Objective Evaluation of CT Imaging in the Treatment of Lumbar Disc Herniation

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The value of CT imaging in evaluating the efficacy of percutaneous transforaminal endoscopic discectomy (PTED) in the treatment of lumbar disc herniation (LDH) is explored. A total of 105 patients with LDH admitted to our hospital from March 2018 to September 2019 are selected for treatment with PTED, and all patients undergo CT examination before and after surgery. The CT imaging parameters (CT value of spinal canal soft tissue shadow, maximum back shift distance, longitudinal axis length, and intervertebral space height) before and 1 week after operation, the Japanese Orthopaedic Association (JOA) scores before and 6 months after the operation are compared, and the excellent and good rate of the operation effect is calculated. The correlation between JOA score and CT imaging parameters are analyzed by Pearson correlation method. The experimental results prove that PTED is effective in treating LDH. CT imaging can quantitatively measure the data of herniated intervertebral discs to clarify the recovery of the compressed dural sac and nerve roots, and the results are highly consistent with JOA score, which can be used as PTED objective evaluation method for the treatment of LDH.

1. Introduction

Lumbar disc herniation (LDH) is a common clinical disease. It is mostly caused by the degeneration of lumbar disc and the rupture of intervertebral disc fibrous ring caused by external force, which makes the nucleus pulposus protrude from the rupture. LDH patients often suffer from lumbar pain and numbness of one or both lower limbs due to compression of adjacent spinal nerve roots. Surgery is the first choice for the clinical treatment of LDH, but the traditional posterior fenestration of nucleus pulposus will cause great damage to the paravertebral muscles, and there is a risk of spinal instability [1].

Percutaneous transforaminal endoscopic discectomy (PTED) is a minimally invasive spinal surgery. It can greatly reduce the surgical trauma and reduce the risk of postoperative spinal instability in patients with LDH with satisfactory results [2]. Imaging can intuitively evaluate the improvement of LDH in patients with LDH. CT examination can accurately reflect the shape, size and location of LDH, evaluate the anatomical structure of lumbar disc before and after operation, and can be used to evaluate the curative effect of LDH patients [3]. In this study, 105 patients with LDH are taken as an example to explore the value of CT imaging in evaluating the efficacy of PTED in the treatment of LDH.

The rest of this paper is organized as follows: Section 2 discusses related work, followed by clinical data and the proposed methods designed in Section 3. Section 4 shows the experimental results and analysis, and Section 5 is a summary of full text, which sums up the purpose of drafting and point to the future work.

2. Related Work

For a long time, the surgery of LDH is mainly open surgery, which requires stripping paravertebral muscle tissue and removing part of articular process and lamina, which is easy to cause postoperative complications such as spinal canal stenosis and spinal instability [4]. In recent years, minimally invasive methods have gradually been widely used in patients with LDH,
and the effect has been recognized. In this study, 105 patients with LDH were treated with PTED, and their waist and leg functions were significantly improved after surgical treatment. The excellent and good rate of Japanese Orthopaedic Association (JOA) 6 months after operation was as high as 90.48%. PTED directly removes the protruding intervertebral disc nucleus pulposus and protrusions from the safe triangular approach under the normal intervertebral foramcn, which can effectively reduce tissue damage, ensure spinal stability, and reduce the risk of spinal canal stenosis and spinal instability. Therefore, patients can obtain ideal waist and leg function [5, 6]. PTED operation is close to direct vision, which is conducive to clearly identify the prominent disc tissue, broken fibrous ring, compressed nerve root and dural sac, accurately remove the nucleus pulposus, and retract the prominent fibrous ring through decompression. Retract the tongue mouth of the working channel to the lateral recess or intervertebral foramcn area and remove the adherent and nonretracted disc tissue under the microscope to achieve secondary decompression [7, 8]. Zhang et al. [9] confirmed that PTED can effectively improve the intervertebral foramcn stenosis and lateral recess stenosis in patients with LDH, which is conducive to the improvement of waist and leg function.

JOA score is an important means to evaluate the surgical efficacy, and waist and leg function, but it has a certain degree of one sidedness and subjectivity, which makes imaging evaluation gradually become one of the important means to evaluate the surgical efficacy of patients with LDH. CT can evaluate the curative effect of LDH patients in the following three aspects: (1) The change of operation area density. After PTED, epidural fat is locally replaced by scar tissue with local fibrosis [10, 11], so the CT value of spinal canal soft tissue shadow will be reduced. In this study, the CT value of spinal canal soft tissue shadow 1 week after operation was (36.75 ± 8.79) Hu, which was lower than that before operation (48.43 ± 9.73) Hu, which was consistent with the conclusions of previous studies [12, 13]. (2) The size and morphology of herniated intervertebral disc. This study mainly measured the maximum retrogression distance and longitudinal axis length of patients with LDH before and after operation to reflect the morphological changes of LDH. The maximum backward displacement mainly reflects the compression of the herniated intervertebral disc on the dural sac and nerve root. The length of the longitudinal axis reflects the filling degree of the lateral fossa and intervertebral foramcn of the spinal canal [14]. In this study, the maximum backward displacement distance and longitudinal axis length of patients 1 week after operation were significantly reduced compared with those before operation, suggesting that the compression of herniated intervertebral disc tissue on dural sac and nerve root was reduced, and the stenosis of intervertebral foramcn and lateral recess were improved. (3) Intervertebral space height. PTED needs to reduce compression and pain by taking out a large amount of protruding disc tissue. The intervertebral disc is the filling material between vertebrae, and partial removal will cause the change of intervertebral space height. The implementation of PTED should minimize the decrease of intervertebral space height on the premise of ensuring the removal of protruding intervertebral disc tissue [15, 16].

In [17], 40 patients with LDH were treated with PTED. The intervertebral space heights before and after operation were (4.91 ± 0.49) mm and (4.57 ± 0.46) mm, respectively, with no significant difference ($P > 0.05$). In this study, the postoperative intervertebral space height of 105 patients was slightly lower than that before operation, but the difference was not statistically significant ($P > 0.05$). It was consistent with the above research conclusions, indicating that the implementation of PTED can effectively reduce the loss of intervertebral height and restore and maintain intervertebral height.

3. Clinical Data and the Proposed Methods

3.1. Clinical Data. 105 patients with LDH treated in our hospital from March 2018 to September 2019 are selected as the research objects. All patients show simple recurrent lumbar pain or sciatic nerve radiation pain or neurogenic claudication. There are 50 males and 55 females patients. The age ranged from 35 to 66 years, with an average of (44.21 ± 7.68) years. The course of disease ranged from 3 to 14 months, with an average of (9.89 ± 2.23) months. Lesion locations are as follows: L3-4 space with 7 cases, L4-5 space with 48 cases, and L5-S1 space in 25 cases. LDH type includes 37 cases of central type and 68 cases of lateral type.

There are five inclusion criteria as follows: (1) After 3 months of conservative treatment, the symptoms still occurred repeatedly. (2) LDH is confirmed by lumbar MRI and CT before operation. (3) Single segment disc herniation or prolapse. (4) The patients are followed up 6 months after operation. (5) Sign informed consent.

There are eight exclusion criteria as follows: (1) Patients with obvious calcification of intervertebral disc. (2) Previous lumbar surgery history. (3) Patients with intervertebral disc infection, deformity, and tumor. (4) Patients with severe organ dysfunction. (5) Imaging showed lumbar instability and spinal canal stenosis. (6) The iliac crest is too high and blocked the surgical approach. (7) Imaging showed that the compression came from behind the dura mater. (8) Those with screws in thoraco-lumbar spine.

3.2. The Proposed Method

3.2.1. Surgical Methods. The MAXMORE percutaneous foraminal endoscopic surgical system (Germany) is used to measure the relevant angles and distances on the anterior and lateral X-ray, CT, and MRI films of the lumbar spine before operation and design the targeted puncture path and target according to MSULDH classification. Local anesthesia with 1% lidocaine combined with intravenous analgesia is used. The patients are prone with empty abdomen. The lumbar spine is flexed forward by adjusting the operating table to fully expose the posterior side of the intervertebral space. Body surface positioning is set as the midline of the spinous process; the horizontal line of the target intervertebral space and the line connecting the iliac crest on the affected side. Horizontal line along the highest point of the iliac spine is marked, and then a diagonal line from the highest point of the iliac spine to the center of the lumbar 5 sacral
1 intervertebral disc is made to jointly determine the direction and angle of puncture. On the lateral image, mark the line through the posterior edge of the lower vertebral body, and the intersection with the above horizontal line is the puncture point. At the same time, the connecting line of the upper edge of the articular process is marked. The secondary line is the safety line. The puncture needle shall not be lower than this safety line to avoid the injury of important blood vessels and organs in the abdominal cavity. Puncture the shoulder of the upper articular process under C-arm X-ray fluoroscopy, inject 0.5% lidocaine for local anesthesia of the articular process, insert the guide wire, cut the skin about 8 mm, and insert the expansion sleeve and working sleeve step by step along the guide wire to expand the soft tissue channel. Tom needle is placed, hammer to the preoperative design target under frontal and lateral fluoroscopy, and guide wire is placed. Along the guide wire, the ventral side of part of the upper articular process is ground with 4, 6, 7, and 8 mm bone grinding drill to expand and form the intervertebral foramen. Working cannula is placed to the preoperative planning target, and then percutaneous spinal endoscopy is placed. Turn the inclined plane of the surgical channel to the direction of the nerve root and complete the operations such as nucleus pulposus extraction, nerve root decompression, and annulus fibroplasty under endoscope. Remove the working cannula, stop bleeding, suture, and press bandage. Antibiotics are routinely used 24 hours after operation, absolutely lying in bed for 3 days, wearing waist circumference protection for 4 ~ 6 weeks after discharge, moderate straight leg lifting exercise, and avoiding violent activities within 3 months after operation.

3.2.2. CT Examination before and after Operation. All cases are scanned by Siemens Somatom Definition dual source spiral CT before and after operation. The voltage is 120 kV, the current is 380 Ma, the layer thickness is 0.625 mm, the spacing is 0.625 mm, and the pitch is 1.375. The scanned data is transmitted to AW4.3 workstation for analysis and multiplanar reconstruction. Two experienced imaging physicians shall read the film and try to ensure that the slice, position, and direction of the image are consistent when reading relevant information and parameters.

3.3. Observation Indicators
3.3.1. CT Image Analysis. All patients undergo CT imaging examination before and 1 week after operation. The CT signs before and after operation are observed, and CT related parameters are recorded, including the CT value of spinal canal soft tissue shadow, the maximum backward displacement distance of herniated intervertebral disc, the length of longitudinal axis, and the height of intervertebral space. These relevant parameters are measured as follows: draw a straight line (line a) along the posterior edge of the adjacent vertebral body of the diseased intervertebral space and make a straight line (line b) tangent to the last edge of the
herniated intervertebral disc parallel to line a. (1) Maximum backward distance: the shortest distance between line segments a and b. (2) Length of longitudinal axis: the linear distance between the midpoint of line a and the farthest point of herniated intervertebral disc. (3) Intervertebral space height: the height of vertebral body and intervertebral space on sagittal CT image.

3.3.2. Follow Up. Results all patients are followed up to 6 months after operation. The functional recovery is evaluated by the JOA low back pain score standard (JOA score 29) [18], expressed by the improvement rate. Improvement rate = [JOA score difference before and after operation] / (29 – preoperative JOA score) × 100%. The improvement rate >75% is regarded as excellent, 50%~74% is regarded as good, 25%~49% is regarded as average, and <24% is regarded as poor. The excellent rate is also calculated.

3.4. Statistical Methods. SPSS19.0 is used for statistical analysis. The counting data are expressed in case (%), and χ² test is used for comparison. The measurement data (x ± s) show that repeated measurement analysis of variance is adopted for comparison at different time points, and t-test is adopted for pairwise comparison. The difference is statistically significant with P < 0.05. The correlation is analyzed by Pearson correlation method.

4. Experimental Results and Analysis

4.1. CT Image Analysis. Preoperative CT examination of lumbar intervertebral disc shows a protruding soft tissue mass, which protrudes into the spinal canal in a crescent or semicircular shape. At the same time, there are compression, deformation, and displacement of dura mater at the protruding part of the spinal canal, which shows lateral displacement or deformation changes. The nerve roots at the protruding part of the spinal canal of the patient shifted inward or outward and backward due to swelling or compression. Figure 1 shows the preoperative CT examination results of lumbar intervertebral disc. It is clear evident from Figure 1 that cortical eminence and hyperplastic osteophyte can be seen on the inner side of some superior articular processes, and the dura mater is compressed and deformed. Figure 2 shows a week after operation CT examination results of lumbar intervertebral disc. It is can be seen from Figure 2 that the intervertebral foramen is enlarged and shaped after the ventral grinding of part of the superior articular process with bone grinding drill; the contour of the intervertebral disc is smooth, and the dural sac at the spinal canal operation site changed from the previous round to more smooth due to reduced compression. The display of the nerve root is vague, and the straight leg is raised up to 70° after operation.
Table 1: Comparison of CT image parameters before and after operation (x ± s).

| Time                  | Case | HU      | Distance (mm) | Length (mm) | Height (mm) |
|-----------------------|------|---------|---------------|-------------|-------------|
| Preoperative          | 105  | 48.43 ± 9.73 | 5.95 ± 1.71   | 8.99 ± 2.86 | 4.77 ± 0.72 |
| 1 week after operation| 105  | 36.75 ± 8.79  | 2.84 ± 0.82   | 4.73 ± 1.02 | 4.60 ± 0.69 |
| t                     | 9.128| 0.001   | 16.804        | 13.671      | 0.755       |
| P                     | 0.001| 0.001   | 0.001         | 0.451       |             |

Table 2: Comparison of CT image parameters of patients with different curative effects 1 week after operation (x ± s).

| Time                  | Case | HU      | Distance (mm) | Length (mm) | Height (mm) |
|-----------------------|------|---------|---------------|-------------|-------------|
| Excellent             | 57   | 32.76 ± 4.43* | 2.37 ± 0.45*  | 4.22 ± 0.82* | 4.53 ± 0.71 |
| Good                  | 38   | 36.26 ± 5.77* | 2.76 ± 0.51*  | 4.64 ± 0.85* | 4.60 ± 0.76 |
| Neutralization difference | 10 | 38.84 ± 7.99** | 2.97 ± 0.55** | 5.31 ± 1.06** | 4.73 ± 0.81 |
| F                     | 8.381| 11.307  | 8.018         | 0.349       |             |
| P                     | 0.001| 0.001   | 0.001         | 0.707       |             |

Table 3: Correlation between JOA score and CT related parameters.

| CT parameters                                   | JOA score | r   | p     |
|-------------------------------------------------|-----------|-----|-------|
| CT value of soft tissue shadow of spinal canal   | -0.453    | <0.001 |     |
| Maximum backward distance                       | -0.378    | <0.001 |     |
| Length of longitudinal axis                     | -0.398    | <0.001 |     |
| Disc height                                     | -0.173    | 0.077 |     |

4.2. Analysis of CT Image Parameters before and after Operation. Table 1 shows the comparison of CT image parameters before and after operation. In Table 1, HU represents the CT value of soft tissue shadow of spinal canal; Distance represents the maximum backward distance and the maximum backward distance; Length represents the length of longitudinal axis; Height represents the disc height. It can be seen from Table 1 that the CT value of spinal canal soft tissue shadow, the maximum backward displacement distance, and the length of longitudinal axis are lower than those before operation (P < 0.05) a week after operation. There is no significant difference in intervertebral space height before and after operation (P > 0.05).

4.3. Follow Up Results. Table 2 shows the comparison of CT image parameters of patients with different curative effects 1 week after operation. In Table 2, HU represents the CT value of soft tissue shadow of spinal canal; Distance represents the maximum backward distance and the maximum backward distance; Length represents the length of longitudinal axis; Height represents the disc height. Compared with excellent grade, *P < 0.05; Compared with good grade, #P < 0.05. It can be seen from Table 2 that the JOA score of LDH patients before operation is (8.91 ± 2.63) (4~17), which is increased to (22.86 ± 4.59) (20~28) 6 months after operation. The difference is statistically significant (t = 126.159, P ≤ 0.001). After 6 months of follow-up, the JOA evaluation results of 105 patients showed that 57 cases are excellent, 38 cases are good, 8 cases are medium, and 2 cases are poor. The excellent and good rate is 90.48% (95/105). There are significant differences in CT value, maximum backward displacement distance and longitudinal axis length of spinal canal soft tissue shadow among excellent, good and poor patients. Among them, excellent patients are higher than good and poor, and good patients are also higher than poor (P < 0.05). There is no significant difference in intervertebral space height between patients with different curative effects (P > 0.05).

4.4. Correlation Analysis. Table 3 shows the correlation between JOA score and CT related parameters. It is can be seen from Table 3 that there is a significant negative correlation between JOA score and CT value of spinal canal soft tissue shadow, maximum backward displacement distance, and longitudinal axis length (P < 0.05). There is no significant correlation between intervertebral space height and JOA score (P > 0.05).

The results of correlation analysis show that the JOA score of patients is significantly negatively correlated with the CT value of spinal canal soft tissue shadow, the maximum backward displacement distance, and the length of longitudinal axis (P < 0.05), indicating that the results of efficacy evaluation by using the relevant parameters of CT imaging examination are significantly correlated with the JOA score evaluation results. It is feasible to evaluate the efficacy of LDH by CT imaging.

5. Conclusion

The value of CT imaging in evaluating the efficacy of PTED in the treatment of LDH is explored. PTED is effective in the treatment of LDH. CT imaging can quantitatively measure the relevant data of herniated intervertebral disc to reflect its morphological changes and clarify the recovery of
compressed dural sac and nerve root. The experimental results are highly consistent with JOA score, which can make up for the lack of strong subjectivity of JOA score and can be used as an objective evaluation method for the postoperative efficacy of PTED in patients with LDH.

Data Availability

The simulation experiment data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors’ Contributions

Guilan Tao and Hui Shi are cofirst authors. All authors contributed equally to this work.

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