

The characteristics of lumbar paraspinal muscle degeneration based on the Roussouly classification: a retrospective study

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Abstract

Background:To analyse the characteristics of lumbar paraspinal muscle degeneration in individuals with different Roussouly types. **Methods:** Eighty patients (20 patients for each Roussouly type) with degenerative lumbar disease were retrospectively enrolled from January 2017 to February 2018. The cross-sectional area (CSA) and percentage of fat infiltration (FI) of the paraspinal muscles at the L1-S1 levels were measured using T2-weighted axial MRI and ImageJ software. The measured data were analysed with independent samples t-tests. **Results:** Degeneration of the paraspinal muscles of the upper lumbar region was significantly severer in Type 1 than in Type 3, the degrees of paraspinal muscle degeneration of Type 2 appeared to be more evenly distributed in all segments than Type 3, and Type 4 showed severer degeneration in L5-S1 than Type 3. **Conclusion:** The degree of paraspinal muscle degeneration in each segment was different across the four Roussouly types, but the degrees of degeneration were consistent with the characteristics of degenerative disease within each type.

Background

Lumbar degeneration is the pathophysiological process of ageing in lumbar tissues, including intervertebral discs, zygapophyseal joints, ligamentum flavum, etc. The mobility and stability of the lumbar spine may be affected by severe degenerative changes. The paraspinal muscles, the effectors of the reflex arc for postural control of the trunk, play a large role in completing movements and maintaining the stability of the spine. In addition to the degeneration of the lumbar tissues, degeneration of the paraspinal muscles also occurs due to the ageing process. Correlations between these two processes have been indicated.

Kang et al found more severe paraspinal muscle degeneration in patients with degenerative kyphosis than in patients with chronic low back pain ^[1]. In a study by Lee et al, significant fat infiltration of the back muscles was found in patients with degenerative lumbar flat back syndrome ^[2]. Guo Xuchao et al assessed paraspinal muscle degeneration in patients with degenerative lumbar instability and normal controls and found significant muscle degeneration in patients with lumbar instability ^[3]. The study by Mitsuru Yagi et al showed different degrees of muscle degeneration between the concave side and convex side of degenerative scoliosis patients ^[4].

Correlations have been shown between the degeneration of the paraspinal muscles and lumbar morphology. However, there are no studies on paraspinal muscle degeneration based on different lumbar spine types. The purpose of this study was to identify the characteristics of the paraspinal muscles in individuals with different lumbar spine types based on the Roussouly classification by MRI evaluations.

Methods

Patients

Eighty patients who were at our institution between January 2016 and January 2018 and had diagnoses of lumbar stenosis were included (20 patients for each Roussouly type). The inclusion criteria were the following: 1) were aged between 50 and 75, 2) were diagnosed with lumbar stenosis, 3) had X-ray and MRI images that showed radiologic degeneration. The exclusion criteria were the following: 1) patients who underwent acupuncture or other therapies that can affect the back muscles, 2) patients with incomplete radiology data, 3) patients who had lumbar instability that was identified by dynamic lumbar X-ray, 4) patients with scoliosis, 5) patients with a history of a spine fracture, and 6) patients with a history of a tumour or other systemic disease. All methods of this experiment were in accordance with the relevant guidelines and regulations of the Helsinki Declaration. All experimental protocols were approved by the Research Ethics Committee of Huashan Hospital, Fudan University. Written informed consent was obtained from all the enrolled participants.

Radiology Examination

A lumbar spine X-ray scan, lumbar flexion and extension X-ray scans and a lumbar MRI scan were taken for all patients. All of the lumbar MRI scans were performed using a 1.5 T Signa Excite MRI machine (GE Healthcare, Milwaukee, WI, USA). The routine spin-echo sequence was used for scanning to obtain sagittal T1-weighted and T2-weighted images and axial T2-weighted images. For the axial T2-weighted images, the scanning plane was parallel to the anterior-posterior axis of the disc in the sagittal images. The scanned images were stored in the PACS system (Centricity 3.0, General Electric Medical System, Milwaukee, WI, USA), and the parameters were measured.

X-ray and MRI Measurements

Pelvic parameters, including the SS, LL, PT and PI, were collected from the lumbar X-ray image for every patient. Patients were divided into the different Roussouly classification types according to the pelvic parameters. The flexion and extension X-ray images were used to exclude patients with lumbar instability.

It has been reported that the main radiological features of paraspinal muscle degeneration are a muscle volume decrease and fat infiltration. On the basis of this finding, the CSA (cross-sectional area) and percentage of FI (fat infiltration) were measured for each patient. Five axial T2-weighted images of each disc layer between L1 and S1 were selected for measurement. The area of paraspinal muscles was regarded as the sum of the multifidus and erector spinae and was measured by ImageJ (Fig.1). The CSA of the layer was calculated as the mean value of the left and right sides of the paraspinal muscle area. The FI percentage was obtained using the threshold technique in ImageJ (Fig.2). Additionally, the ratio of the parameters of each layer and L4–5 were calculated for the purpose of learning the distribution of muscle degeneration.

Statistical analysis

Statistical analyses were performed using SPSS 21.0 (SPSS Inc., Chicago, IL, USA). An independent sample t-test was used for the comparison of the parameters between different Roussouly types. A p value of <0.05 was considered significant.

Results

Type 3 has been regarded as the standard type in the Roussouly classification. In this study, the CSA gradually increased from the L1–2 level, reached a maximum at the L4–5 level, and decreased at the L5-S1 level. The FI percentage increased from the L1–2 level and reached a maximum at the L5-S1 level. The parameters of type 3 were regarded as standard controls for comparison.

The L1–2/L4–5 FI and L2–3/L4–5 FI in type 1 (0.76 ± 0.19 and 0.83 ± 0.25) were significantly larger than those in type 3 (0.58 ± 0.18 and 0.65 ± 0.17). This result indicated that the paraspinal muscles at the L1–2 and L2–3 levels received relatively more fat infiltration in type 1 than in type 3. The other parameters showed no significant differences between type 1 and 3 (Table 1).

The L4–5 CSA and L5-S1 CSA in type 2 (19.2 ± 3.0 and 14.1 ± 3.7) were significantly smaller than those in type 3 (22.3 ± 3.7 and 18.7 ± 3.3). In addition, the L5-S1/L4–5 CSA was smaller in type 2 than in type 3. No other significant differences were found between type 2 and type 3 (Table 2).

The L5-S1/L4–5 FI was higher in type 4 (1.36 ± 0.19) than in type 3 (1.22 ± 0.22). The other parameters of type 4 appeared similar to those of type 3 (Table 3).

Discussion

Degeneration of the paraspinal muscles affects spine stability and induces lumbar degeneration in certain segments. The lumbar spine type can determine the magnitude of tension on the paraspinal muscles. Although the mechanism of paraspinal muscle degeneration remains unclear, the burden of tension is believed to be one important cause of the degeneration. High levels of tension can induce compensatory hypertrophy in the short term but atrophy and fatty infiltration in the long term. These features have been proven by MRI studies [5]. The risk factors of degeneration include age, race, job, and others; age is the most important factor among them. Atrophy of the paraspinal muscles occurs gradually during the ageing process, as they are skeletal muscles. Crawford et al studied people of different ages, who were aged 18 to 60, and found that the percentage of fat infiltration of the paraspinal muscles increased by 0.17% on average every year [6]. Kalichman et al found a positive correlation between the density of the paraspinal muscles and BMI [7]. In this study, we included individuals aged between 50 and 75. The patient characteristics of age and BMI are not statistically significantly different between the 4 morphology types.

The Roussouly classification is based on features of spine morphology, including the sacral slope (SS) and apex of lumbar lordosis [8]. The classification increases the understanding of the sagittal features, including the regional and global biomechanisms and degeneration of the spine, which helps to make better clinical decisions. As a result, the Roussouly classification has become one of the most widely used classification systems since 2005, when it was first reported. Many studies have proven the effects of the classification system on surgical decisions and outcomes [9,10,11]. In addition, studies have assessed the correlation between the morbidity of spine disorders and different Roussouly types. Mardare et al found more severe levels of intervertebral disc degeneration in type 1 and type 2 patients than in type 3 and type 4 patients [12]. Li Song et al retrospectively studied upper lumbar disc herniation patients and found that 48.3% of them were classified as type 1, which is a much higher percentage than that of normal people [13]. Similar results have been found by J bae et al [14]. A study by Lee et al indicated a higher rate of Roussouly type 2 in patients with degenerative lumbar flat back than in patients without degenerative lumbar flat back [2]. Type 4 has been associated with a higher rate of degenerative lumbar spondylolisthesis than the other classification types have [15,16]. Among all the studies, to the best of our knowledge, there have not been any reports about paraspinal muscle degeneration and the Roussouly classification.

In this study, we found that the paraspinal muscles at the L1–2 and L2–3 levels received relatively more fat infiltration in type 1 than in type 3. This finding may be attributed to the low apex at L5 in the lumbar lordosis region and large kyphosis in the thoracolumbar region in type 1. Based on these features, the end plates of the vertebrae make a large angle with the horizontal plane at L1–2 and L2–3, which are the transition regions of thoracolumbar kyphosis and lumbar lordosis. A larger angle leads to a larger shearing force on the intervertebral joints and paraspinal muscles at certain segments and increases the risk of degeneration of both the joints and muscles, which may explain the high rate of upper lumbar disc herniation (ULDH) in type 1.

Compared to type 3, type 2 showed almost equal degrees of degeneration in all the measured segments. A small amount of lumbar lordosis as in type 2 creates a straight spine, which casts more vertically directed tension on the paraspinal muscles than a type 3 spine. Similarly, a straight spine can increase the vertically directed force on the intervertebral discs, thus increasing the risk of early degeneration and even multilevel degeneration of the lumbar spine. Additionally, lumbar degeneration aggravates paraspinal muscle degeneration. As an example, the study by Lee indicated that patients with multiple segment degeneration and degenerative lumbar flat back syndrome were mostly categorized as type 2 [2].

There was a larger CSA and a higher percentage of FI at the L5-S1 segment in type 4 than in type 3. The reason for these differences may be that a large amount of lumbar lordosis makes the posterior space congested in the vertical dimension, leading to a large CSA. However, the large SS of type 4 leads to a large shearing force on the lumbosacral joint, which can induce degenerative spondylolisthesis and degeneration of the paraspinal muscles.

This study has limitations. First, degeneration of the paraspinal muscles was evaluated by MRI only, and histopathological evidence was not included. Second, the biomechanisms still need to be studied. Despite all the limitations, to the best of our knowledge, this study is the first to identify the characteristics of the paraspinal muscles in individuals with different Roussouly types.

Conclusion

In summary, atrophy and fatty infiltration reveal the degeneration of paraspinal muscles. The degree of paraspinal muscle degeneration in each segment was different across the four Roussouly types, but the degrees of degeneration were consistent with the characteristics of degenerative disease within each type.

Abbreviations

BMI: Body Mass Index

CSA: Cross-sectional Area

FI: Fat Infiltration

MRI: Magnetic Resonance Imaging

***PACS*: Picture archiving and Communication systems**

ULDH: Upper Lumbar Disc Herniation

Declarations

Ethics approval and consent to participate

The present study was approved by the Research Ethics Committee of Huashan Hospital, Fudan University. Informed consent obtained from each participant was written.

Consent for publication

Not applicable.

Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MXS carried out the design of the study. YS carried out the acquisitions of data, and drafted the manuscript. XGY also carried out the acquisitions of data, and revised the manuscript. ZF and XXL performed the statistical analysis. JJY and LFZ participated in the design of this study and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1 Comparison of lumbar paraspinal muscles between Roussouly type I and type III

	Type I	Type III	P value
Age	64.1±6.2	61.1±6.1	0.166
BMI	25.6±4.8	24.7±2.8	0.479
L1-2 CSA (cm ²)	18.3±4.3	19.1±3.2	0.539
L1-2 FI (%)	24.7±11.7	22.9±8.6	0.604
L2-3 CSA (cm ²)	19.1±3.9	19.9±3.1	0.533
L2-3 FI (%)	28.7±10.3	25.6±9.0	0.345
L3-4 CSA (cm ²)	21.4±5.3	21.7±3.4	0.861
L3-4 FI (%)	31.8±11.6	32.8±10.6	0.801
L4-5 CSA (cm ²)	21.3±5.1	22.3±3.7	0.502
L4-5 FI (%)	37.0±14.9	40.4±11.4	0.450
L5-S1 CSA (cm ²)	17.0±4.1	18.7±3.3	0.172
L5-S1 FI (%)	43.7±18.2	47.7±10.8	0.427
L1-2/L4-5 CSA	0.87±0.11	0.86±0.12	0.890
L1-2/L4-5 FI	0.76±0.19	0.58±0.18	0.041
L2-3/L4-5 CSA	0.91±0.13	0.89±0.09	0.633
L2-3/L4-5 FI	0.83±0.25	0.65±0.17	0.018
L3-4/L4-5 CSA	1.01±0.13	0.98±0.11	0.430
L3-4/L4-5 FI	0.91±0.28	0.82±0.17	0.291
L5-S1/L4-5 CSA	0.81±0.13	0.85±0.16	0.375
L5-S1/L4-5 FI	1.19±0.18	1.22±0.22	0.655

Table 2 Comparison of lumbar paraspinal muscles between Roussouly type II and type III

	Type II	Type III	P value
Age	62.4±7.5	61.1±6.1	0.603
BMI	24.4±3.2	24.7±2.8	0.800
L1-2 CSA (cm ²)	18.3±3.9	19.1±3.2	0.540
L1-2 FI (%)	23.3±14.2	22.9±8.6	0.919
L2-3 CSA (cm ²)	18.6±3.3	19.9±3.1	0.252
L2-3 FI (%)	26.7±11.6	25.6±9.0	0.752
L3-4 CSA (cm ²)	19.4±3.3	21.7±3.4	0.064
L3-4 FI (%)	31.0±11.5	32.8±10.6	0.647
L4-5 CSA (cm ²)	19.2±3.0	22.3±3.7	0.014
L4-5 FI (%)	36.9±16.6	40.4±11.4	0.482
L5-S1 CSA (cm ²)	14.1±3.7	18.7±3.3	0.001
L5-S1 FI (%)	42.2±17.1	47.7±10.8	0.269
L1-2/L4-5 CSA	0.96±0.14	0.86±0.12	0.047
L1-2/L4-5 FI	0.70±0.38	0.58±0.18	0.261
L2-3/L4-5 CSA	0.98±0.13	0.89±0.09	0.050
L2-3/L4-5 FI	0.78±0.24	0.65±0.17	0.079
L3-4/L4-5 CSA	1.01±0.09	0.98±0.11	0.352
L3-4/L4-5 FI	0.90±0.23	0.82±0.17	0.294
L5-S1/L4-5 CSA	0.73±0.14	0.85±0.16	0.039
L5-S1/L4-5 FI	1.22±0.33	1.22±0.22	0.976

Table 3 Comparison of lumbar paraspinal muscles between Roussouly type IV and type III

	Type IV	Type III	P value
Age	61.3±6.6	61.1±6.1	0.532
BMI	24.3±2.5	24.7±2.8	0.671
L1-2 CSA (cm ²)	19.9±3.3	19.1±3.2	0.474
L1-2 FI (%)	21.6±12.4	22.9±8.6	0.697
L2-3 CSA (cm ²)	20.2±2.3	19.9±3.1	0.762
L2-3 FI (%)	23.5±12.7	25.6±9.0	0.566
L3-4 CSA (cm ²)	22.8±3.4	21.7±3.4	0.303
L3-4 FI (%)	28.6±11.1	32.8±10.6	0.252
L4-5 CSA (cm ²)	23.2±3.9	22.3±3.7	0.482
L4-5 FI (%)	34.6±11.3	40.4±11.4	0.134
L5-S1 CSA (cm ²)	19.4±3.4	18.7±3.3	0.562
L5-S1 FI (%)	45.8±10.5	47.7±10.8	0.591
L1-2/L4-5 CSA	0.87±0.14	0.86±0.12	0.904
L1-2/L4-5 FI	0.60±0.19	0.58±0.18	0.701
L2-3/L4-5 CSA	0.88±0.12	0.89±0.09	0.720
L2-3/L4-5 FI	0.66±0.20	0.65±0.17	0.842
L3-4/L4-5 CSA	0.99±0.13	0.98±0.11	0.676
L3-4/L4-5 FI	0.82±0.13	0.82±0.17	0.995
L5-S1/L4-5 CSA	0.85±0.15	0.85±0.16	0.940
L5-S1/L4-5 FI	1.36±0.19	1.22±0.22	0.037

Figures

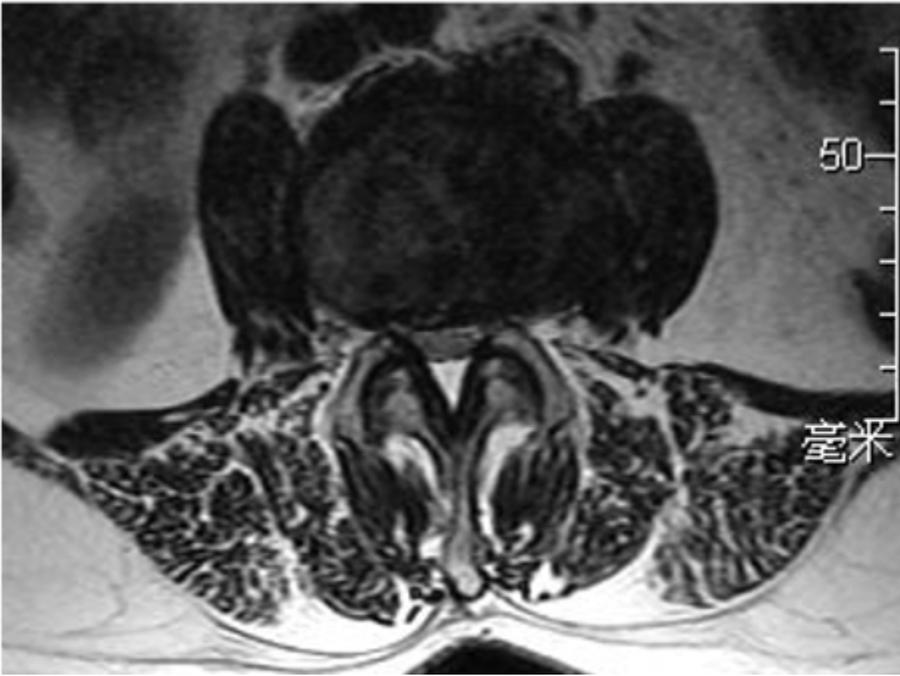


Figure 1

T2-weighted image of the intervertebral disc level (White area is infiltrated by fat, while gray area is muscle)

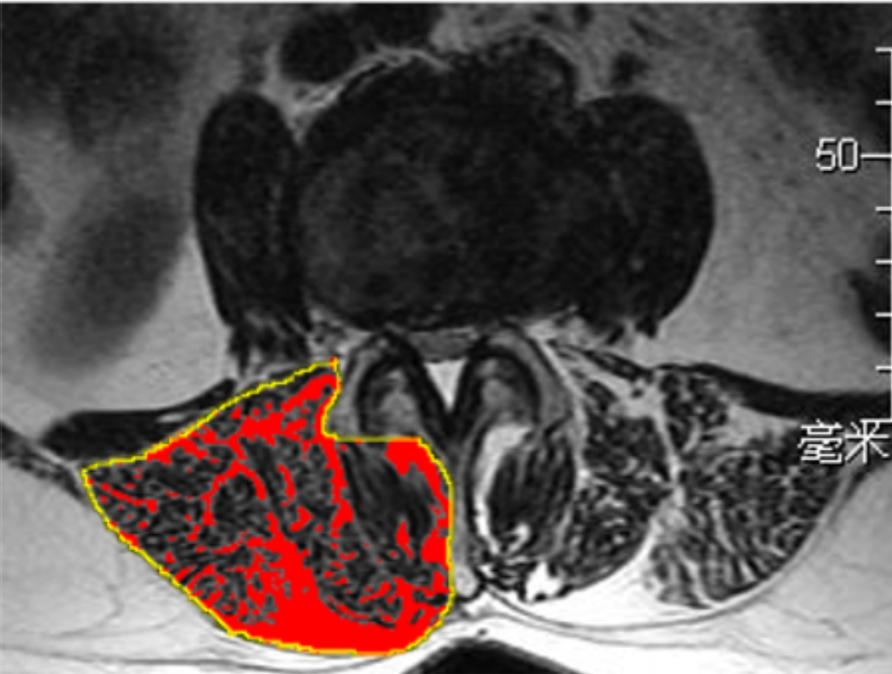


Figure 2

T2-weighted image of the intervertebral disc level which is processed in threshold technique of Image J software (Red area is infiltrated by fat, while gray area is muscle)