



Significance of spinal canal and dural sac dimensions in predicting treatment of lumbar disc herniation

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This retrospective study was performed to investigate the significance of quantitative MRI measurements of spinal canal and dural sac dimensions for treatment decisions and clinical outcome of lumbar disc herniation. 182 patients (111 nonsurgical patients and 71 surgical patients) were included, while 78 nonsurgical patients and 50 surgical patients were enrolled in the final follow-up. The initial JOA score in nonsurgical patients was significantly superior to surgical patients (t-test : $p < 0.001$), whereas the final JOA score and the rate of improvement were not significantly different between the two groups of patients (t-test : $p > 0.05$). 88.46% of nonsurgical patients and 90.00% of surgical patients had a good or excellent outcome (chi-square test : $p > 0.05$). However, if the 16 recurrent cases were included, the proportions dropped to 75.82% and 84.90% for nonsurgical and surgical patients, respectively. Compared with nonsurgical patients, quantitative parameters, such as midsagittal diameter and available diameter of spinal canal, lateral recess width and cross-sectional areas of spinal canal and dural sac, were significantly smaller in surgical patients (t-test : $p < 0.001$), and was reflected in the initial JOA score (128 cases ; Spearman rank correlation coefficient : $r_{0.01} = 0.486, 0.499, 0.493, 0.507, 0.484$; $p < 0.001$). The spinal canal and dural sac dimensions were important predictive factors for treatment selection of lumbar disc herniation.

Keywords : lumbar disc herniation ; spinal canal ; dural sac ; MRI ; parameter ; treatment.

INTRODUCTION

Conservative treatment and surgery are the primary therapies for lumbar disc herniation (LDH). Many investigators have shown satisfactory short-term outcomes following surgical treatment. Nevertheless, long-term outcomes do not differ significantly between conservative treatment and surgery (6,8,11,13), leading to controversy in regard to the need for surgery. The recommendation for surgery is primarily dependent on a patient's clinical symptoms, but morphological characteristics of disc herniation, identified by imaging diagnosis, should not be ignored. Morphological characteristics of disc herniation have been reported to be much more powerful predictors for surgery and

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clinical outcome in lumbar disc herniation (1,2). Spinal canal and dural sac dimensions have also been suggested to play a role in discriminating symptomatic from asymptomatic lumbar disc herniation (3,9). However, the predictive value of spinal canal and dural sac dimensions are inconclusive for surgery. The aim of this retrospective controlled study is to determine the parameters related to spinal canal and dural sac dimensions, by quantitative magnetic resonance imaging (MRI) measurements, compare them to clinical symptoms, and further investigate their clinical significance for treatment decisions of lumbar disc herniation.

PATIENTS AND METHODS

Patients

In this retrospective controlled study, 182 patients were selected from a pool of 242 patients with lumbar disc herniation who underwent treatment in the Second Affiliated Hospital of Shantou University Medical College from 2009 to 2011. Inclusion criteria were : 1) first hospitalization ; 2) age between 18-68 years ; 3) complaint of back pain with sciatica ; 4) MRI-confirmed single-level disc herniation at L4/5 or L5/S1 ; and 5) complaints were consistent with the MRI findings. Exclusion criteria were : 1) age over 68 or less than 18 ; 2) more than one symptomatic level ; 3) MRI-confirmed intraforaminal, prolapsed and ruptured or sequestered disc herniation ; 4) recurrent disc herniation ; 5) conservative treatment for less than one month ; 6) prior lumbar spine surgery ; 7) cauda equina syndrome ; 8) scoliosis and spondylolysis ; 9) tuberculosis, infection, tumor, or metabolic bone disease ; 10) extra spinal causes of sciatica ; or 11) pregnancy and severe co-morbid conditions. There were 76 females and 106 males. The average age was 45 years (range : 20 to 68 years). 79 patients with L4/5 herniation, and 103 patients with L5/S1 herniation. 110 patients had paracentral herniation, and 72 patients had central herniation. 111 patients were treated non-surgically, and 71 patients had standard open microdiscectomy.

Follow-up and Assessment

At least 2 years later, 182 patients were reviewed (Fig. 1). Outcome score was recorded before treatment and after follow-up, according to the Japanese Orthopaedic

Association (JOA) Back Pain Evaluation Questionnaire (5). 29 points was the best possible score. The rate of improvement (RI) was calculated by dividing the post-treatment score minus the pre-treatment score by 29 minus the pre-treatment score, and multiplying by 100. Improvement $\geq 75\%$ was seen as excellent, 50-74.99% improvement as good, 25-49.99% improvement as fair, and $< 25\%$ improvement as poor. Recurrent lumbar disc herniation was also considered poor.

Parameters and Measurements

Digital measurements were taken from initial MRI images, using the Picture Archiving and Communication System (PACS). The parameters at L4/5 and L5/S1 levels were separately quantified by the same investigator in a blinded fashion. The midsagittal diameter of the canal (MDC), available diameter of the canal (ADC) and lateral recess width (LRW) were directly measured. The canal cross-sectional area (CCSA) and dura cross-sectional area (DCSA) were measured after the borders were traced using the magnetic lasso tool on the axial T2-weighted images (3,9) (Fig. 2-4). The lateral recess widths on both sides were measured and averaged for central herniation, and on one side for paracentral herniation.

Statistical analysis

Data were analyzed with IBM SPSS Statistics 20.0 software. Continuous data, such as JOA scores, RI and quantitative parameters were analyzed with Student's t-test. Categorical data such as gender, herniation level, herniation type, and combined excellent and good rates of JOA scores were analyzed with the chi-square test. Correlation between initial JOA scores and quantitative parameters were evaluated with the Spearman correlation test. Continuous data were presented as the mean and standard deviation, categorical data were calculated using percentage. The level of statistical significance was set at $p < 0.05$.

RESULTS

All 182 patients were followed up for more than two years, while 38 patients (21%) were lost to follow-up for various reasons. Patients who were re-examined were divided into two groups based on treatment. 78 non-surgical patients (86%) and 50 surgical patients (94%) responded effectively, but

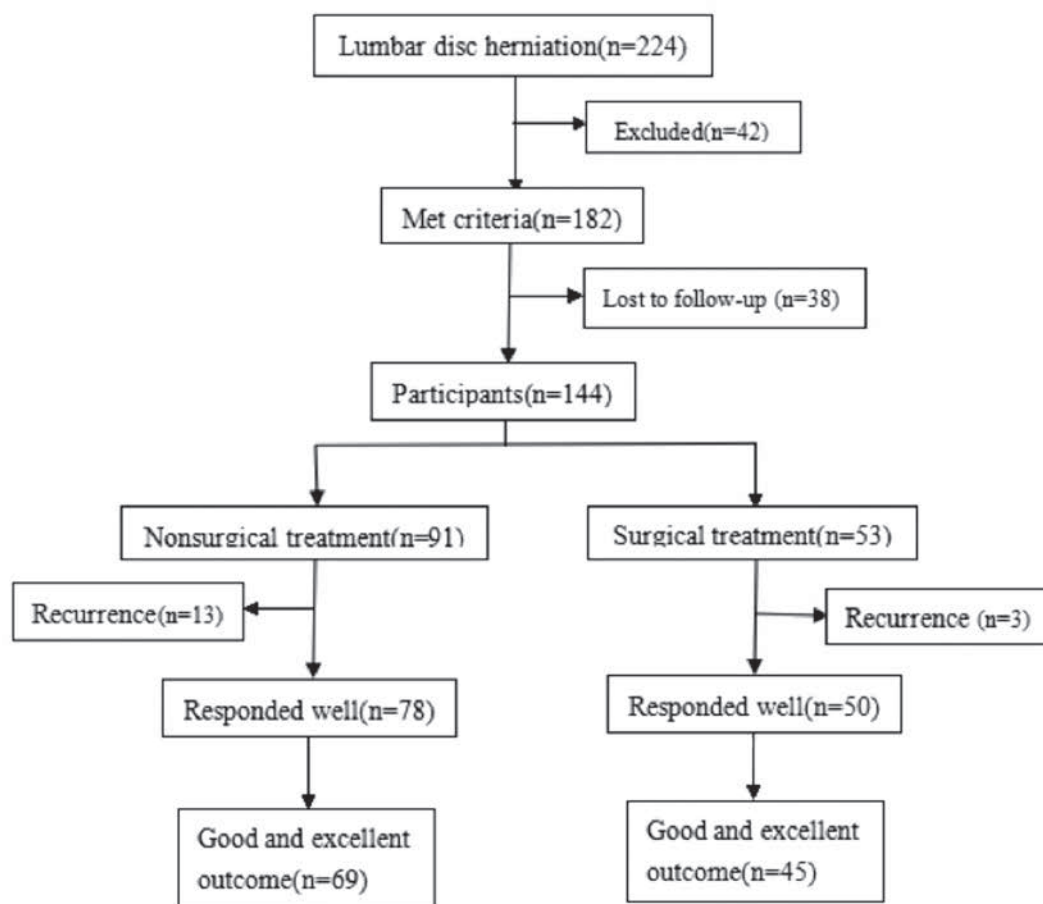


Fig. 1. — Flow chart of review

13 nonsurgical patients and 3 surgical patients underwent further retreatment because of no effect (Fig. 1). For all criteria, except for symptoms (chi-square test: $p < 0.001$) and duration (t-test: $p < 0.05$), there were no statistically significant differences between the two groups (chi-square test and t-test: $p > 0.05$) (Table I).

The initial JOA score in the nonsurgical group of 78 patients (16.27 ± 2.96) was significantly superior to the surgical group of 50 patients (12.64 ± 3.30) (t-test: $p < 0.001$). However, the final JOA score (25.41 ± 2.22 versus 25.76 ± 2.29) and the mean RI ($72.95\% \pm 12.54\%$ versus $76.80\% \pm 9.45\%$) did not differ significantly between nonsurgical and surgical groups (t-test: $p > 0.05$). Also the excellent and good outcomes (88.46% versus 90.00%) were

similar in both groups (chi-square test: $p > 0.05$) (Table II). However, if the 16 recurrent cases were included, the percentage of excellent and good outcomes dropped to 75.82% in the nonsurgical patients vs. 84.90% in the surgical patients.

Generally, compared with nonsurgical patients, all quantitative parameters of spinal canal and dural sac obtained from MRI images were significantly smaller in surgical patients (t-test: $p < 0.001$). There were also significant differences at the L4/5 and L5/S1 levels (t-test: $p < 0.05$) (Table III). Moreover, there were definite correlations between the initial JOA score and MDC, ADC, LRW, CCSA, and DCSA (Spearman rank correlation coefficient: $r = 0.01 = 0.486, 0.499, 0.493, 0.507, 0.484$; $p < 0.001$) (Table III).

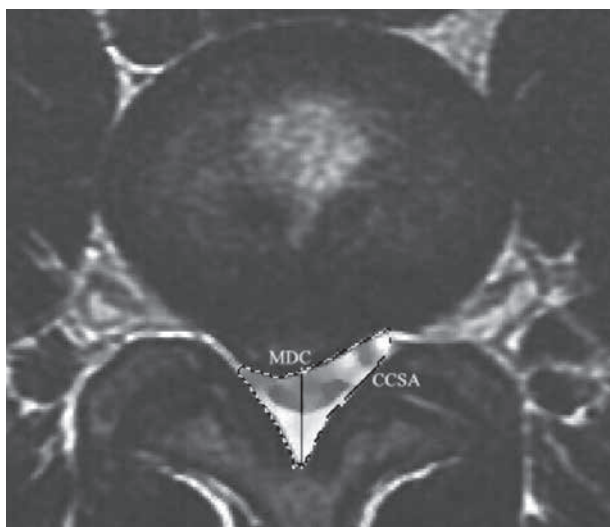


Fig. 2. — Axial T2-weighted MR image of the lumbar spine. The sketch map for measuring the midsagittal diameter of the canal (MDC) and canal cross-sectional area (CCSA).

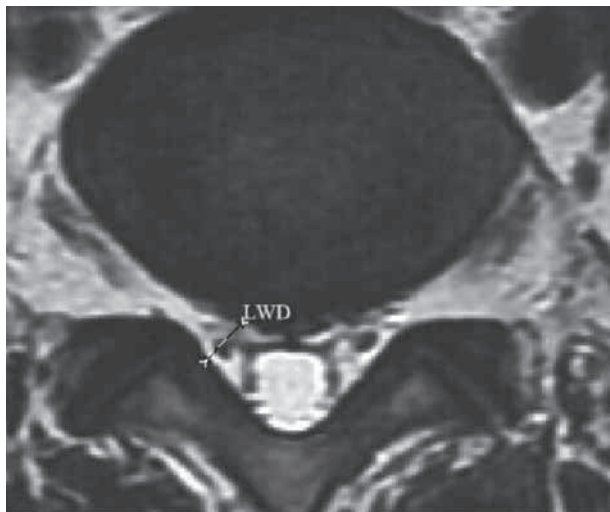


Fig. 3. — Axial T2-weighted MR image of the lumbar spine. Sketch map for measuring the lateral recess width (LRW).

DISCUSSION

Treatment and outcome of LDH

For decades, different recommendations and comparisons among surgical and conservative treatment for patients with lumbar disc herniation have been published, but long-term outcomes of surgery

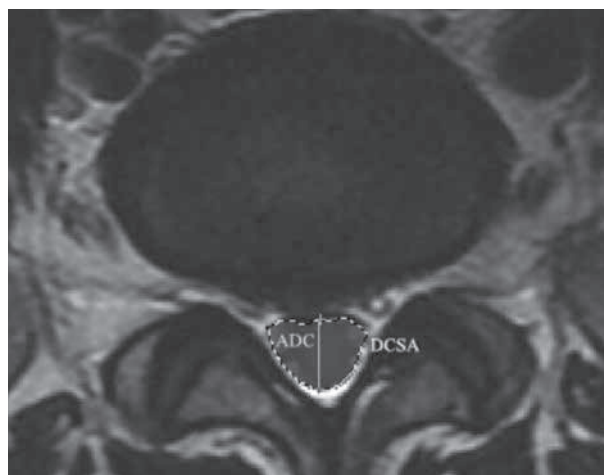


Fig. 4. — Axial T2-weighted MR image of the lumbar spine. Sketch map for measuring the available diameter of the canal (ADC) and dura cross-sectional area (DCSA).

have remained controversial. Weber *et al* (11) performed a landmark randomized clinical trial that showed a statistically significant better outcome for surgery at the one-year follow-up, whereas the difference between surgery and conservative treatment was no longer statistically significant after four years of follow-up (12). Weinstein *et al* (13) and Lurie *et al* (6) also demonstrated that patients who underwent surgery achieved greater improvement than nonsurgical patients, but there was little to no difference in outcomes between either group when evaluated at 4 to 8 years after treatment. This investigation confirmed the results of Peul *et al* (7) that the two-year outcomes of conservative treatment were satisfactory, although early surgery achieved more rapid relief of sciatica. Indeed, there were no significant differences in final JOA score, RI or the percent of excellent and good results between conservative and surgical treatment after two-year follow-up if recurrent cases were excluded in our series of patients. Thus no absolute conclusion can be drawn that surgery is superior to conservative treatment.

Correlation between treatment and imaging features

Clinical symptoms of lumbar disc herniation are more clearly associated with compromised dura and

Table I. — Patient's baseline demographic characteristics and clinical finding

	Nonsurgical treatment (n = 91)	Surgical treatment (n = 53)
Age (range)	43.37 years (20-68 years)	42.98 years (20-64 years)
Gender		
Male	60.44%	52.83%
Female	39.56%	47.17%
Mean duration of symptom (range)*	3.6 months (1 days-2 years)	12.6 months (10 days-7 years)
Herniation level		
L4/5	47.25%	43.40%
L5/S1	52.75%	56.60%
Herniation type		
Paracentral herniation	54.95%	66.04%
Central herniation	45.05%	33.96%
Subjective symptoms and Objective findings ^Δ		
Low back and/or leg pain	100%	100%
Leg numbness	38.46%	66.04%
Lumbar dysfunction	93.41%	86.79%
Claudication	23.08%	49.06%
Sensory disturbance	46.15%	77.36%
Motor weakness	38.46%	67.92%
Reflexes weakness	14.63%	47.17%
SLR tests (+)	81.32%	86.79%
Bladder function	0%	11.32%

* = p < 0.001.

Table II. — Comparison of the efficacy before and after treatment between nonsurgical and surgical patients

Group	Initial JOA score	Final JOA score	RI (%)	Excellent result	Good result	Fair result	Poor result	Excellent and good results (%)
Nonsurgical group (n = 78)	16.27 ± 2.96	25.41 ± 2.22	72.95 ± 12.54	42	27	9	0	88.46
Surgical group (n = 50)	12.64 ± 3.30*	25.74 ± 2.29	76.80 ± 9.45	31	14	5	0	90.00

JOA = Japanese Orthopaedic Association: 29 = best possible result; RI = Rate of Improvement.

* = p < 0.001 ; ^Δ = p < 0.001.

nerve root, so that treatment and clinical outcome are considered to depend on the morphological characteristics of disc herniation. Thelander *et al* (10) provided a practical and accurate way of linear measurement to describe the size of disc herniation, and found that the absolute and relative size of disc herniation correlates with the severity of sciatica. Carragee *et al* (2) and Carlisle *et al* (1) suggest that a smaller anteroposterior diameter and area of disc herniation are associated with better nonsurgical outcome, while a larger percentage of canal compromise, due to larger area of disc herniation, as well as a smaller canal cross-section area, is more likely to fail conservative treatment. Nevertheless,

Halldin *et al* (4), using a new three-dimensional system, found there is no relation between the distribution or size of disc herniation and surgical outcome at the 2-year follow-up. The ability to predict the need for surgery, based on size and location of disc herniation, is inconsistent. Pneumáticos *et al* (9) and Dora *et al* (3) concluded that the spinal canal and dural sac dimensions in symptomatic patients were significantly smaller than those in asymptomatic patients, and were important factors in discriminating the two groups of patients. Thus it is speculated that the spinal canal and dural sac dimensions should also be taken under consideration in the decision to treat lumbar disc herniation.

Table III. — Quantitative parameters obtained from MRI images in nonsurgical and surgical patients

Parameter	Nonsurgical group (n = 78)			Surgical group (n = 50)		
	Total	L4/5	L5/S1	Total	L4/5	L5/S1
MDC (mm)	8.65 ± 1.73	9.11 ± 1.71	9.17 ± 1.64	6.93 ± 1.72*	6.76 ± 1.67 ^Δ	7.10 ± 1.80 [∇]
ADC (mm)	6.23 ± 1.77	5.95 ± 1.76	6.52 ± 1.75	4.52 ± 1.74*	3.75 ± 1.29 ^Δ	5.32 ± 1.80 [▲]
LRW (mm)	3.21 ± 1.04	3.09 ± 1.02	3.47 ± 1.17	2.36 ± 0.87*	2.09 ± 0.75 ^Δ	2.42 ± 0.94 [▲]
CCSA (mm ²)	176.18 ± 70.71	161.69 ± 59.81	191.01 ± 78.29	114.58 ± 54.96*	91.97 ± 41.39 ^Δ	138.01 ± 58.08 [∇]
DCSA (mm ²)	100.79 ± 43.40	103.32 ± 46.46	98.20 ± 40.40	70.95 ± 34.34*	92.46 ± 30.92 ^Δ	79.77 ± 36.03 [▲]

MDC = midsagittal diameter of canal ; ADC = available diameter of canal ; LRW = lateral recess width ; CCSA = canal cross-sectional area ; DCSA = dural sac cross-sectional area.

* = p < 0.001 ; ^Δ = p < 0.001 ; [∇] = p < 0.01 ; [▲] = p < 0.05.

Table IV. — Correlation between initial JOA score and quantitative parameters in 128 patients

Parameter	Correlation coefficient (p value)		
	Total	L4/5	L5/S1
MDC	0.486 (0.000)	0.498 (0.000)	0.478 (0.000)
ADC	0.499 (0.000)	0.526 (0.000)	0.507 (0.000)
LRW	0.493 (0.000)	0.539 (0.000)	0.466 (0.000)
CCSA	0.507 (0.000)	0.534 (0.000)	0.517 (0.000)
DCSA	0.848 (0.000)	0.509 (0.000)	0.455 (0.000)

MDC = midsagittal diameter of canal ; ADC = available diameter of canal ; LRW = lateral recess width ; CCSA = canal cross-sectional area ; DCSA = dural sac cross-sectional area.

This study demonstrates a new method to evaluate the correlation between radiological characteristics and treatment of lumbar disc herniation by measuring the remaining spinal canal and dural sac dimensions on the initial MRI image, which is more simple and effective compared with direct measurement of disc herniation as reported in literature. The results of this study indicate that the compromised dura and nerve root in surgical patients is more serious than in non-surgical patients, and the quantitative parameters support clinical criteria in treatment selection of lumbar disc herniation based on the strong correlation with initial JOA score. In conclusion, this retrospective study suggests that spinal canal and dural sac dimensions on initial MRI images were important predictive factors for lumbar disc herniation in assisting decision making for surgery or nonsurgical treatment. However, further studies are needed to investigate utility and validity of the predictive value of spinal canal and dural sac dimensions. At the current time, MRI is paramount

in the diagnosis and treatment planning of lumbar disc herniation, and a better understanding of such parameters may assist in selecting the appropriate treatment to improve outcome. Although clinical symptoms remain the most important determinant for treatment decisions of lumbar disc herniation, the radiographic characteristics, such as size and location of disc herniation, spinal canal and dural sac dimensions, dura and nerve root compromise and their spatial relationship should be taken into consideration.

Limitations

The current study has several limitations : small sample size, short follow-up time, single evaluation of outcome with JOA score, and MRI scans performed at different time points. In addition, the notable weaknesses of this study is that the generalizability of the conclusions is uncertain because the investigation was conducted in a single center and

randomization was not part of the experimental design. Thus the utility and validity should be confirmed in a larger number of cases via randomized controlled trials in subsequent studies.

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