo an MRI examination of the lumbar spine. These MRI examinations were carried out over the following three years. PACS search for NFBC1966 lumbar spine MRI scans between 2012-2015 yielded 1507 scans. Scans with any of the following criteria were excluded: 1) any spinal implantation; 2) missing coronal, axial and/or sagittal sequences; or 3) subpar quality of sequences or imaging artefacts which rendered reliable, objective evaluation impossible. A total of 39 scans were excluded yielding the final study population of 1468 subjects. One hundred cohort subjects without LSTV were selected at random to form a control group and the number of controls was matched to the cumulative amount of LSTV types II-IV.

The cohort subjects who underwent the MRI examination supplied follow-up data on their health via postal questionnaire. The prevalence of LBP was elicited by asking the question: “Have you ever had aches or pain in your lower back?” The response options were ‘no’ and ‘yes’. If the response was affirmative, the follow-up question was: “How often have you had

lower back pain in the past 12 months?" The response options were '1 to 7 days', '8 to 30 days', 'over 30 days but not daily' and 'daily'. We deemed >30 days in the past 12 months to be a suitable threshold to indicate significant LBP affecting ordinary life.

Imaging technique and analysis

All of the imaging was acquired using 1.5T MRI scanners. A routine clinical lumbar spine protocol was used, which included T2-weighted fast spin-echo axial and sagittal planes, T1 FLAIR (fluid-attenuated inversion recovery) sagittal plane as well as STIR (short tau inversion recovery) coronal plane. The initial imaging data was collected by J.H. Studies flagged as Castellvi types II-IV were then re-evaluated by a musculoskeletal radiology fellow with 6 years of experience, M.N, who made the call on Castellvi typing in challenging cases, and reviewed the grading of degenerative changes. The readers were not blinded to the study data.

The 1468 lumbar spine MRI scans were assessed for the presence of LSTV using Castellvi classification. Type I includes an enlarged transverse process measuring at least 19 mm craniocaudally, type II exhibits an enlarged transverse process which forms a pseudoarticulation with the adjacent ala of the sacrum, type III describes an osseous fusion of the transverse process with the adjacent ala of the sacrum, type IV combines types II and III with a pseudo-articulation on one side and an osseus fusion on the contralateral side. Types I-III are further subtyped by the presence of unilateral (a) or bilateral (b) changes [2].

Disc protrusions and extrusions were assessed following the recommended standard definitions presented by Fardon et al [16]. Disc degeneration (DD) was graded using the standard Pfirrmann classification system [17]. Facet degeneration (FD) was graded on a scale of 0 to 3 following the grading system by Weishaupt et al. [18]. Grade 1 refers to narrowing of the joint space and/or mild osteophytosis and/or mild hypertrophy of the articular process. In grade 2,

the aforementioned changes are moderate in nature and mild bone erosions may be present. In grade 3, the changes are severe and subchondral cysts may be present. Modic changes were evaluated as type 1 (MC1), type 2 (MC2) and type 3 (MC3) changes [19-21]. MC1 shows a low signal intensity on T1-weighted images, and a high signal intensity on T2-weighted images demonstrating vertebral bone marrow edema. MC2 has a high signal intensity on both T1-weighted and T2-weighted images depicting fatty regeneration of the normal bone marrow while MC3 has a low signal intensity on both T1-weighted and T2-weighted images depicting bone sclerosis. Mixed MC1/2 and MC2/3 were also evaluated [22].

Lumbar central canal stenosis (LCCS) was graded on a scale of 0 to 3 following the grading system proposed by Lee et al. 2011 [24]. Grade 0 refers to no LCCS with no obliteration of the anterior cerebrospinal fluid (CSF) space; grade 1 refers to mild LCCS in which the anterior CSF space is mildly obliterated, but all cauda equina could clearly be separated from each other; grade 2 refers to moderate LCCS in which the anterior CSF space is moderately obliterated with some aggregation of the cauda equina; and finally grade 3 refers to severe LCCS in which the anterior CSF space is severely obliterated and none of the cauda equina can be visually separated from each other.

Foraminal stenosis was graded on a scale of 0 to 3 following the grading system proposed by Lee et al. [23]: Grade 0 refers to absence of foraminal stenosis; grade 1 refers to mild stenosis with perineural fat obliteration in two opposing directions either vertical or transverse; grade 2 refers to moderate stenosis with perineural obliteration in four directions without morphologic change of the nerve root; and grade 3 refers to severe stenosis with morphologic change of the nerve root. Foraminal stenosis was given a single grade per lumbar level based on the foramen which exhibited a more severe degree of stenosis. Recess stenosis was evaluated on axial T2-

weighted images either present or absent. Bulging disc or hypertrophic degenerative facet displacing the nerve root was considered as a recess stenosis.

Statistical analysis

Statistical software (IBM SPSS Statistics for Windows, Version 24.0) was used for the analysis. Chi square test, independent samples t-test and multinomial logistic regression analyses were used to evaluate the differences between the groups.

In the final study population among subjects with LSTV and the control group, four subjects had missing questionnaire data. Thus, they were included only in the univariate analyses of the degenerative findings. For multivariate analyses, DD summary score was calculated by adding all three Pfirrmann scores from L3/4 to L5/S1 to gain the comprehensive impact of the DD from the lower lumbar spine.

For statistical analyses, degenerative findings were dichotomized. Protrusions and extrusions were combined and evaluated as present or absent. DD was divided into non-severe (grades 1-3) and severe (grades 4-5). Facet degeneration, foraminal stenosis and LCCS were divided into absent/mild (grades 0 and 1) and moderate/severe (grades 2 and 3). Any MC group included subjects with any MC, and MC1 group subjects with MC1 or MC1/2.

Results

Study population characteristics and the prevalence of LSTV

The mean age of the study population was 47.2 years (range from 46 to 49 years). Out of 1468 lumbar spine MRI cases, LSTV morphology was found in 310 (21.1%) cases. Of those, Castellvi type I was found in 62.6% cases, type II in 24.8%, type III in 9.0%, and type IV in 3.5% cases. Only 47 (15.2%) cases had bilateral LSTV findings. Among subjects with LSTV

there were 38.1% females and 61.9% males, and in the control group 50.5% and 49.5%, respectively (**Table 1**).

Association of LSTV with prolonged LBP

Prolonged LBP was reported in controls, Castellvi type I, II, III and IV groups in 20.2%, 25.7%, 21.1%, 46.4% and 27.3% cases, respectively (**Table 1**). After adjusting for age, sex and DD sum, subjects with Castellvi type III reported prolonged LBP significantly more frequently than the control group (OR=8.9, p=0.001, 95% CI 2.562-30.766). Other Castellvi types were not significantly associated with prolonged LBP (**Table 2**).

Association of LSTV with degenerative findings on MRI

The prevalence of degenerative findings on MRI is presented in **Table 3.** The prevalences of DD and FD are presented in **Figures 1** and **2**, respectively. Multivariate analyses for degenerative findings on MRI were adjusted for age and sex and the results are presented in **Table 4**. Using the control group as a reference, Castellvi type I showed higher prevalence of FD at all levels from L3/L4 to L5/S1. Castellvi type II had a higher prevalence of DD at L4/L5, and FD at L3/L4 and L4/L5. In addition, Castellvi type II demonstrated higher prevalence of disc protrusion/extrusion at L3/L4 and L4/L5, as well as MC1 at all levels from L3/L4 to L5/S1. In the Castellvi type III group, we observed higher prevalence of DD at L4/L5, FD at L3/L4 and L4/L5, and disc protrusion/extrusion at L3/L4. Castellvi type IV had a higher prevalence of DD at L4/L5, FD at L3/L4 and L4/L5, and MC at L4/L5. **Figures 3 & 4** show examples of LSTV anatomy with associated degenerative findings.

Discussion

In our large cohort study, the prevalence of LSTV was 21.1%, with Castellvi type I LSTV being the most common (62.2%), followed by type II (24.8%), type III (9.0%), and type IV (3.5%). Our findings are in line with previous large-scale studies with a prevalence of 9.9% to

28.6% [3-6]. In smaller studies, the reported prevalence of LSTV has ranged from as low as 2.6% [25] to as high as 35.6% [26]. This wide range can be attributed to different imaging modalities, variable size of study populations, and exclusion of Castellvi type I LSTV in some studies' analyses.

We found Castellvi type III to be significantly associated with LBP. Previously, Nardo et al. [3] and Tang et al. [5] have found Castellvi types II and IV to be associated with LBP. Nonetheless, these studies utilized radiographs, not MRI, and it has been shown recently that classification of LSTV types is not accurate using radiographs [27]. With regards to LBP evaluation, we included only subjects who reported LBP over 30 days in the past 12 months to exclude mild LBP episodes with short duration and low clinical relevance. Some studies have evaluated LBP in the past 30 days with notably higher LBP prevalence than in our study [3]. Moreover, the selection of the study population could complicate the evaluation between the studies as there are also studies consisting of purely LBP patients [1]. However, we acknowledge the rather small number of Castellvi type III cases in our study. Even though the size of our study population was fairly large, the low number of Castellvi type III cases can naturally impact our results.

As expected, DD, FD and disc protrusions/extrusions were more prevalent in the LSTV group than the control group, and these degenerative changes occurred more frequently above the transitional level (**Table 4**). The presence of LSTV causes biomechanical alterations to the lumbar spine [28]. A partial or a complete fusion of the transverse process of LSTV with the adjacent ala of the sacrum limits movement between LSTV and sacrum, i.e., at the transitional level. As the transitional level is stabilized, the movement occurs at the superjacent level [14]. This excessive mobility can lead to accelerated degeneration, whereas the restriction of rotational and bending movements at the transitional level has a protective effect at that level.

Multiple previous studies have shown this typical pattern of degeneration which is associated with LSTV [8, 9, 14, 29, 30]. In fact, Elster found that disc herniations were nine times more likely to occur above the transitional vertebra and no herniations were observed between the LSTV and the sacrum [30]. Changes in the biomechanical environment can also explain the significantly higher prevalence of MC at superjacent level as MC are associated with greater DD and other degenerative MRI findings and motion characteristics such as translational motion [22, 31]. The association of MC with LBP is controversial and typically MC1 have been associated with LBP [11, 32, 33]. Theoretically, LSTV could cause LBP through MC1. However, only Castellvi type II cases were significantly associated with MC1 in multivariate analyses.

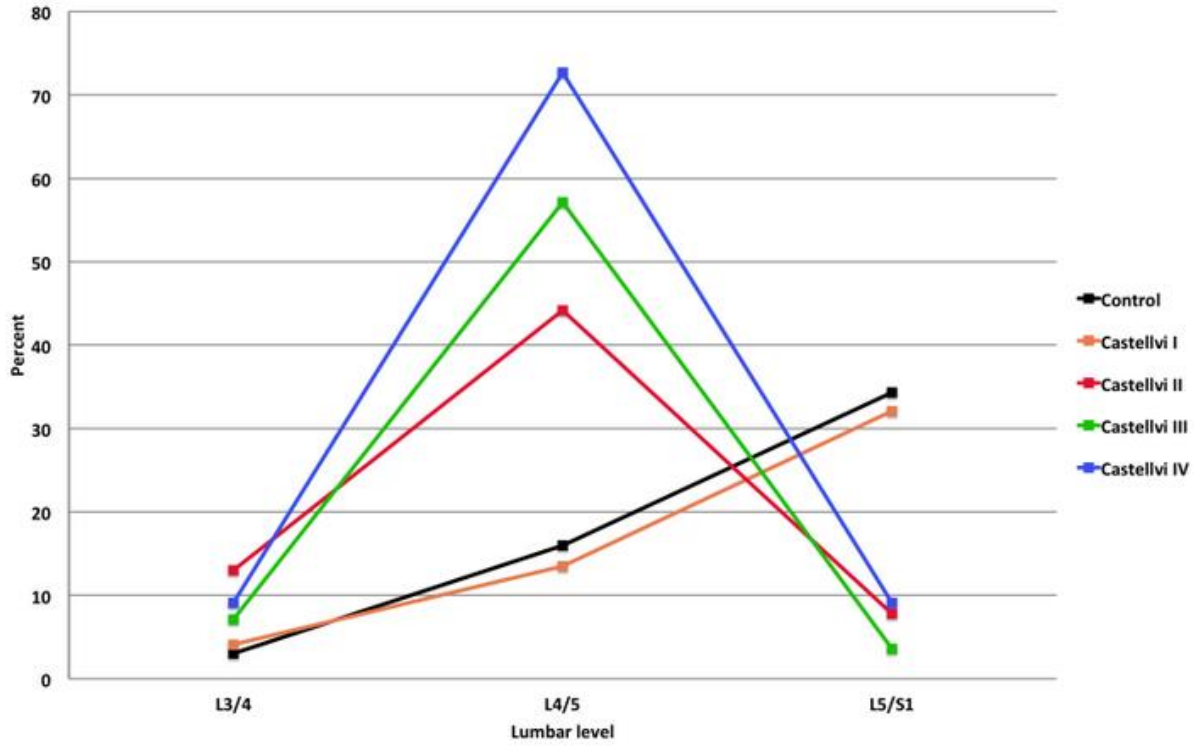
As LSTV anatomy is associated with common lumbar degeneration [6], it is plausible that degeneration of the three-joint complex can lead to significant narrowing of the central canal over time. In a study of 2000 consecutive patients, the prevalence of LCCS in the LSTV group did not differ from the control group. However, the location of the pathology followed the typical pattern: LCCS was noted to occur more frequently at or near the level above the transitional vertebra [30]. A recent cross-sectional study of 165 individuals with a diagnosis of LCCS on computed tomography showed that the prevalence of LSTV was higher in the symptomatic group than the control group (57% vs 26%) [34]. With regards to foraminal stenosis, Vergauwen et al. found that foraminal stenosis is more prevalent in patients with LSTV than without LSTV, and when present, is more likely to occur above the transitional level [29]. Another study found that there is no difference in the prevalence of foraminal stenosis between LSTV patients and the control group, but again showed that foraminal stenosis is more common above the transitional vertebra [30]. Our study population had a very low overall prevalence of both LCCS and foraminal stenosis, likely due to the relatively young

age of the cohort subjects, and as such our data does not support the association of LCCS and LSTV nor foraminal stenosis and LSTV (**Table 3**).

There are several limitations in our study. First, this was a cross-sectional study with no follow-up data available currently. Second, although the initial study population was 1468 subjects, the final number of specific Castellvi cases - especially type III and IV - were rather low, only 28 and 11, respectively, which affected our analyses. As our study consisted of the cohort study population, we could not influence the size of the study population. Third, in the control group, the distribution of age and sex differed from the LSTV groups; this is due to the initial blinding of the NFBC1966 data, which could not be taken into consideration in the collection of the control group. However, due to cohort study population, age range was only three years and, thus, age difference was not considered to have a major role in the analyses. Nevertheless, the multivariate analyses were adjusted with age and sex. Fourth, although MRI provides superior contrast of soft tissues, the resolution and imaging planes to assess bony anatomy are inferior to CT imaging; accordingly, the classification of LSTV anatomy was challenging in borderline cases. Fifth, as this was a cohort study including the general population in their late forties, we did not specifically study subjects with LBP. However, this could be seen also as a strength as there was no selection bias towards subjects with LBP [32]. Sixth, the measuring and reporting of LBP was based only on self-reported questionnaires. However, to decrease the possible bias, we assessed prolonged LBP over 30 days in the past 12 months to increase the clinical relevance of LBP. And lastly, the questionnaire did not probe for LBP experienced over a lifetime, and as such, our study does not describe the association of LSTV and LBP over a lifetime, but rather the association during a twelve month period in the mid to late forties.

In conclusion, in this cross-sectional large-scale cohort study, we have shown that LSTV is a common finding in the general population. Degenerative findings observed on MRI are

associated with LSTV anatomy and occur more commonly above the transitional level. Furthermore, Castellvi type III LSTVs seem to be associated with prolonged LBP. These findings highlight the importance of reporting LSTV anatomy on lumbar MRI scans.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Percent
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Lumbar level
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Castellvi I
Castellvi II
Castellvi III
Castellvi IV

Fig. 1

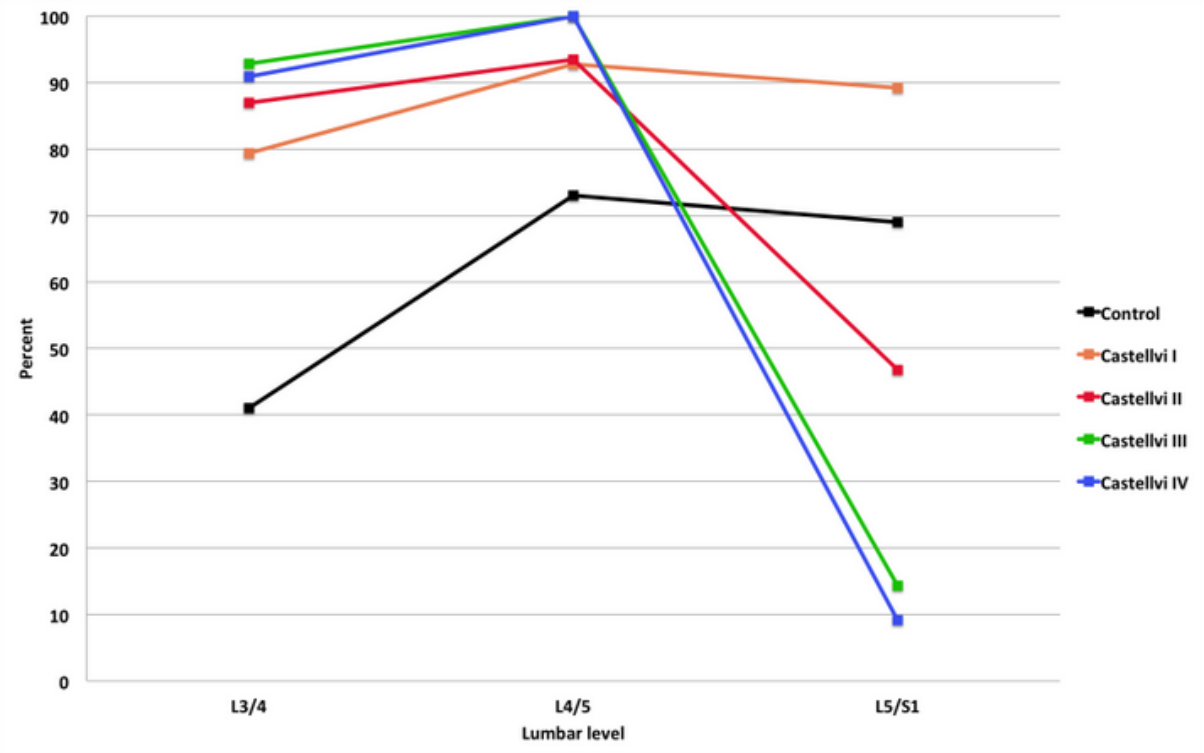
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Fig. 2

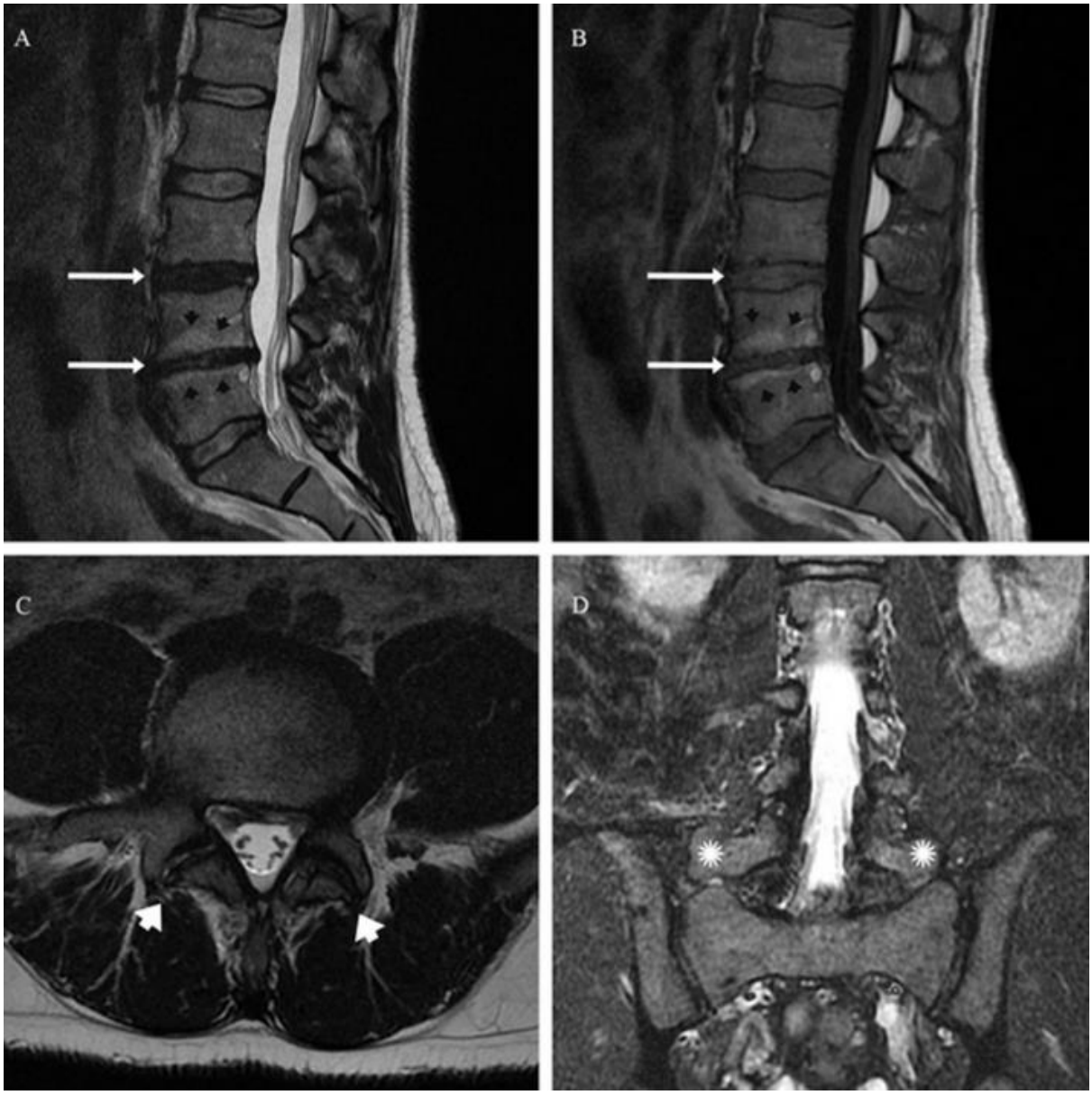

Fig. 3

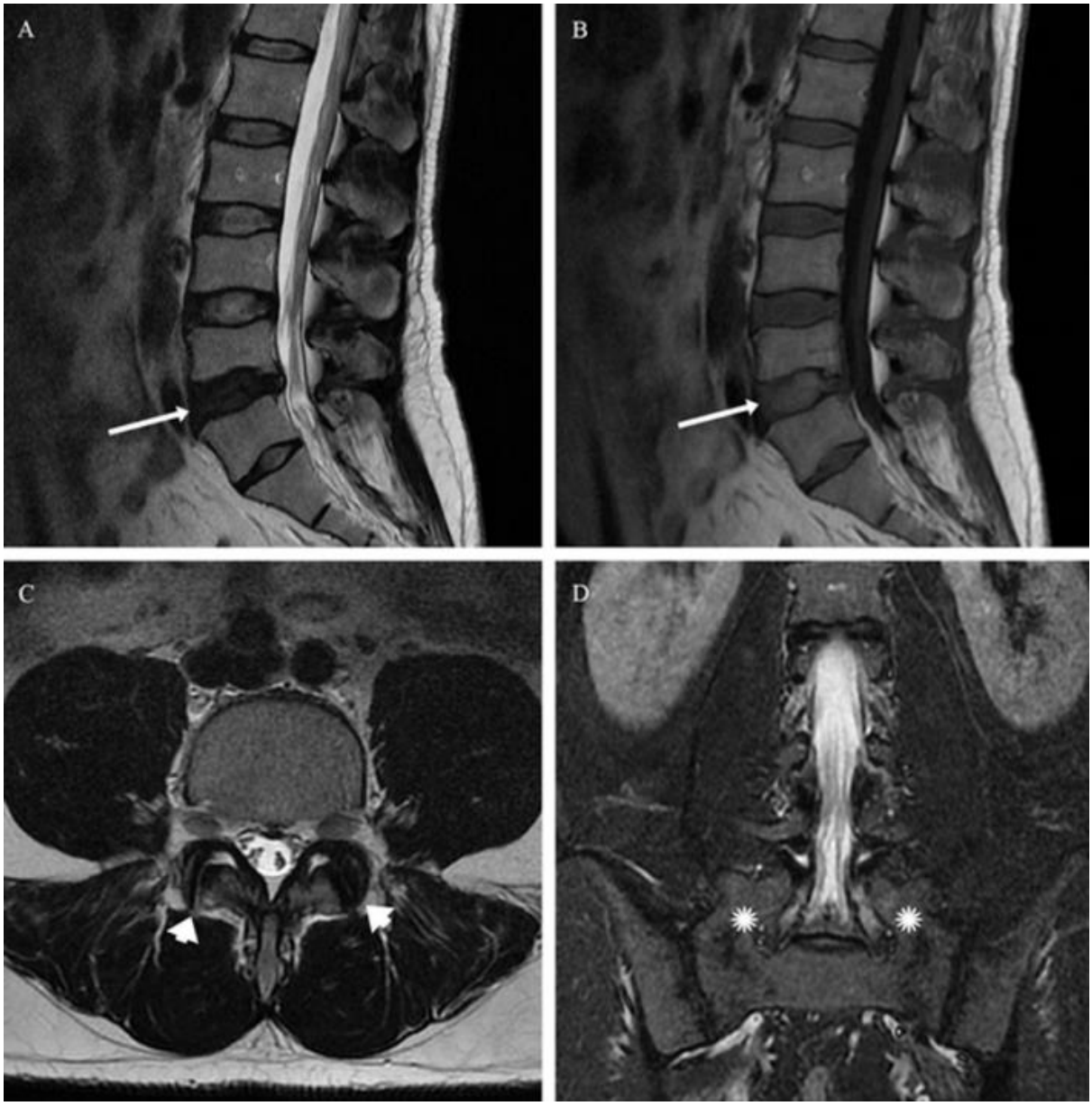

Fig. 4

Figure 1. The prevalence of disc degeneration per lumbar level in percentages.

Figure 2. The prevalence of facet degeneration per lumbar level in percentages.

Figure 3. MR images of a subject with Castellvi IIb lumbosacral transitional vertebra and associated degenerative changes. In T2-weighted (A) and T1-weighted (B) sagittal MR images, Pfirrmann grade III and IV disc degeneration (white arrows) is seen at L3/4 and L4/5 levels, respectively. Additionally, type 2 Modic change (black arrowheads) is observed at L4/5 (A, B). In T2-weighted axial (C) MR image from L4/5 level, moderate facet degeneration (white arrowheads) is present. The coronal STIR MR image reveals the typical Castellvi IIb lumbosacral anatomy (white asterisks).

Figure 4. MR images of a subject with Castellvi IIIb lumbosacral transitional vertebra and associated degenerative changes. In T2-weighted (A) and T1-weighted (B) sagittal MR images, Pfirrmann grade III disc degeneration (white arrows) is seen at L4/5 level. In T2-weighted axial (C) MR image from L4/5 level, moderate facet degeneration (white arrowheads) is present. The coronal STIR MR image shows the typical Castellvi IIIb lumbosacral anatomy (white asterisks).

Table 1. Study population characteristics and the prevalences of Castellvi types and prolonged low back pain (LBP).

Variable	**LSTV cases, N (%)**	**Controls, N (%)**	**P-value**
Sex			**0.045**
Male	190 (61.9)	49 (49.5)	
Female	117 (38.1)	50 (50.5)	
Age, years (mean, SD)	47.3 (0.80)	46.8 (0.56)	**<0.001**
Prevalence of LSTV	310 (21.1)		
Castellvi I	194 (62.6)		
Castellvi II	77 (24.8)		
Castellvi III	28 (9.0)		
Castellvi IV	11 (3.5)		
Prolonged LBP	80 (26.5)	20 (20.2)	0.21
Castellvi I	48 (25.7)		0.30
Castellvi II	16 (21.1)		0.89
Castellvi III	13 (46.4)		**0.005**
Castellvi IV	3 (27.3)		0.70

Table 2. Association of Castellvi types with prolonged low back pain in multivariate analyses.

Variable	Coefficient	Standard Error	Wald chi2	P-value	OR	95% CI
Castellvi I	0.368	0.322	1.308	0.253	1.445	0.769-2.715
Castellvi II	0.322	0.424	0.575	0.448	1.379	0.601-3.166
Castellvi III	**2.184**	**0.634**	**11.856**	**0.001**	**8.877**	**2.562-30.766**
Castellvi IV	0.478	0.771	0.385	0.535	1.614	0.356-7.312

Multinomial logistic regression analysis was performed using age, sex, disc degeneration sum and Castellvi type. The control group was used as a reference variable. CI=confidence interval, OR=odds ratio

Table 3. The prevalence of degenerative findings on MRI in controls and in Castellvi groups.

Variable	**Controls**	**Castellvi I**	**Castellvi II**	**Castellvi III**	**Castellvi IV**
	N (%)	N (%)	N (%)	N (%)	N (%)
DD[1] L3/4	3 (3.0)	8 (4.1)	10 (13.0)	2 (7.1)	1 (9.1)
DD[1] L4/5	16 (16.0)	26 (13.5)	34 (44.2)	16 (57.1)	8 (72.7)
DD[1] L5/S1	34 (34.3)	62 (32.1)	6 (7.8)	1 (3.6)	1 (9.1)
FD[2] L3/4	41 (41.0)	154 (79.4)	67 (87.0)	26 (92.9)	10 (90.9)
FD[2] L4/5	73 (73.0)	180 (92.8)	72 (93.5)	28 (100.0)	11 (100.0)
FD[2] L5/S1	69 (69.0)	173 (89.2)	36 (46.8)	4 (14.3)	1 (9.1)
Foraminal stenosis[3] L3/4	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Foraminal stenosis[3] L4/5	0 (0.0)	2 (1.0)	3 (3.9)	2 (7.1)	0 (0.0)
Foraminal stenosis[3] L5/S1	5 (5.0)	3 (1.5)	1 (1.3)	0 (0.0)	0 (0.0)
Central stenosis[4] L3/4	1 (1.0)	1 (0.5)	1 (1.3)	0 (0.0)	0 (0.0)
Central stenosis[4] L4/5	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Central stenosis[4] L5/S1	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Recess stenosis L3/4	4 (4.0)	2 (1.0)	5 (6.6)	2 (7.1)	0 (0.0)
Recess stenosis L4/5	12 (12.0)	19 (9.8)	14 (18.2)	6 (21.4)	2 (18.2)
Recess stenosis L5/S1	2 (2.0)	10 (5.2)	1 (1.3)	0 (0.0)	0 (0.0)
Pro-/extrusion[5] L3/4	22 (22.0)	66 (34.0)	40 (51.9)	21 (75.0)	5 (45.5)
Pro-/extrusion[5] L4/5	60 (60.0)	137 (70.6)	66 (85.7)	23 (82.1)	10 (90.9)
Pro-/extrusion[5] L5/S1	61 (61.0)	141 (72.7)	11 (14.3)	0 (0.0)	1 (9.1)
Any MC L3/4	7 (7.0)	17 (8.8)	12 (15.6)	3 (10.7)	2 (18.2)
Any MC L4/5	24 (24.0)	47 (24.4)	40 (51.9)	13 (46.4)	10 (90.9)

Any MC L5/S1	47 (47.0)	78 (40.4)	6 (7.8)	1 (3.6)	0 (0.0)
MC1[6] L3/4	2 (2.0)	6 (3.1)	10 (13.0)	2 (7.1)	1 (9.1)
MC1[6] L4/5	11 (11.0)	26 (13.5)	22 (28.6)	9 (32.1)	3 (27.3)
MC1[6] L5/S1	29 (29.0)	46 (23.8)	2 (2.6)	0 (0.0)	0 (0.0)

[1]Disc degeneration (DD) is classified as severe if the Pfirrmann grade is 4 or 5
[2]Facet degeneration (FD) is classified as moderate/severe if the grade is 2 or 3
[3]Foraminal stenosis is classified as moderate/severe if the grade is 2 or 3
[4]Central stenosis is classified as moderate/severe if the grade is 2 or 3
[5]Protrusion or extrusion
[6]MC1 and MC1/2 are classified as MC1

Table 4. Significant associations of Castellvi types with degenerative findings on MRI in multivariate analyses.

Variable	Coefficient	Standard Error	Wald chi2	P-value	OR	95% CI
DD[1] L4/5						
Castellvi II	1.358	0.396	11.749	0.001	3.887	1.788-8.449
Castellvi III	1.992	0.542	13.486	<0.001	7.330	2.532-21.224
Castellvi IV	2.578	0.740	12.141	<0.001	13.170	3.089-56.147
DD[1] L5/S1						
Castellvi II	-1.973	0.533	13.706	<0.001	0.139	0.049-0.395
Castellvi III	-2.827	1.081	6.845	0.009	0.059	0.007-0.492
FD[2] L3/4						
Castellvi I	1.485	0.283	27.540	<0.001	4.417	2.536-7.693
Castellvi II	2.076	0.425	23.865	<0.001	7.971	3.466-18.330
Castellvi III	2.616	0.787	11.053	0.001	13.675	2.926-63.913
Castellvi IV	2.531	1.078	5.515	0.019	12.563	1.520-103.837
FD[2] L4/5						
Castellvi I	1.211	0.380	10.175	0.001	3.356	1.595-7.061
Castellvi II	1.625	0.563	8.335	0.004	5.081	1.685-15.318
FD[2] L5/S1						
Castellvi I	1.030	0.333	9.558	0.002	2.802	1.458-5.383
Castellvi II	-0.856	0.348	6.046	0.014	0.425	0.215-0.841
Castellvi III	-2.532	0.617	16.860	<0.001	0.079	0.024-0.266
Castellvi IV	-3.070	1.078	8.114	0.004	0.046	0.006-0.384

Pro-/extrusion[3] L3/4						
Castellvi II	0.932	0.365	6.527	0.011	2.541	1.242-5.196
Castellvi III	1.884	0.533	12.505	<0.001	6.581	2.316-18.701
Pro-/extrusion[3] L4/5						
Castellvi II	1.251	0.414	9.142	0.002	3.494	1.553-7.862
Pro-/extrusion[3] L5/S1						
Castellvi II	-2.222	0.423	27.559	<0.001	0.108	0.047-0.248
Castellvi III	-20.141	0.000				
Castellvi IV	-2.650	1.079	6.031	0.014	0.071	0.009-0.586
Any MC L4/5						
Castellvi II	1.231	0.367	11.241	0.001	3.423	1.667-7.028
Castellvi IV	3.500	1.086	10.389	0.001	33.102	3.942-278.004
Any MC L5/S1						
Castellvi II	-2.533	0.526	23.151	<0.001	0.079	0.028-0.223
Castellvi III	-3.460	1.082	10.224	0.001	0.031	0.004-0.262
MC1[4] L3/4						
Castellvi II	1.855	0.864	4.608	0.032	6.390	1.175-34.747
MC1[4] L4/5						
Castellvi II	1.071	0.451	5.623	0.018	2.917	1.204-7.068
MC1[4] L5/S1						
Castellvi II	-3.307	0.859	14.825	<0.001	0.037	0.007-0.197

Multinomial logistic regression analysis was performed using age, sex and Castellvi type. The control group was used as a reference variable.
CI=confidence interval, OR=odds ratio
[1]Disc degeneration (DD) is classified as severe if the Pfirrmann grade is 4 or 5

[2]Facet degeneration (FD) is classified as moderate/severe if the grade is 2 or 3
[3]Protrusion or extrusion
[4]MC1 and MC1/2 are classified as MC1