

Assessment of the association between paraspinal muscle degeneration and quality of life in patients with degenerative lumbar scoliosis

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Abstract. The present study aimed to determine the characteristics of multifidus, erector spinae and psoas major degeneration in elderly patients with degenerative lumbar scoliosis (DLS) and the correlation between asymmetric changes and patient quality of life. A total of 49 patients with lumbar scoliosis (DLS group) and 38 healthy individuals (control group) were prospectively examined. The functional cross-sectional area, cross-sectional area difference index (CDI) and fat infiltration rate (FIR) of the multifidus, erector spinae and psoas major at the apical vertebral level were measured using MRI. The visual analogue scale (VAS) score, Oswestry Disability Index (ODI) and 36-item Short Form Health Survey (SF-36) score were used to evaluate patient quality of life. Correlations between the degree of asymmetric muscular degeneration and quality of life were analysed. The CDI of the multifidus, erector spinal and psoas major was higher in the DLS group compared with that in the control group. The CDI of the multifidus was found to be positively associated with the Cobb angle of lumbar scoliosis. Similar results were obtained for fat infiltration between the two groups. In addition, the CDI and FIR difference index of the multifidus was positively correlated with the VAS score and ODI but negatively correlated with the SF-36 score. The quality of life significantly decreased with increasing asymmetric atrophy

and fat infiltration in the multifidus. Thus, strategies to enhance the function of the multifidus may have a positive impact on quality of life (Chinese Clinical Trial Registry, registration date, 2018.11.12; registration no. ChiCTR1800019459.).

Introduction

Degenerative lumbar scoliosis (DLS) is a degenerative disease in patients >50 years with a Cobb angle of >10° as the diagnostic criterion (1). Degeneration of the spine may occur along the full length of the spine but is more common in the lumbar spine (2). It is frequently accompanied by a series of degenerative changes involving the vertebrae, intervertebral discs and facet joints (3). Paravertebral muscles (PVMs) and ligaments provide dynamic stability to the lumbar spine (4). Previous studies have focused on the degeneration of intervertebral discs and small joints but did not examine the role of PVMs in supporting spinal balance (5-8). However, the association between PVMs and scoliosis remains to be elucidated.

PVMs are divided into superficial and deep layers. The superficial layer is mainly composed of the erector spinae and the deep layer predominantly consists of the multifidus (9). These are important components of the dynamic spinal stabilization system that provide the power of trunk movements (10). PVM degeneration is characterized by increased fat infiltration and decreased muscle volume (11). PVM degeneration is associated with various lumbar diseases and post-operative complications (12,13). It was reported that the degree of fat infiltration and atrophy of the multifidus is closely linked to the severity of lower back pain (LBP) (14-16). These results suggested that PVM degeneration may be associated with LBP and neurological symptoms. These symptoms have different degrees of impact on the quality of life of DLS patients. However, there is no consensus regarding the association between PVM degeneration and quality of life in DLS.

The aim of the present study was to observe the characteristics of the multifidus, erector spinae and psoas major degeneration in elderly patients with DLS and to study the correlation between asymmetric changes and patient quality of life.

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Materials and methods

General information. The present prospective clinical study was approved by the Ethics Committee of the Southwest Hospital (First Affiliated Hospital) of the Third Military Medical University (Chongqing, China; approval no. KY201853). All study participants provided written informed consent prior to evaluation and all research activities adhered to the tenets of the Declaration of Helsinki. A total of 49 patients with DLS were recruited at Southwest Hospital, the Third Military Medical University (Chongqing, China) between July 2018 and June 2019 for the DLS group. The inclusion criteria were as follows: Age at onset of DLS (Cobb angle $>10^\circ$) of >50 years; no radiculopathy and no previous therapy for DLS. A total of 38 healthy subjects from outpatient department health check-up were recruited as the control group. All patients were aged >50 years, had no degenerative lumbar spine disease and had not received any previous therapy. The exclusion criteria were as follows: Ankylosing spondylitis; spinal tumour; spinal tuberculosis; spinal infection; history of spinal surgery within 2 years; history of traumatic or osteoporotic spinal compression fracture within 1 year; severe pelvic, hip, knee or lower limb lesions; patients with metal implants anywhere in the body, who could not undergo MRI examination; and other serious systemic diseases. Basic characteristics, including sex, age and body mass index (BMI), were not significantly different between the two groups (Table I).

MRI procedure. All patients underwent X-ray and MRI examination using the same equipment. The MRI system was a 3.0 Tesla Imaging System (Siemens Healthineers). T1- and T2-weighted images of the lumbar sagittal plane were captured. The same sequence was used to obtain transverse images at the disc level from T12-L1 to L5-S1. The section thickness was 3 mm, the field of view was 240x240 mm and each layer was a 512x384 matrix. The repetition time and echo time was 644 and 9.5 msec for T1-weighted imaging (T1WI) and 4,290 and 93 msec for T2WI, respectively.

MRI evaluation. To minimize the impact of deformity of the spine itself on the morphological measurements of PVMs and psoas, horizontal images in terms of the cross-sectional area (CSA) at the plane of the apex were compared. Images obtained using a T2 sequence were selected for measurement. The region of interest (ROI) was determined by manually tracing the boundaries of the muscles and measured using ImageJ software (v2.1.4.7; National Institutes of Health).

Greyscale images were used to distinguish the pixels of intramuscular adipose tissue on each disc plane from L1-L2 to L5-S1, with 120 as the threshold (17). The fat infiltration rate (FIR) of the muscles was measured on each side. The FIR difference index (FDI) was measured as the degree of asymmetry between bilateral muscles. The functional CSA (FCSA) was defined as the area of pure muscle without fat using the following formula: $FCSA = CSA \times (1 - FIR)$. To compare the FCSA between the concave and convex sides and eliminate the interference of individual differences, the normalized FCSA difference index (CDI) was adopted as the evaluation index (1): $CDI = [1 - (FCSA_{concave} / FCSA_{convex})] \times 100\%$. The CDI was also considered as the degree of asymmetric change in the

PVMs. A total of two orthopaedic attending surgeons who had no direct contact with the patients measured all parameters separately. The mean value of their results was used. In a typical case, there was significant asymmetric degeneration in the bilateral paravertebral muscle (Fig. 1).

Quality of life assessment

Pain. The visual analogue scale (VAS) score was used to evaluate the degree of LBP (18). The VAS score scale ranged from 0 to 10, with a higher VAS score indicating a higher pain intensity.

Dysfunction. The Oswestry Disability Index (ODI) was used to assess dysfunction (19). The ODI scale ranged from 0 to 100%, with a higher ODI indicating more severe dysfunction.

Health-associated quality of life scores. The Medical Outcomes Study 36-item Short Form Health Survey (SF-36) was used to evaluate quality of life in the general population (20). The SF-36 score scale ranged from 0 to 100%, with a higher SF-36 score indicating a better physical condition.

Statistical analysis. Data were analysed using SPSS 17.0 (SPSS, Inc.). Age, VAS score, ODI and SF-36 score were compared using an independent-samples t-test. The CDI and FDI were compared using a Wilcoxon signed-rank test. The FIR was compared using a paired-samples t-test. Differences in sex were analysed using a χ^2 test. Pearson correlation analysis was performed to assess the correlation between CDI or FDI and the VAS score, ODI or SF-36 score. $P < 0.05$ was considered to indicate a statistically significant difference.

Results

General information. In the DLS group, 49 patients (sex, 23 males and 26 females; mean age, 61.3 ± 5.2 years; age range, 52-83 years; Table I). Among them, 25 and 24 patients exhibited a curved vertex on the left and on the right, respectively. Spinal segments L2-L3 and L3-L4 were the most common apical levels (Fig. 2). The mean Cobb angle was $18.85 \pm 9.22^\circ$ (range, $10.7-37.2^\circ$). In the Control group, 38 patients were enrolled (sex, 16 males and 22 females; mean age, 62.4 ± 5.7 years; age range, 51-82 years; Table I).

Differences between the two groups. The CDI of the multifidus, erector spinae and psoas major were significantly higher in the DLS group compared with those in the control group (Fig. 3). There were no significant correlations between CDI and age, sex, BMI, the side or level of the apex (Table II). However, an association was identified between the CDI of the multifidus at the apical vertebral level and the Cobb angle of lumbar scoliosis ($P = 0.028$; Table II). It was indicated that the volume of the multifidus was closely associated with the degree of lumbar scoliosis (21). The FIR of the multifidus was also significantly higher on the concave side compared with that on the convex side at the apical vertebral level (1.48 fold-change vs. the convex side), but this difference was not statistically significant for the erector spinae or psoas major (Fig. 4). In addition, the FDI for the multifidus from L1-L5 in the DLS group was significantly higher compared with that in the control group (25.5 fold-change vs. control; Fig. 5). No

Table I. General characteristics of the study subjects.

Characteristics	DLS group (n=49)	Control group (n=38)	Statistic	P-value
Sex (male/female)	23/26	16/22	$\chi^2=0.2022$	0.6530
Age (years)	61.3±5.2	62.4±5.7	t=0.9383	0.3507
BMI (kg/m ²)	23.3±2.6	23.7±2.9	t=0.6767	0.5004
Cobb angle (°)	18.85±9.22	2.67±5.23	t'(0.05)=2.0110	0.0235

DLS, degenerative lumbar scoliosis; BMI, body mass index.

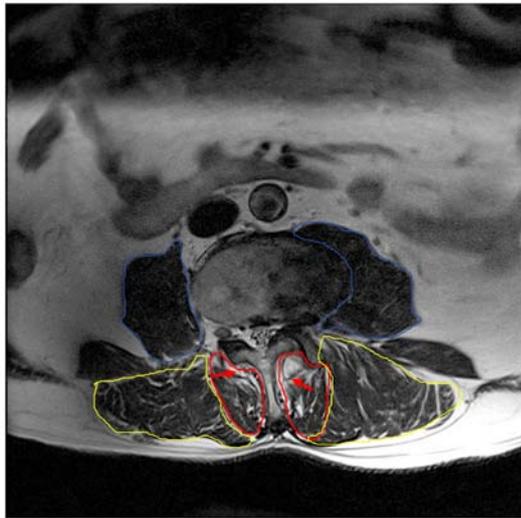


Figure 1. Representative MRI image of a male patient aged 70 years with degenerative lumbar scoliosis. The Cobb angle was 13.8° and the apical level was L3-L4. The cross-sectional area difference indices of the multifidus, erector spinae and psoas major was 19.6, 5.4 and 15.4%, respectively. The FIR of the multifidus, erector spinae and psoas major were 14.1, 7.4 and 0.3% on the concave side (left side) and 9.8, 6.8 and 0.1% on the convex side (right side). The degree of FIR asymmetry was 4.3%. The image indicates asymmetric degeneration of the cross-sectional area and the degree of fat infiltration of the bilateral paraspinal muscles. The red region of interest is the shape of the multifidus. The red arrows indicate a large amount of fat infiltrating the muscle. FIR, fat infiltration rate. The yellow region of interest is the shape of the erector spinae. The blue region of interest is the shape of the psoas major.

statistically significant differences were observed not for that of the erector spinae or psoas major. These results suggested that there was an asymmetrical degree of fat infiltration in the bilateral multifidus in patients with lumbar scoliosis. There was no significant difference in paravertebral muscle of cross-sectional area and fat infiltration in the control group. The contrast between the degeneration and control groups is reflected in the asymmetry between the two sides.

Analysis of associated factors with PVMs change. Comparing the quality of life between the two groups, the VAS score and ODI were also significantly higher in the DLS group (5.48 and 14.39 fold-change vs. control, respectively), while the SF-36 score was significantly lower in the DLS group compared with the control group (66.7%; Fig. 6). According to the correlation analysis, the CDI of the multifidus at the apical vertebral level was positively correlated with the VAS score as well as with

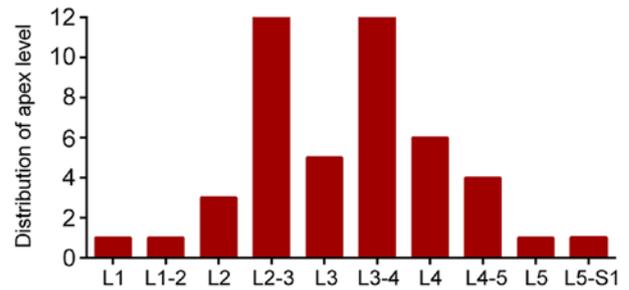


Figure 2. Apex distribution. According to the X-ray image, the apex vertebra is the vertebral body with the longest distance from CSVL, the most horizontal, the greatest degree of rotation and the most obvious wedge-shaped change in the entire bending range. In patients with degenerative lumbar scoliosis, the apical levels of bending were mainly distributed in L2-L3 and L3-L4.

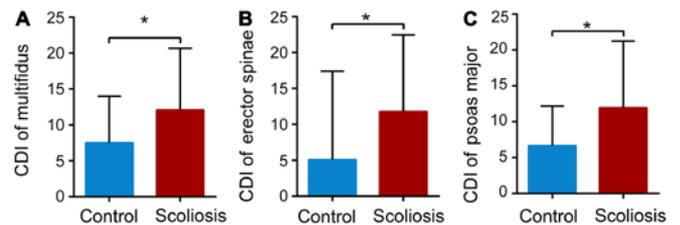


Figure 3. Differences in the CDI of the multifidus, erector spinae and psoas major at the apical level between the degenerative lumbar scoliosis and control groups. CDI of the (A) multifidus, (B) erector spinae and (C) psoas major. *P<0.05. CDI, cross-sectional area difference index.

the ODI but negatively correlated with the SF-36 score in the DLS group (Table III). The FDI of the multifidus from L1-L5 was also positively correlated with the VAS score and ODI and negatively correlated with the SF-36 score. This indicated that the volume and fat infiltration of the multifidus reflected the degree of muscle degeneration. It also indicated that the function of the multifidus was closely associated with the quality of life of patients.

Discussion

The incidence of DLS increases with age and gradually becomes a public health concern in the elderly population (22). PVMs have an important role in maintaining the stability of the spine. Degeneration of PVMs is associated with various lumbar diseases and post-operative complications (23,24). However, the pathogenesis of DLS remains to be elucidated.

Table II. Analysis of correlation between the cross-sectional area difference indices of paravertebral and psoas muscles at the apex level with clinicopathological features.

Scoring system/index	Cross-sectional area difference indices		
	Multifidus	Erector spinae	Psoas major
Sex			
Coefficient	0.124	0.079	0.087
P-value	0.465	0.523	0.498
Age			
Coefficient	0.189	0.113	0.065
P-value	0.381	0.485	0.573
BMI			
Coefficient	0.116	0.114	0.111
P-value	0.434	0.452	0.478
Side of apex			
Coefficient	0.042	0.056	0.078
P-value	0.706	0.672	0.598
Level of apex			
Coefficient	0.139	0.114	0.141
P-value	0.342	0.457	0.323
Cobb's angle			
Coefficient	0.325	0.224	0.265
P-value	0.028	0.123	0.095

BMI, body mass index.

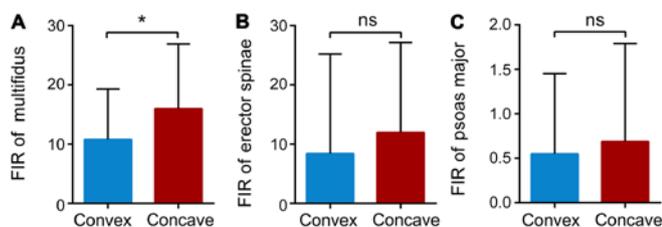


Figure 4. Differences in the FIR of the paravertebral and psoas muscles at the apical level between the concave and convex sides. FIR of the (A) multifidus, (B) erector spinae and (C) psoas major. * $P < 0.05$. ns, no significance; FIR, fat infiltration rate.

The factors that affect the development of DLS are complex and include the vertebral bodies, intervertebral discs, joints, ligaments and muscles (25). Different degrees of PVM degeneration may lead to an imbalance in bilateral lumbar force and aggravate the progression of lumbar scoliosis (26). Current research on lumbar PVMs mainly focuses on the association with the sagittal balance of the spine (26). However, there have been few reports on the association between PVM degeneration and quality of life. Therefore, the present study focused on asymmetric changes in the PVMs and psoas major in patients with degenerative scoliosis and validated the association between PVM degeneration and quality of life.

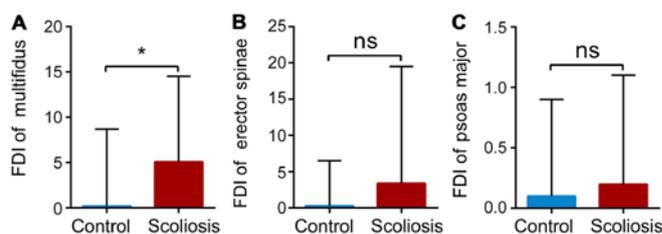


Figure 5. FDI of the paravertebral and psoas muscles at the apical level between the degenerative lumbar scoliosis and control groups. FDI of the (A) multifidus, (B) erector spinae and (C) psoas major. * $P < 0.05$. ns, no significance; FDI, fat infiltration rate difference index.

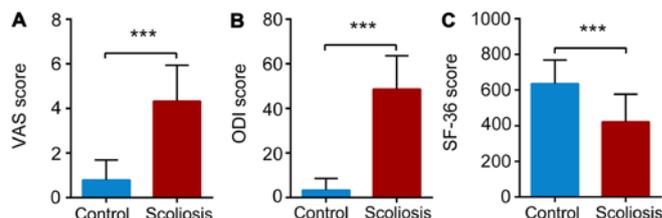


Figure 6. Comparison of quality of life. (A) VAS, (B) ODI and (C) SF-36 scores compared between the degenerative lumbar scoliosis and control groups. *** $P < 0.001$. VAS, visual analogue scale; ODI, Oswestry Disability Index; SF-36, 36-item Short Form Health Survey.

A decrease in the CSA indicates muscle atrophy and an increase in the FIR reflects muscle degeneration (11). It has been reported that the CSA of the PVMs significantly decreased, while the FIR of the PVMs increased in patients with LBP (27,28). Muscle atrophy and fat infiltration occur simultaneously, which is due to the tendency of myosatellite cells to undergo adipocytic differentiation under pathological conditions (29). Therefore, the degree of PVM change measured by MRI mainly includes changes in the CSA and FIR (30,31). To measure the CSA, the ROI must be drawn along the muscle boundary. Although this method involves a certain amount of subjectivity, studies have proven that it has good internal and external reliability (32). A previous study measured the total muscle CSA, including fat, while others have measured the pure muscle area without adjacent degenerative fat, referred to as the FCSA (33). The difference in bilateral back muscle mass was indicated to be most significant at the apical vertebral level (34). To reduce individual differences, the FCSA on both sides of the apical vertebral level was adopted and the concave side was compared with the convex side to obtain the relative asymmetry. At present, there are no particularly accurate methods for measuring fat infiltration, while MRI is the most accurate method. However, there are numerous methods based on MRI, including fat three-dimensional reconstruction, magnetic resonance spectroscopy and Dixon technology (35,36). Muscular atrophy and fatty infiltration occur simultaneously and there is maximum tension between two sides of the apex level (25). The apex level was selected to eliminate individual and segmental differences for measuring CDI. The infiltration of fat is in the whole muscle. However, when evaluating the degree of fat infiltration, the average muscle fat infiltration rate of all segments of L1 to L5 was selected. The present results indicated that the CDI was only

Table III. Correlation analysis between the CDI or FDI with VAS, ODI and SF-36 scores.

Scoring system/index	CDI			FDI		
	Multifidus	Erector spinae	Psoas major	Multifidus	Erector spinae	Psoas major
VAS						
Coefficient	0.459	0.177	0.152	0.387	0.071	-0.142
P-value	0.010	0.218	0.293	0.006	0.624	0.324
ODI						
Coefficient	0.643	0.240	0.258	0.354	0.040	-0.037
P-value	<0.001	0.093	0.070	0.013	0.783	0.799
SF-36						
Coefficient	-0.318	0.036	-0.079	-0.338	-0.178	-0.062
P-value	0.024	0.806	0.584	0.018	0.215	0.671

CDI, cross-sectional area difference index; FDI, fat infiltration rate difference index; VAS, visual analogue scale; ODI, Oswestry Disability Index; SF-36, 36-item Short Form Health Survey.

positively correlated with the Cobb angle and not correlated with age, sex or BMI.

In the DLS group, there were significant differences in the CSA of the bilateral multifidus, erector spinae and psoas major. Unlike healthy individuals, patients with scoliosis experience asymmetrical pressure loads on both sides of the spine, which may be responsible for asymmetric paraspinal atrophy and fat infiltration (25). On the convex side, due to continuous tensile stress, PVMs are in a state of long-term hyperproliferation, which inhibits adipocytic differentiation (37). The PVMs and psoas major maintain the dynamic stability of the spine (34). The increase in the CSA on the convex side may be the result of balance compensation, which eventually achieves the effect of increasing tensile traction and preventing the spine from leaning further to the concave side (4). The characteristics of fat distribution in the bilateral paraspinal muscles also support this explanation, as muscular atrophy is closely associated with increased fat infiltration (38). Therefore, biomechanical changes may lead to asymmetric changes in the PVMs, which is consistent with earlier research on scoliosis (25).

The strength of muscles is proportional to the CSA, and the CSA of the PVMs is frequently used to represent muscle strength in the lower back (39). Therefore, the CDI of the PVMs may directly reflect the difference in muscle strength between the two sides on the same plane. The present results suggest that the CDI of the multifidus at the apical vertebral level was positively correlated with the Cobb angle. A greater Cobb angle of scoliosis is indicative of a higher asymmetry of the gravity load on the two sides. Biomechanical studies have suggested that the load of the multifidus increases by 1.5 kg/cm² for each 1 cm of deviation from the midline of the vertebral apex on the convex side (40). When the spine is in a neutral position, the multifidus contributes up to 60% of segment stability (41). The present results indicated that the apical vertebrae of patients with DLS tend to appear in the L2-L3 and L3-L4 segments. The reason may be that the multifidus has a key role in maintaining stability between L2 and L4, which is consistent with a previous report (25). Compared with other lumbar muscles,

the multifidus is characterized by short fibres and a large CSA (42). This morphological feature allows the multifidus to exert a large force in a relatively narrow space, controlling the stability of the back of the spine (4). In addition, muscle atrophy on the concave side may be closely linked to increased fat infiltration (38). The FIR exhibited marked inter-individual differences and was closely associated with vertebral segment, sex, age and BMI. The present results indicated that only the FIR of the multifidus on the concave side was significantly higher compared with that on the opposite side at the apical vertebral level. It is possible that, as the multifidus is a medial PVM, it is sensitive to changes in the tensile load (30).

The present study indicated that the CDI and FDI of the multifidus were positively correlated with the VAS score and ODI but negatively correlated with the SF-36 score. PVM degeneration is closely associated with LBP. The majority of patients present with back pain as the primary symptom, which has an adverse impact on quality of life and the capacity of patients to work or study (33). LBP causes patients to further reduce functional exercise of the lower back muscles (43). Large amounts of lactic acid and various metabolites accumulate, resulting in muscle oedema and stimulating or aggravating nerve pain (32). The multifidus gradually becomes undernourished and replaced with adipose tissue, which leads to muscle atrophy (44). Patients with lumbar scoliosis have a higher level of dysfunction compared with the general population, which limits their quality of daily life, and certain patients lose the ability to take care of themselves (45). One study reported that the CSA of the PVMs in patients with chronic LBP was smaller compared with that in the controls (42). Decreased PVM CSA is a risk factor for post-operative pedicle screw loosening (46). One study reported the correlation between pre-operative PVM degeneration and cage displacement after fusion (47). Reduced PVM strength and an increased pre-operative FIA may lead to proximal junctional kyphosis (48). Altogether, asymmetric degeneration of the multifidus reduces the quality of life and may even affect the outcome of surgery.

The present study has certain shortcomings that require to be mentioned. First, the population of the present study consisted of subjects from only a single centre and the sample size was relatively small. Furthermore, analyses were not performed according to the severity of lumbar scoliosis. In addition, there may have been certain bias. For instance, degenerative disc and endplate degeneration were present in the degenerative group, but not in the control group. These factors were not considered, which may have an impact on the assessment of quality of life. Therefore, it is required to further expand the sample size to eliminate bias in future research. It will be endeavoured to perform detailed studies with large samples through multicentre recruitment.

To conclude, in the present study, patients with DLS had asymmetric degeneration of the PVMs and psoas major. The CDI and FDI of the multifidus are closely correlated with the quality of life. These results may provide a strategy of clinical treatments to improve PVM function in order to improve the quality of life and reduce pain.

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Availability of data and materials

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

Authors' contributions

YT, SY, CC designed the study and optimized the experimental scheme, collected clinical samples and wrote papers. KL, YC, DW, JT, QD, CZ and WW performed the experiments and statistical analyses. JX and FL designed the present study and revised the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Ethics Committee of the First Affiliated Hospital, Third Military Medical University (approval no. KY201853). Written informed consent was obtained from all participants prior to the study.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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