MRI Characteristics at a Mean of Thirteen Years After Lumbar Disc Herniation Surgery in Adolescents

A Case-Control Study

Tobias Lagerbäck, MD, PhD, Gránit Kastrati, MSc, Hans Möller, MD, PhD, Karin Jensen, PhD, AssocProf., Mikael Skorpil, MD, PhD, and Paul Gerdhem, MD, PhD, Professor

Investigation performed at Karolinska Institutet and Karolinska University Hospital, Stockholm, Sweden

Background: The purpose of this study was to describe the prevalence of lumbar spine degeneration in adult individuals who had undergone lumbar disc herniation surgery during adolescence.

Methods: Twenty-three individuals who had been surgically treated for lumbar disc herniation as adolescents (≤18 years of age) participated in this study at a mean of 13.8 years (range, 8.6 to 20.4 years) after the surgery; they were matched for age and sex to 23 controls without any known previous disc herniation or spinal surgery. Magnetic resonance imaging included sagittal T1-weighted, T2-weighted, and short tau inversion recovery (STIR) sequences of the lumbar spine. Disc degeneration was assessed with the Pfirrmann grading system. Changes in the vertebral end plate and body were assessed according to Modic changes and total end plate (TEP) score. Patient-reported outcome measures included the Oswestry Disability Index, a visual analog scale (VAS) for leg and back pain, the EuroQol-5 Dimension-3 Level (EQ-5D-3L) questionnaire, and the mental and physical component summary scores of the Short Form (SF)-36. Statistical analyses were made with the chi-square test and the Welch-Satterthwaite t test.

Results: Compared with the controls, the cases that underwent surgery had a higher prevalence of the following: severe degeneration according to the Pfirrmann grading system at the L4-L5 (p = 0.007) and L5-S1 (p = 0.002) levels, Modic changes at the L4-L5 (p = 0.022) and L5-S1 (p = 0.026) levels, and a TEP score of ≥6 at the L5-S1 level (p = 0.001). The surgical cases had a significantly worse patient-reported outcome compared with the controls (all p ≤ 0.010), with the exception of the VAS for leg pain (p = 0.093) and the mental component summary score of the SF-36 (p = 0.844).

Conclusions: Lumbar disc herniation surgery that was performed during adolescence was associated with more frequent lumbar spine degeneration and lower health-related quality of life in adulthood when compared with the control group.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

L umbar disc herniation surgery in adolescents is rare, accounting for 0.6% to 2.5% of all lumbar disc herniation surgeries[1-4]. The prevalence of repeated lumbar spine surgery after surgery for lumbar disc herniation during adolescence is 10% to 28%, which is similar to the prevalence in adults[3,5-7]. This suggests that the occurrence of lumbar disc herniation during adolescence is a sign of early progressive spinal degeneration[5,8-12].

Lee et al. reported that all 15 of their adolescent patients who underwent surgery because of lumbar disc herniation showed histological signs of disc degeneration[4]. Erkintalo et al. found degeneration to be more frequent in adolescents with low back pain compared with asymptomatic subjects[13]. In adults, increased degeneration at 5 years after surgery for lumbar disc herniation has been reported, but it is unclear if this is the result of the disc herniation, the surgery, or patient age[14].

In this study, we included individuals who underwent surgery for lumbar disc herniation at ≤18 years of age and controls to describe any differences (1) in lumbar spine degeneration at long-term follow-up and (2) in patient-reported outcome measures (PROMs).

Materials and Methods

Study Cohort

The flowchart that was used for this study is shown in Figure 1. The study cohort was derived from previous studies based on

the Swedish spine register (Swespine), including 151 participants who underwent surgery at ≤18 years of age, because of persistent leg pain, that included removal of a lumbar disc hernia and any sequestration[1,5]. Of the 151 cases, 40 had a current residence in Stockholm County and were contacted by mail regarding participation in the study. Of those 40 cases, 23 participated; 11 cases did not reply despite 3 attempts, 1 individual declined to participate, 3 cases had relative contraindications for magnetic resonance imaging (MRI) (1 individual was claustrophobic and 2 were pregnant), and 2 cases were unavailable for a scheduled MRI during the study period.

The participants in the control group were selected through advertisement in the Karolinska Institutet, the Karolinska University Hospital, and 3 private companies (1 in the mechanical industry and 2 in telecommunications). The only exclusion criteria were known previous disc herniation and spinal surgery. In total, 58 individuals replied. For each case that underwent surgery, 1 control was matched for age, sex, and, if possible, current occupation.

MRI

Imaging data were acquired between May 2019 and January 2020, with identical sequences for all 46 participants with use of a 3.0-T MRI scanner (Discovery MR750; GE Healthcare) at the MR Research Center in the Karolinska Institutet in Stockholm, Sweden. Imaging included sagittal T1-weighted, T2-weighted, and short tau inversion recovery (STIR) sequences of the lumbar spine.

MRI Analyses

The prevalence of disc degeneration was assessed with the morphologic and semiquantitative Pfirrmann grading system, and each segment received a grade from 1 to 5[15]. Grading for each level in each group is reported. For analysis, the Pfirrmann grading was dichotomized as no to moderate degenerative changes (grades 1, 2, and 3) or severe degenerative changes (grades 4 and 5)[16].

Changes in the vertebral end plate and body were assessed according to Modic et al.[17] For analysis, the Modic changes were dichotomized for each segment (above and below each disc) as absent (grade 0) or present (grades 1, 2, and 3).

In accordance with Rajasekaran et al., end plate defects were assessed and scored from 1 to 6 and converted into the total end plate (TEP) score for each segment (the sum of the scores above and below each disc; range, 2 to 12)[16]. End plate score is classified according to the severity of end plate damage: 1 = no end plate defects and a uniform symmetrically concave hypointense band, 2 = focal thinning of the end plate but no breaks, 3 = focal disc-marrow contact regions with normal contour of the end plate, 4 = end plate defect up to 25% of the width and typical depression, 5 = end plate defect up to 50% of the width and typical depression, and 6 = complete end plate damage with end plate irregularity or sclerosis[16]. For analysis, the TEP scores were dichotomized as <6 or ≥6[16].

The planned measures had sufficient intra- and interobserver reliability[16,18,19] and were analyzed by 1 of the authors (M.S.), an experienced radiologist. To reduce possible bias, the
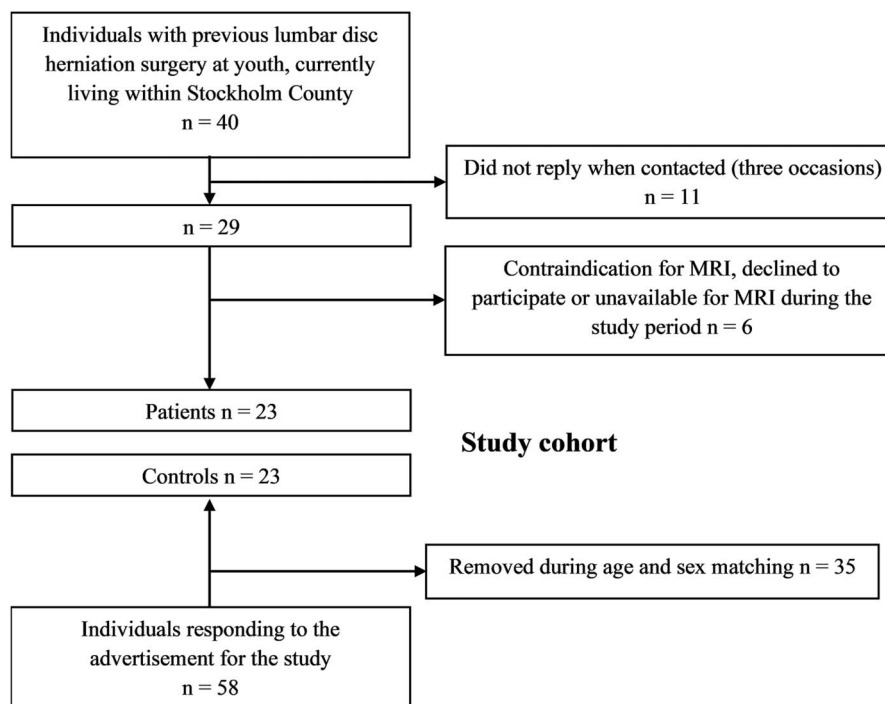

Fig. 1
Flowchart of the participants in the study.

analysis was blinded, and the examinations were presented in random order without any information on age, sex, and group (i.e., surgical cases or those in the control group).

Patient Data and Questionnaire

Preoperative data and data on additional surgery were collected from Swespine and the participant's medical records. The mean age at surgery was 17.5 years (range, 14.6 to 18.6 years), and the mean time from surgery to the follow-up MRI examination was 13.8 years (range, 8.6 to 20.4 years). Among the surgical patients, 7 (30%) underwent surgery because of a lumbar disc herniation at the L4-L5 level, and 16 (70%) underwent surgery because of a lumbar disc herniation at the L5-S1 level. At the time of admission for surgery, 1 patient was a smoker. Fourteen patients had undergone only the index discectomy. Seven patients had undergone additional surgery at the index level: discectomy (n = 4), decompression (n = 1), discectomy and later decompression (n = 1), and discectomy and later fusion (n = 1). Two patients had undergone surgery at an adjacent level: discectomy (n = 1) and discectomy with a later repeated discectomy at the adjacent level (n = 1). Degenerative changes were not assessed for the operated level in the patient who had undergone fusion.

All 46 of the participants answered the same questionnaire at the time of the MRI examination. The self-assessed questionnaire included questions about anthropometrics,

physical activity, smoking habits, occupational strain, and PROMs.

The International Physical Activity Questionnaire-Short Form (IPAQ-SF) was used to assess physical activity[20]. Activity at 3 different levels (vigorous, moderate, and walking), which was performed for at least 10 minutes during the 7 days prior to the questionnaire, was recorded[20]. As per the protocol for the IPAQ-SF guidelines regarding data processing, activities that exceeded 180 minutes per day were coded as 180 minutes. Activity level and metabolic equivalent of task (MET) values (minutes per week) were calculated[21].

Occupational strain was recorded according to 4 levels of activity: a predominantly sedentary occupation, sitting or standing with some walking, walking with some handling of material, and heavy manual work[22].

The PROMs included the back-specific Oswestry Disability Index (ODI, version 2.1), with scores ranging from 0 (no disability) to 100 (maximum disability)[23]; leg and back pain that was measured by a 100-mm visual analog scale (VAS), with scores ranging from 0 (no pain) to 100 (maximum pain)[24]; the EuroQol-5 Dimension-3 Level (EQ-5D-3L) quality-of-life index according to the British tariff (UK-TTO), with scores ranging from -0.59 (worst possible health) to 1.00 (perfect health)[25]; the mental component summary (MCS) and physical component summary (PCS) scores of the Short Form (SF)-36, ranging from 0 (poorest

TABLE I Patient Characteristics at the Time of MRI Examination for Both Groups*			
	Surgery	Control	P Value
Age (yr)	31.3 (29.8-32.9)	31.6 (30.1-33.2)	0.762
Height (cm)	177 (172-181)	174 (171-177)	0.324
BMI (kg/m²)	24.0 (22.5-25.5)	23.9 (22.7-25.2)	0.934
MET (minutes weekly)	2910 (2283-3537)	2867 (2248-3485)	0.919
Activity level			0.974
Low	1 (5%)	1 (5%)	
Moderate	7 (32%)	6 (29%)	
High	14 (64%)	14 (67%)	
Occupational strain			0.727
Predominantly sedentary work	14 (61%)	15 (71%)	
Sitting or standing with some walking	8 (35%)	5 (24%)	
Walking with some handling of material	1 (4%)	1 (5%)	
Heavy manual work	0 (0%)	0 (0%)	
Smoking status			0.746
Yes	2 (9%)	1 (4%)	
Previous smoker	4 (17%)	3 (13%)	
No	17 (74%)	19 (83%)	
Pack-years, in smokers + previous smokers†	2.9 (0.0-5.8)	1.6 (−0.8-4.1)	0.378

*Data are given as the mean (95% CI) or number (% of the total responses for each question). P values are given for the Pearson chi-square test or the Welch-Satterthwaite t test for the differences between the 2 groups. The numbers do not always correspond to the group numbers because of missing data. †Pack-years were calculated as (number of cigarettes per day) × (years smoking)/20 (20 is 1 pack of cigarettes).

health) to 100 (best health)[26]; and satisfaction and global assessment of those who underwent surgery.

Statistics

Data are presented as the mean and 95% confidence interval of the mean (95% CI) or the number and percentage. The Welch-Satterthwaite t test was used for continuous variables, and the Pearson chi-square test was used for dichotomous variables. All analyses were done using SPSS software (version 26; IBM). When data were missing, cases were excluded from analyses involving those variables. A p value of 0.05 was considered significant.

Power Analysis

The prevalence of disc degeneration after lumbar disc herniation surgery that was performed during adolescence is unknown. Using a grading system in which the limit for disc degeneration corresponds to an approximate Pfirrmann grade of ≥3, the prevalence of disc degeneration has been reported to be 58% in 18-year-olds with low back pain and 26% in 18-year-olds without low back pain[13]. Additionally, Lee et al. found that 73% of adolescents who underwent surgery because of lumbar disc herniation showed marked histological signs of disc degeneration[4]. Therefore, we hypothesized that, at a mean age of approximately 30 years, the group of individuals who had undergone surgery would have a prevalence of severe degenerative change (Pfirrmann grades 4 to 5) of 70%, and the control group would have a prevalence of severe degenerative change of 30%. With 80% power and a confidence level of 95%, 21 individuals were needed in each group.

Study Preparation and Ethics

This study was prepared in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement for case-control studies[27]. Approval of this study was obtained from the Ethical Review Board in Stockholm (numbers 2018/299-31/1 and 2019-01713). All of the participants in both groups provided signed informed consent before the MRI examination and completion of the questionnaire.

Results

At the time of the MRI examination, there were no significant differences between the cases that underwent surgery
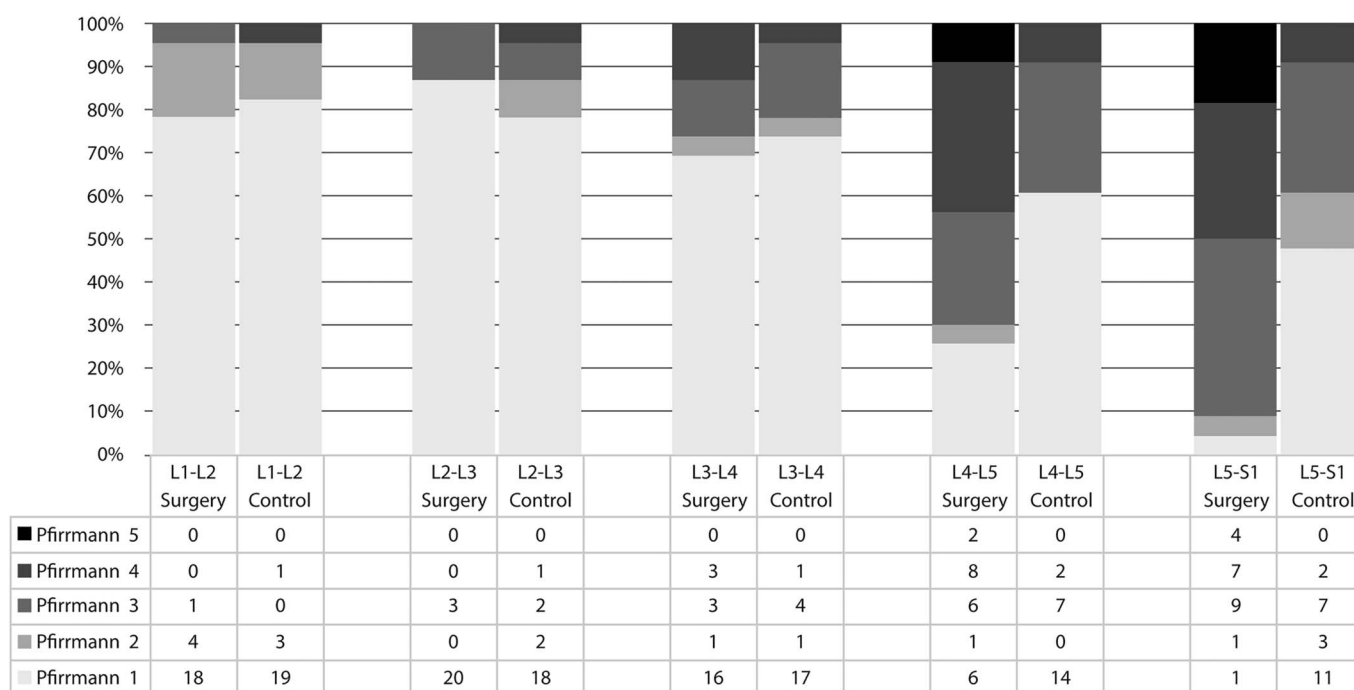

Fig. 2

Pfirrmann grading for each lumbar disc level. Pfirrmann grading for the L5-S1 level was not assessed in 1 of the cases because of fusion of the segment. The grades range from 1 (homogeneous disc with bright hyperintense white signal intensity and normal disc height [no degeneration]) to 5 (inhomogeneous disc with a hypointense black signal intensity, no difference between the nucleus pulposus and the anulus fibrosus, and a collapsed disc space [severely degenerated]).

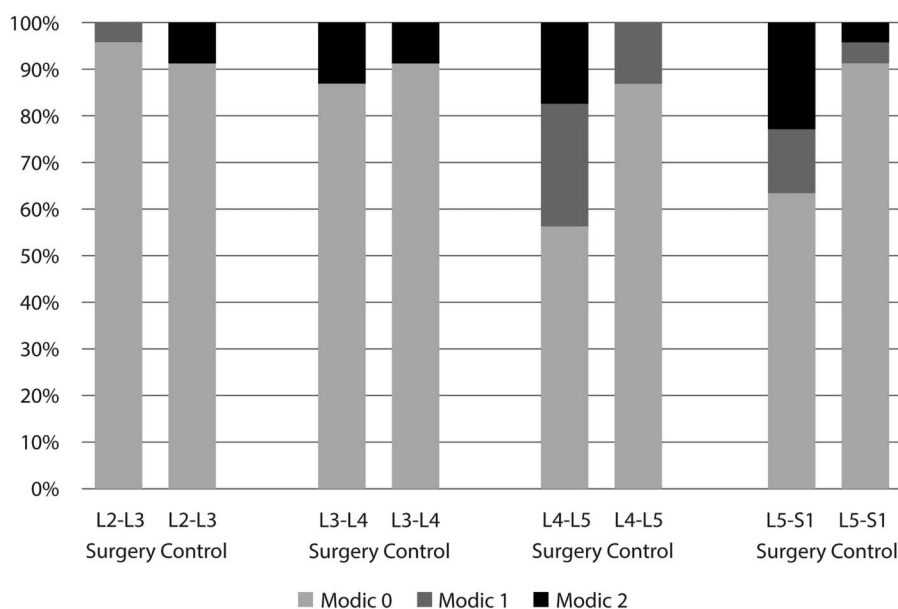|	L1-L2 Surgery	L1-L2 Control		L2-L3 Surgery	L2-L3 Control		L3-L4 Surgery	L3-L4 Control		L4-L5 Surgery	L4-L5 Control		L5-S1 Surgery	L5-S1 Control
■ Pfirrmann 5	0	0		0	0		0	0		2	0		4	0
■ Pfirrmann 4	0	1		0	1		3	1		8	2		7	2
■ Pfirrmann 3	1	0		3	2		3	4		6	7		9	7
■ Pfirrmann 2	4	3		0	2		1	1		1	0		1	3
■ Pfirrmann 1	18	19		20	18		16	17		6	14		1	11

Fig. 3

Modic changes (vertebral bone marrow changes at the end plates) for each segment. The type of Modic change is set by the highest value in the segment. None of the individuals had type-3 Modic changes. None of the individuals had Modic changes at the L1-L2 level. Modic changes at the L5-S1 level were not assessed in 1 of the cases because of fusion of the segment. Modic 0 = no changes, Modic 1 = edema, and Modic 2 = fat replacement.

and the controls regarding age, height, body mass index (BMI), MET (minutes per week), activity level, occupational strain, and smoking status (Table I).

Degenerative Signs
The Pfirrmann grading for each level is shown in Figure 2. When comparing the groups for no to moderate degeneration versus severe degeneration, there were no significant differences at the L1-L2, L2-L3, and L3-L4 levels (p ≥ 0.295 for all). A higher prevalence of severe degeneration was seen in the surgical group compared with the control group at the L4-L5 (p = 0.007) and L5-S1 (p = 0.002) levels.

Compared with the control group, the surgical group had a similar prevalence of Modic changes at the L1-L2, L2-L3, and L3-L4 (p ≥ 0.550 for all) levels, but a higher prevalence of

Modic changes at the L4-L5 (p = 0.022) and L5-S1 (p = 0.026) levels (Fig. 3).

The dichotomized TEP scores for each group are shown in Table II. There were significantly more individuals with a TEP score of ≥6 at the L5-S1 level in the surgical group compared with the control group (p = 0.001). No other significant differences were seen regarding TEP scores.

PROMs
The PROMs are shown in Table III. Among the surgically treated patients, 22 (96%) were satisfied with their surgery and 1 (4%) was uncertain. For global assessment of leg pain, 9 (39%) were pain-free, 12 (52%) were much improved, and 2 (9%) were somewhat improved. The corresponding numbers for global assessment of back pain were 5 (23%), 14 (64%), and 3 (14%), respectively. Compared with the control group, the surgical group had more disability according to the ODI (12 vs. 1, p < 0.001), more back pain according to the VAS (18 vs. 3, p = 0.002), lower quality of life according to the EQ-5D-3L (0.83 vs. 0.94, p = 0.010), and lower physical function according to the SF-36 PCS (50 vs. 56, p < 0.001). There were no significant differences between the groups for the VAS leg pain (p = 0.093) and the SF-36 MCS (p = 0.844).

Analysis of the Non-Responders
In an analysis of the non-responders, we compared the baseline and short-term outcome data from Swespine for the surgical cases that were included in this study with the surgical cases that were contacted but did not participate. The comparison included anthropometrics, surgical level, the duration of leg and back pain, smoking status at admission, additional lumbar

TABLE II TEP Score of ≥6 According to Level*			
Level	Cases	Controls	P Value
L1-L2	3 (13%)	1 (4%)	0.295
L2-L3	1 (4%)	2 (9%)	0.550
L3-L4	3 (13%)	3 (13%)	1.0
L4-L5	10 (43%)	4 (17%)	0.055
L5-S1	13 (59%)	3 (13%)	0.001

*Data are given as the number (%). Grading for the L5-S1 level was not assessed in 1 patient because of fusion of the segment. P values are given for the Pearson chi-square test for the differences between the 2 groups.

TABLE III PROMs at the Time of MRI Examination*			
	Surgery	Control	P Value
Satisfaction			
Satisfied	22 (96%)		
Uncertain	1 (4%)		
Unsatisfied	0		
Global assessment of leg pain			
Pain-free	9 (39%)		
Much improved	12 (52%)		
Somewhat improved	2 (9%)		
Global assessment of back pain			
Pain-free	5 (23%)		
Much improved	14 (64%)		
Somewhat improved	3 (14%)		
ODI	12 (8-16)	1 (0-3)	<0.001
VAS leg	8 (3-13)	3 (1-6)	0.093
VAS back	18 (9-27)	3 (1-5)	0.002
EQ-5D-3L	0.83 (0.75-0.91)	0.94 (0.91-0.98)	0.010
SF-36 MCS	49 (46-52)	49 (46-53)	0.844
SF-36 PCS	50 (47-53)	56 (55-58)	<0.001

*Data are given as the mean (95% CI) or number (% of the total responses for each question). P values are given for the Pearson chi-square test or the Welch-Satterthwaite t test for the differences between the 2 groups. The numbers do not always correspond to the group numbers because of missing data.

spine surgeries, the ODI, the VAS score for leg and back pain, the EQ-5D-3L, the SF-36 MCS and PCS, and participant satisfaction and global assessment of leg and back pain (see Appendix). There were no significant differences between the groups.

Discussion

At a mean of 13.8 years after lumbar disc herniation surgery during adolescence, the cases that underwent surgery had a higher prevalence of degenerative signs in the 2 lower lumbar levels compared with the controls. Most of the surgical cases experienced an improvement according to the global assessment of leg and back pain and a high percentage were satisfied with their treatment but, in general, the participants who underwent surgery had significantly worse PROMs compared with the controls.

Disc degeneration has been discussed as a cause of lumbar back pain[28-32]. The Pfirrmann grade, the presence of Modic changes, and end plate score have been found to be strongly associated with each other, and a higher end plate score has been identified as an independent risk factor for the progression of Pfirrmann grade and Modic changes[19,33,34]. Furthermore, end plate defects have been suggested as the initiating factor for the cascade of degeneration as indicated by the Pfirrmann grade and Modic changes, with Modic changes being the last to occur on MRI[19,33,34]. There were significantly more individuals with a TEP score of ≥6 at the L5-S1 level and a trend toward a higher TEP score (≥6) at the L4-L5 level

among the surgical cases when compared with the control group. In line with the suggested associations, we also found a significantly higher prevalence of severe degeneration according to Pfirrmann grade and the presence of Modic changes in the same levels among surgical cases when compared with the control group.

Using a grading system similar to the Pfirrmann grade, Bendix et al. found a higher prevalence of low back pain in subjects with severe degeneration compared with subjects with moderate degeneration and normal discs[28]. They did not find any difference between subjects with moderate degeneration and subjects with normal discs. In the present study, the control group had no individuals with a Pfirrmann grade of 5, and at the L4-L5 and L5-S1 levels, a Pfirrmann grade of 4 or 5 was approximately 5 times more common in the surgical participants. Consistent with the findings of Bendix et al., we also observed more back pain in the surgical participants.

The prevalence of Modic changes has been associated with low back pain, but reports are conflicting[30-32,35,36]. Furthermore, Modic changes are also found in asymptomatic individuals, and the presence of Modic changes is, to some degree, dependent on age: there is a higher presence of Modic changes with increasing age until the 70s[35,37,38]. In the reviews by Ract et al. and Rahyussalim et al., type-1 Modic changes seemed to be relatively correlated with low back pain[31,35]. We found a larger proportion of type-1 Modic changes at the L4-L5 level and, especially, the L5-S1 level in the surgical cases compared with the control

group. In combination with the findings for Pfirrmann grading as described above, this could further explain the relationship with greater back pain in the surgical cases.

In agreement with the higher prevalence of degeneration among adolescents with lumbar back pain as described by Erkintalo et al., we found a higher prevalence of degeneration among individuals who were treated surgically for a lumbar disc herniation during adolescence compared with age and sex-matched controls[13]. The differences were situated in the 2 lower levels, which were also the levels of surgery.

Whether it is the lumbar disc herniation, the degeneration at baseline, or the surgery that is performed that causes a higher prevalence of degeneration remains unclear. In a randomized controlled trial, no differences in patient-reported outcome were found at the 2-year follow-up between patients who were treated surgically and those who were treated nonoperatively for lumbar disc herniation[39]. To delineate this further in adolescents, future studies should include baseline MRI, a control group without disc herniation, and a group that is treated nonoperatively for lumbar disc herniation.

Among adults, lumbar disc herniation is considered to be part of degeneration, and smoking, obesity, height, heavy manual labor, anxiety and depression, a history of lower back problems, and male sex have been reported as factors that are associated with disc-related sciatica[40-42]. The examined risk factors did not differ between the groups in the present study. However, we cannot exclude that there are unknown variables that could have an impact on the prevalence of degeneration.

The inferior PROM results among those who underwent surgery compared with those in the control group are in line with what has previously been observed with surgically treated lumbar conditions[1,43]. Despite worse patient-reported outcomes, the participants who underwent surgery had a high level of satisfaction and improvement according to the global assessment for leg and back pain, which indicates that surgery is a feasible option. The cases in this study had a high prevalence of additional lumbar spine surgery compared with the national average in the same age group[5]. However, there were no differences in patient characteristics and PROMs at baseline and short-term follow-up between the cases that participated in the study and the individuals who did not participate, suggesting a more liberal view on additional surgery in the Stockholm area rather than a selection bias. Nevertheless, the relatively high prevalence of additional lumbar spine surgery could have contributed to the findings in this study.

The main strengths of this study were the long follow-up time for the age group and the diagnosis in question, the use of matched controls, the fulfillment of the preplanned power analysis, the blinded MRI evaluation, the use of recognized MRI measures with sufficient intra- and interobserver reliability, and the use of validated outcome instruments[16,18,19]. The main limitations were the lack of preoperative MRI and the absence of a control group that was treated nonoperatively for lumbar disc herniation for comparison. Even though MRI assessments were blinded, whether a participant was treated surgically or in the control group may have been assumed because of the nature of the condition.

Conclusions

Adolescents who undergo surgery for lumbar disc herniation have a higher prevalence of degenerative signs in the 2 lower segments of the lumbar spine in adulthood compared with individuals without any known previous disc herniation or spinal surgery. Additional studies are needed to determine if this is a result of the lumbar disc herniation itself, degeneration at baseline, or the surgery that is performed. Even though the rate of satisfaction among the participants who undergo surgery is high, these cases experience slightly more back disability, more back pain, and a lower quality of life more than a decade after the surgery when compared with individuals in the control group.

Appendix

(eA) Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJSOA/A338). ∎

Tobias Lagerbäck, MD, PhD[1,2]
Gránit Kastrati, MSc[3]
Hans Möller, MD, PhD[1,4]
Karin Jensen, PhD, AssocProf.[3]
Mikael Skorpil, MD, PhD[5,6]
Paul Gerdhem, MD, PhD, Professor[1,2]

[1]Department of Clinical Science, Intervention and Technology, Division of Orthopedics and Biotechnology, Karolinska Institutet, Stockholm, Sweden

[2]Department of Reconstructive Orthopedics, Karolinska University Hospital, Stockholm, Sweden

[3]Department of Clinical Neuroscience, Division of Neuro, Karolinska Institutet, Stockholm, Sweden

[4]Center for Spine Surgery in Stockholm, Södra Fiskartorpsvägen, Stockholm, Sweden

[5]Department of Molecular Medicine and Surgery, Karolinska Institutet, Stockholm, Sweden

[6]Department of Neuroradiology, Karolinska University Hospital, Stockholm, Sweden

Email for corresponding author: tobias.lagerback@ki.se

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