Correlation Among Residual Pain, Spinopelvic Parameters and Area of Fat Infiltration in Lumbar Multifidus Muscles in Patients after Lumbar Surgery: A Cross-Sectional Study.

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Abstract

**Background:** Numerous studies have reported that pelvic functional training is beneficial for improving low back pain (LBP) in patients with lumbar disc herniation (LDH) after lumbar surgery and that fat infiltration of the lumbar multifidus muscles (LMMs) is one of the most important reasons for residual LBP after surgery. However, little is known about the exact relationship among residual LBP, spinopelvic parameters and the area of fat infiltration in LMM after lumbar surgery. This study aimed to confirm the relationship among residual LBP, spinopelvic parameters and the area of fat infiltration in LMM and to investigate why pelvic functional training can relieve pain symptoms in patients with LDH after lumbar surgery.

**Methods:** One hundred forty-three patients with LDH were involved in this study. Clinical data were collected from a system of digital medical records, including age, gender, course, and weight. On the MRI images, the cross-sectional areas (CSAs) of bilateral fat infiltration in the LMM were measured using a picture archiving and communication system (PACS). On the X-ray, sacral slope (SS), pelvic tilt (PT) and pelvic incidence (PI) were also measured by PACS. Pearson correlation analysis was applied to analyse the differences between CSA of fat infiltration in LMM and spinopelvic parameters, and ROC curves were used to reflect the degree of fat infiltration in LMM with spinopelvic parameters.

**Results:** One hundred and twenty-five patients met the inclusion criteria. SS and PI were positively correlated with CSA of fat infiltration in LMM at L3-4 and L4-5 (p < 0.01). At L4-5, SS and PI demonstrated significant positive correlation with the CSA of fat infiltration in the LMM (0.5 < | r | < 0.8). PI also exhibited a significant positive correlation with VAS (0.5 < | r | < 0.8), but SS had a low correlation with VAS (0.3 < | r | < 0.5). At L4-5, only the PI had a significant ROC curve (AUC = 0.836) with a cut-off point score of 0.556 and sensitivity and specificity values of 62.8% and 87.4%, respectively. However, at L3-4 and L5-S1, the AUCs of the ROC curves were all < 0.7 for SS, PT and PI.

**Conclusions:** The wider pelvic anterior tilt, the more severe fat the infiltration in LMM. Residual LBP can be relieved by spinopelvic correction training potentially due to the improvement of fat infiltration in LMM.

**Background**

Despite advances in spinal surgery including endoscopic surgery for lumbar disc herniation (LDH), recent studies on postoperative low back pain (LBP) have reported high rates of persistent opioid use many years after lumbar surgery\(^1\), and postoperative pain heavily lowers the quality of life of patients \(^2\)\(^3\). According to statistics from Parker et al\(^4\), the proportion of patients reporting short-term (6–24 months) and long-term (> 24 months) recurrent LBP ranged from 3–34% and 5–36%, respectively. Even for minimally invasive operations, approximately 8.4–25% of patients receiving lumbar percutaneous transforaminal endoscopic discectomy (PTED) still have residual LBP after surgery\(^5\)\(^6\). In addition, postoperative LBP can be improved by rehabilitation treatment\(^7\)\(^8\), especially spinopelvic rehabilitation\(^9\). One in vitro study attributed this improvement achieved by spinopelvic exercise to activation of the
endogenous anti-inflammatory cytokine interleukin 10 in the spinal cord\cite{10}. However, little is known about the musculoskeletal reason why postoperative LBP can be relieved by spinopelvic rehabilitation.

Paraspinal muscles are inevitably affected by channel establishment during lumbar surgery\cite{11}. As the most important paraspinal deep muscle, the lumbar multifidus muscle (LMM) reinforces lumbar lordosis during rotation, antagonize lumbar flexion and provides segmental stabilization and proprioception to the lumbar spine\cite{12}. More importantly, LMM is thought to be responsible for remnants of LBP after surgery\cite{13}. Additionally, unlike posttraumatic muscle wastage for phasic muscles, fat infiltration always occurs in the LMM after muscle fibres are damaged\cite{14}. Based on the understanding of the above literature analysis, it is worth thinking about whether the effectiveness of spinopelvic rehabilitation relates to the improvement of fat infiltration in LMM for patients with postoperative LBP. Therefore, the aim of this study was to determine the relationship among residual pain, spinopelvic parameters and the area of fat infiltration in LMM for patients after lumbar surgery.

**Methods**

**Participants**

This study retrospectively followed 143 patients with LDH who initially presented to our clinic in the Pain and Rehabilitation Medicine Centre of The Six Medical Center of Chinese PLA General Hospital for PTED between March 2019 and March 2020. In all, 18 cases were excluded for the following reasons: 13 could not show complete spinopelvic parameters on X-ray, 3 had no records of magnetic resonance imaging (MRI), and 2 had diagnoses that were not in accordance with the description of medical records. Inclusion criteria were as follows: (1) patients met the diagnostic criteria of LDH according to the medical records and final diagnosis; (2) preoperative disc herniation at the following disc levels: L3-4, L4-5 and L5-S1; and (3) LBP remained 3 to 6 months after PTED, and pain visual analogue scale (VAS) > 2. The primary exclusion criteria were as follows: (1) diseases of the spinal canal caused by metastatic tumour or spine infection; (2) history of spinal trauma or spinal deformity; (3) syndrome of the cauda equina; and (4) incomplete necessary imaging records. Finally, 125 patients (61 females and 64 males) were included. Demographic details, course and clinical data including sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI) and cross-sectional areas (CSA) of bilateral fat infiltration in LMM were recorded from patients’ medical records. For details, see Table 1.
Table 1
Descriptive statistics of the studied sample (n = 125).

| Variables      | Total(%) | Male(%)   | Female(%) | p    |
|----------------|----------|-----------|-----------|------|
| Cases (n)      | 125      | 64(51.2)  | 61(48.8)  | -    |
| Age (years)    |          | 50.81 ± 10.10 | 51.41 ± 10.94 | 50.18 ± 9.19 | 0.503 |
| Course (Months)|          | 3.92 ± 0.99   | 3.78 ± 0.95   | 4.07 ± 1.01 | 0.114 |
| Weight (kg)    |          | 59.18 ± 9.90  | 61.21 ± 11.49 | 57.03 ± 9.15* | 0.015 |
| SS (°)         |          | 35.78 ± 7.27  | 35.05 ± 7.29  | 36.56 ± 7.24 | 0.274 |
| PT (°)         |          | 16.74 ± 5.16   | 16.55 ± 4.80   | 16.93 ± 5.55 | 0.677 |
| PI (°)         |          | 52.58 ± 5.34   | 51.65 ± 6.04   | 53.56 ± 4.81 | 0.055 |
| VAS            |          | 3.32 ± 1.26    | 3.15 ± 1.16    | 3.49 ± 1.35 | 0.138 |

SS: Sacral slope, PT: Pelvic tilt, PI: Pelvic incidence. *Significantly different from male, p<0.05

MRI and X-ray methods

Three spinal doctors who had been trained professionally and were qualified were responsible for collecting X-ray and MRI imaging data and for data processing. Lumbar MRI was performed using Siemens 3.0 T Magnetom Vision and patients were placed in the prone position in the MRI device. The picture archiving and communication system (PACS) was applied to analyse the T2-weighted axial images at the inferior endplate of L3, L4 and L5 bilaterally. On the endplate levels, the contour line was constructed by polygon points around the outer edge of the fat infiltration in LMM. For details see Fig. 1. The abovementioned methods were referred to in the study by Kjaer[15] and Q Li[16], and there is also evidence that this measure of fat infiltration in LMM, which uses MRI images, is reliable[17][18].

Spinopelvic parameters on X-ray were measured with the angle measure module in PACS. Specific methods were as follows: SS, the angle between the superior plate of S1 and a horizontal line; PT, the angle between the sagittal pelvic thickness line and a vertical line through the femoral head; PI, the angle between a line perpendicular to the sacral plate at its midpoint and a line connecting the same point to the centre of the bicoxofemoral axis. For details see Fig. 2.

To reduce the error of measurement, all the mean values were calculated from the three physicians mentioned above.

Statistical analysis

Statistical analyses of the findings were performed with the SPSS for Windows v.10.0 software program. Descriptive statistics were analysed for clinical data results. The relationships among spinopelvic parameters, VAS and CSA of fat infiltration in LMM were analysed based on the Pearson correlation coefficient. To examine the predictive effect of spinopelvic parameters on the degree of fat infiltration in
LMM, continuous variables were converted into dichotomous variables. For the degree of fat infiltration in LMM, the CSA of fat infiltration in LMM was dichotomized into mild and severe (< 50% vs ≥ 50%) based on the fat percentage in LMM described by Hildebrandt[13] (Fig. 3). Finally, ROC curves were utilized to determine the optimal cut-off point for spinopelvic parameters in predicting the degree of fat infiltration in LMM. Statistical significance was accepted as $p < 0.05$.

**Results**

One hundred and twenty-five patients with LDH met the inclusion criteria. The mean age, course and weight were $50.81 \pm 10.10$ years, $3.92 \pm 0.99$ months and $59.18 \pm 9.90$ kg, respectively, and the mean angles of SS, PT and PI were $35.78 \pm 7.27^\circ$, $16.74 \pm 5.16^\circ$ and $52.58 \pm 5.34^\circ$, respectively. The mean VAS of postoperation pain was $3.32 \pm 1.26$. There were no significant differences in mean age, course, angles of SS, PT and PI or VAS between male and female patients ($p > 0.05$). However, the mean weight of male patients was significantly greater than that of female patients ($p < 0.05$) (Table 1).

At L3-4 and L4-5, SS and PI were positively correlated with the CSA of fat infiltration in the LMM ($p < 0.01$). At L3-4, SS had a low correlation with the CSA of fat infiltration in the LMM ($|r| > 0.3$), and PI had a weak correlation with the CSA of fat infiltration in the LMM ($0 < |r| < 0.3$). However, SS and PI exhibited a significant positive correlation with the CSA of fat infiltration in the LMM ($0.5 < |r| < 0.8$) at L4-5. These findings indicate that the larger SS/PI, the larger the CSA of fat infiltration. In addition, PI also exhibited a significant positive correlation with VAS ($0.5 < |r| < 0.8$), but SS had a low correlation with VAS ($0.3 < |r| < 0.5$). See Table 2 for details.

**Table 2**

Results of correlation analysis among spinopelvic parameters, CSA of fat infiltration in LMM at each segment and VAS.

|       | SS      | PT      | PI      |
|-------|---------|---------|---------|
|       | $r$     | $p$     | $r$     | $p$     | $r$     | $p$     |
| CSA(L3-4) | 0.353   | 0.001   | -0.203  | 0.023   | 0.281   | 0.001   |
| CSA(L4-5) | **0.582** | **0.000** | -0.063  | 0.485   | **0.694** | **0.000** |
| CSA(L5-S1) | 0.020   | 0.821   | 0.041   | 0.650   | 0.064   | 0.478   |
| VAS    | 0.480   | **0.000** | 0.489   | -0.063  | **0.569** | **0.000** |

SS: Sacral slope, PT: Pelvic tilt, PI: Pelvic incidence, CSA: Cross-sectional areas, VAS: Visual analogue scale.

Finally, at L4-5, only the PI had a significant ROC curve (AUC = 0.836) with a cut-off point score of 0.556 and sensitivity and specificity values of 62.8% and 87.4%, respectively (Fig. 4). However, at L3-4 and L5-S1, the AUCs of the ROC curves were all < 0.7 for SS, PT and PI (Fig. 4 and Table 3).
Table 3
Results of AUC on predictive ability of spinopelvic parameters to degree of fat infiltration in LMM

|               | SS          | PT          | PI          |
|---------------|-------------|-------------|-------------|
| AUC<sub>SS</sub> | 0.602(0.485~0.718) | 0.515(0.384~0.674) | 0.645(0.534~0.755) |
| Degree of FI(L3-4) |             |             |             |
| Degree of FI(L4-5) | 0.674(0.574~0.775) | 0.580(0.457~0.702) | 0.836(0.743~0.930) |
| Degree of FI(L5-S1) | 0.559(0.457~0.662) | 0.494(0.389~0.599) | 0.583(0.482~0.684) |

SS: Sacral slope, PT: Pelvic tilt, PI: Pelvic incidence, FI: Fat infiltration; AUC: Area under roc curve

Discussion

LBP is defined as pain in the back from the level of the lowest rib down to the gluteal fold with a lifetime prevalence of 84%<sup>[19]</sup>. It is pragmatically classified as either nonspecific or specific by the German National Disease Management Guideline<sup>[20]</sup>, and residual LBP after surgery is often considered nonspecific pain because there are no clear causal relationships among the symptoms, orthopaedic physical examination and imaging findings in most cases. By definition, residual LBP does not have a clear pathoanatomical cause after responsible focuses are removed by operation. Therefore, there are no specific treatments that can be provided, and the advice for residual LBP management is quite similar between various countries, for example, nonsteroidal anti-inflammatory drugs, manual therapy, acupuncture, and physiotherapy<sup>[21]</sup>. However, this routine therapeutic schedule does not conform to the principle of precision medicine due to unknown pathogenetic causes.

Studies have confirmed that residual LBP after surgery can be improved significantly by functional exercise, including pelvic exercise<sup>[21]</sup>. Tatsumi et al believed that the incidence of LBP was remarkably correlated with anterior tilt of the pelvis<sup>[22]</sup>, and Hasebe et al reported that LBP was improved significantly after spinopelvic alignment was corrected by dynamic stretching on some phasic muscles<sup>[23]</sup>. In addition, it has been reported that a larger anterior pelvic tilt during gait loading may affect the aggravation of LBP by gait loading<sup>[24]</sup>. According to the above, we know that although the correlation between spinopelvic parameters and LBP has been confirmed by many studies, the specific reason remains unclear. It is worth noting that lumbar multifidus muscles (LMMs) are considered to be the most important muscle for lumbar segmental stability<sup>[25]</sup>, and LBP is related to fat infiltration in LMMs<sup>[26]</sup>. However, fat infiltration may be an important feature of degenerating LMMs that are affected in lumbar operations<sup>[27]</sup>. Therefore, we assumed that residual LBP after surgery may be relieved by correcting spinopelvic alignment through improvement of fat infiltration of LMM, and it is worth studying the association among residual pain, spinopelvic parameters and area of fat infiltration in LMM.

In this study, PI had a significant positive correlation with VAS for LBP with correlation coefficient value of 0.569. At L4-5, SS and PI all had significant positive correlations with CSA of fat infiltration in LMM with
correlation coefficient values of 0.582 and 0.694, respectively, for patients with residual LBP after surgery. Thus, the larger SS/PI, the larger CSA of fat infiltration. In other words, according to the conclusion of a positive association between PI and pelvic anterior tilt embraced by Diebo\textsuperscript{[28]}, the wider pelvic anterior tilt, the more severe the fat infiltration in LMM. Moreover, to further observe the relationship between spinopelvic parameters and fat infiltration in LMM, we found that PI exhibited a significant ROC curve with an AUC value of 0.836 for CSA of fat infiltration in LMM at L4-5, which means that PI can also to some extent reflect the degree of fat infiltration in LMM at certain lumbar levels. This result might explain why some studies found that a smaller anterior lumbar tilt and a larger anterior pelvic tilt affect the aggravation of LBP\textsuperscript{[24],[29],[30]}, and we believe that fat infiltration in LMM has a bridge effect.

There were several limitations in this study. The first is that time factors and precedence relationships were not included because this is a cross-sectional study. Second, spinopelvic parameters were measured only in the sagittal plane, and rotation, scoliosis and lateral tilt of the pelvis were not taken into account. Furthermore, the approach may need to be different for males and females in future studies because there may be gender differences in the CSA of LMM according to Hides et al\textsuperscript{[31]}. The above factors are essential for further evaluation.

Conclusions

The study investigated whether spinopelvic parameters are related to the degree of residual LBP and CSA of fat infiltration in LMM for patients with postoperative LBP. Our findings suggest that at L4-5, PI had a significant positive correlation with VAS for LBP and CSA of fat infiltration in LMM and may also reflect the degree of fat infiltration in LMM. Therefore, residual LBP is potentially relieved by spinopelvic correction training based on the improvement of fat infiltration in LMM. We hope this study will enhance the precision of spinal postoperative rehabilitation.

Abbreviations

LDH: Lumbar disc herniation; LBP: Low back pain; LMM: Lumbar multifidus muscle; CSA: Cross-sectional area; SS: Sacral slope; PT: Pelvic tilt; PI: Pelvic incidence; PTED: Percutaneous transforaminal endoscopic discectomy; PACS: Picture archiving and communication system.

Declarations

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Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.
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Consent for publication

Not applicable.

Authors’ contributions

Ling Guan designed this cross-sectional study. Yu Ding, Bensheng Fu and Guanghao Ma analyzed the patient data regarding MRI and X-ray. Yuxian Zhong further processed the data and performed the statistical analysis, and was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

This study was established, according to the ethical guidelines of the Helsinki Declaration and was approved by the Ethics Committee of The Six Medical Center of Chinese PLA General Hospital (original PLA Navy General Hospital). Written informed consent was obtained from individual or guardian participants.

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