Three-dimensional radiological classification of lumbar disc herniation in relation to surgical outcome

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Abstract Centrally located lumbar disc herniations have been reported to be of predictive value for poor post-operative clinical outcome. One hundred and fifty patients undergoing lumbar disc herniation surgery were prospectively included. Herniation-related parameters, including the grading of contours, were assessed from pre-operative computed tomography (CT) and magnetic resonance imaging (MRI) images using a new three-dimensional grading system. The radiological findings were compared with outcome parameters two years post-operatively (patient-assessed pain, function/health scores and evaluation by an independent observer). An intra- and inter-observer validation of the classification was performed in a subgroup of patients. High intra-observer and good inter-observer reliability for both CT and MRI was seen. In the study population, no relation between the distribution or size of the herniations and outcome at 2-year follow-up were found. The distribution and size of the lumbar disc herniations with the three-dimensional classification were not found to be of importance for the clinical outcome.

Résumé Les hernies discales lombaires sur la partie centrale du disque ont été accusées d'entraîner une évolution clinique

peu satisfaisante. Matériel et méthode : 150 patients ayant présenté une hernie discale lombaire opérée ont été inclus de façon prospective. Les paramètres relatifs à la hernie ont été classés à l'aide du scanner et de l'IRM en utilisant un système de classement tridimensionnel. Les paramètres radiologiques ont été comparés aux paramètres d'évolution clinique en post-opératoire (douleur-fonction) et évalués par un observateur indépendant en utilisant le score de Macnab avec une étude intra et inter observateurs pour chaque sous-groupe de patients. Résultats, il n'a été trouvé aucune relation significative entre l'évolution et la localisation de la hernie à deux ans de suivi post-opératoire. En conclusion : la localisation et l'aspect de la hernie n'ont pas d'influence sur le devenir clinique des patients.

Introduction

Patients undergoing surgery for lumbar disc herniation report less favourable clinical results using different outcome criteria in 10–30% of cases [1]. Various factors of predictive value for the clinical outcome have been identified [3, 6, 10]. Morphological characteristics have been suggested to play a role. A correlation between morphology based on surgical findings and clinical outcome has been reported [9, 10]. Pre-operative studies of disc herniation morphology are dependent on imaging technology, such as computed tomography (CT) and magnetic resonance imaging (MRI). MRI is increasingly used for primary investigation. Using these techniques, an association between central and multi-regional distribution of the herniation and poor clinical outcome has been reported [2, 4]. To further evaluate the importance of the distribution of the disc herniation for the post-operative result, a detailed new three-dimensional radiological classification has been created.

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Thus, the aim of our study was to determine radiological characteristics related to the distribution and size of lumbar disc herniations and other pathological findings on pre-operative CT and MRI images, compare them to peri-operative findings and analyse their importance for the 2-year outcome following surgery.

Materials and methods

Patients

One hundred and fifty patients (mean age 40.2 years, median SD 11.1) referred to Sahlgrenska University Hospital between 1997 and 2002 and selected for the surgical treatment of lumbar disc herniation at the L4–L5 or L5–S1 level were prospectively included in the study. Patients with prior surgery on the same level or other spinal disorders were not included. Informed consent was obtained from all participating patients. The study population comprised 81 men (54%) and 69 women (46%). Pre-operative CT was performed in 106 patients (71%) and MRI in 44 patients (29%). Sixty-seven patients (45%) underwent surgery at the L4–L5 level and 83 (55%) at the L5–S1 level. A partial discectomy, i.e. herniated disc material and the removal of loose disc fragments from the dorsal aspect of the disc, was carried out. The finding was categorised as sequestered herniation, contained herniation, disc protrusion or normal disc. The study was approved by the Regional Ethical Review Board.

Evaluation of pre-operative films

Grading of the distribution and the size of disc herniation

A new grading used to standardise the evaluation of the size and distribution of a disc herniation was used. The

grading provides determination of the distribution of the disc herniation in the transverse, sagittal and longitudinal planes on pre-operative images (Fig. 1a–c). From these parameters, the estimated size of the herniation and distribution in relation to the midsagittal line (central value) was calculated:

$$\text{size} = \frac{\text{right} + \text{left transverse distribution}}{2} + \text{sagittal distribution} + \text{longitudinal distribution}$$

$$\text{central value} = \text{abs} \left[(\text{right} - \text{left}) \text{transverse distribution} \right]$$

A central value equal to 0 defines a central herniation and a large herniation was defined as size ≥ 8 .

In our study, the pre-operative CT and MRI images were graded by an independent neuro-radiologist blinded to clinical findings and previous reports.

Intra- and interobserver evaluation of the grading system

To evaluate the intra- and interobserver agreement of this grading system, CT and MRI images of an additional 17 patients (14 women and three men), mean age 38.8 years (range 25–58) with lumbar disc herniation were examined with both scanning techniques. Six patients had a disc herniation at the L4–L5 level and 11 at the L5–S1 level.

The CT and MRI films were coded and all annotations were removed. One musculoskeletal radiologist (examiner 1) and one spine surgeon (examiner 2) graded the CT and MRI findings randomly according to the classification day 0 and two weeks thereafter. The 14-day period of the two occasions of CT grading was started one week ahead of the corresponding 14-day period of the MRI.

The levels of agreement were analysed, together with calculation of the mean (SD) for the differences. The degree

Fig. 1 **a** Transverse distribution. The transverse views of the spinal canal were equally divided into four sectors on each side of the midline. **b** Sagittal distribution. The sagittal plane of the spinal canal was divided into four sectors. **c** Longitudinal distribution. The longitudinal distribution of the disc herniations was estimated as being located cranial and/or equal and/or caudal to the level of the disc

of difference between the study groups were analysed using the Fisher's exact test for paired analysis.

Supplementary parameters documented

In addition to the classification of the disc herniation, the presence of dural and/or nerve root compromise and disc height reduction ($>$ or $<$ than 50% of the normal adjacent disc) were noted. The end plate abnormalities on the pre-operative MRI films were graded according to Modic et al. [8].

Pre-operative, peri-operative and follow-up assessments

Pre-operatively, all patients filled out questionnaires, including the visual analogue scale (VAS) score for leg and back pain, Oswestry Low Back Pain Disability Index, Zung Self-Rating Depression Scale and EuroQol.

The surgeons graded the peri-operative finding as sequestration, prolapse, protrusion or no herniation.

At the 2-year follow-up, the patients filled out the same questionnaires as before surgery. An independent observer, a neurologist, examined the patients and graded the post-operative clinical result for each patient as excellent, good, fair or poor according to Macnab [5].

Statistics

Pitman's test (non-parametric) was used, except for the calculation of the relation between re-operation and large/central herniation, where Fisher's permutation test was used. The level of significance was set at $p < 0.05$.

Results

Imaging findings

The results from the radiological classification are presented in Table 1.

Central herniations (central value=0) were found in 20 of the patients (13%), large herniations (size ≥ 8) in 26 patients (17%) and the combination of central and large herniations in nine patients (6%). Nerve root compromise was noted in 144 patients (96%) and dural compromise in 129 patients (86%). Seven patients (5%) had a decrease of $>50\%$ of estimated disc height at the level of the disc herniation. Of the 44 patients examined with MRI, Modic type 0 (normal disc) was found in 31 patients (71%), Modic type 1 in one patient (2%) and Modic type 2 in 12 patients (27%). No patient had Modic type 3 changes.

Neither the size, relation to nerve tissue structures nor signs of disc degeneration demonstrated any correlation to

Table 1 Results of the grading of the pre-operative films by the independent neuro-radiologist according to the proposed classification

Classification parameter (range)	Classification results (median, range)
Transverse right distribution (-4-4)	3 (-3-4)
Transverse left distribution (-4-4)	3 (-3-4)
Total transverse distribution (1-8)	5 (1-8)
Central value (0-7)	2 (0-7)
Sagittal distribution (1-4)	2 (1-4)
Longitudinal distribution (1-4)	2 (1-3)
Size (3-11)	6.5 (2.5-10)

the level of surgery, gender or re-operation. An increasing transverse distribution of the herniations was found with increasing age ($p=0.04$).

Intraobserver analysis (test-retest) of the classification, CT and MRI

The probability of a difference of ≤ 1 sector between examiners 1 and 2 was 0.94–1.00 and 1.00, respectively, for CT and, correspondingly, 1.00 and 0.94–1.00 for MRI. When comparing the mean grading of day 0 and day 14, the probability of a difference of ≤ 0.5 sectors was 0.88–1.00 for CT and 0.88–0.94 for MRI, respectively, and 0.94–1.00 and 1.00, respectively, of a difference of ≤ 1 sector.

Interobserver analysis of the classification, CT and MRI

The probability of a difference of ≤ 1 sector was 0.94–1.00 (both day 0 and 14) for CT and 0.88–1.00 and 0.94–1.00 for MRI.

When comparing the mean grading of days 0 and 14, the probability of a difference of ≤ 0.5 sectors was 0.76–0.88 for CT and 0.88–0.94 for MRI. The probability of a difference of ≤ 1 sector was 0.88–1.00 for both CT and MRI.

Agreement between CT and MRI

Comparing the mean grading of both examiners, the probability of a difference of ≤ 0.5 sectors was 0.47–0.88 and the probability of a difference of ≤ 1 sector was 0.76–1.00. The sagittal and longitudinal distributions were graded significantly higher on CT ($p < 0.01$).

Peri-operative findings

The mean time between the pre-operative radiological examination and surgery was 101 days (median 70, SD 123). Peri-operative findings reported by the surgeon

comprised of 40% sequestered herniations, 44% herniations contained by annular tissue or PLL, 11% protrusions and 5% normal discs. In 127 patients (85%), the surgeon reported good association between the pre-operative radiological findings and the peri-operative findings. The mean time interval between radiological examination and surgery for this subgroup was 91 days (median 62, SD116). The mean time interval for the remaining 23 patients (15%), with non-corresponding findings, was 152 days (median 124, SD 145). A smaller herniation than expected was found in nine of these 23 patients, a protrusion in 12 patients and other pathologies in two patients (lateral recess stenosis and large epidural veins).

Patient assessment results

A significant improvement of the pre-operative VAS score for leg and back pain, Oswestry Disability Index, EQ5D and Zung Depression scale was found 2 years post-operatively (Table 2). At the 2-year follow-up, the independent neurologist evaluated the overall outcome as excellent, good, fair and poor in 28%, 37%, 26% and 9% of the patients, respectively. Five patients were not available for clinical follow-up. Six patients (4%) were re-operated at upon the same level (four recurrent herniation, one lateral stenosis, one fusion) during the follow-up period. Eight of 144 (6%) patients in the group not re-operated upon had >50% loss of disc height compared to none of the re-operated patients ($p<0.001$).

None of the 9/144 (6.8%) patients who had a combination of large and central herniations were found in the re-operated group ($p<0.001$) (Fisher's permutation test).

Comparison of classification results and patient-based outcome

No associations were found between clinical outcome and the parameters from the classification, i.e. the extent of distribution in any of the three examined planes, total size, central localisation or the combination of size and central localisation. Neither did dural compromise, disc height reduction or grade of Modic changes show any association with outcome. The absence of nerve root

compromise on the pre-operative images demonstrated higher scores on VAS for leg pain (median 59, range 23–72 vs. median 18, range 0–95; $p=0.013$) and back pain (median 54, range 18–74 vs. median 22, range 0–95; $p=0.033$) 2 years post-operatively compared to patients with nerve root compromise. There were no differences between these groups in the other outcome scores studied.

No association was found between the radiological parameters and the post-operative result as graded by the independent observer.

Comparison between radiological and surgical agreement in relation to outcome

Disagreement between surgical and radiological findings had no influence on the clinical outcome (Fisher's permutation test) (Table 3).

Comparison between surgical findings and outcome

In patients where the surgeon reported a true herniation, i.e. a sequestration or a prolapse, the VAS score for leg pain ($p=0.046$), the Oswestry Index ($p=0.043$) and the EQ5D ($p=0.035$) were significantly more favourable at the 2-year post-operative follow-up (Fisher's permutation test) (Table 4). No difference was found in VAS assessed back pain.

Discussion

This study demonstrates high intraobserver reliability and a good interobserver reliability for a proposed radiological classification of lumbar disc herniation. When using this classification in a prospective study, no association was demonstrated between the classification parameters of disc herniation, i.e. direction in any plane, sagittal distribution, central location, large size or combination of the latter two and the clinical outcome.

It has been reported earlier that patients with centrally located disc herniations have a poor post-operative outcome. In a retrospective analysis, Knop-Jergas et al. [4] reported that 53% of the patients with central herniations

Table 2 Comparison of the pre-operative and 2-year post-operative patient-assessed outcome measures

	Pre-operative (median, range)	2-year follow-up (median, range)	<i>p</i> -value
VAS leg pain, (0–100), mm	60 (2–97)	20 (0–95)	<0.001
VAS back pain, (0–100), mm	51 (0–97)	23 (0–95)	<0.001
Oswestry Disability Index, 0–100	52 (8–94)	18 (0–78)	<0.001
EQ5D	0.030 (–0.594–0.796)	0.727 (–0.239–1.000)	<0.001
Zung Depression Scale, 20–80	42 (23–68)	35 (20–64)	<0.001

Fisher's permutation test.
n=150

Table 3 Comparison of radiological and surgical agreement and disagreement to clinical outcome

	Comparison between radiological and peri-operative findings, median (range)		<i>p</i> -value
	Agreement, <i>n</i> =127	Disagreement, <i>n</i> =23	
VAS leg pain (0–100)	18 (0–95)	32 (2–61)	>0.30
VAS back pain (0–100)	21 (0–95)	32 (2–74)	>0.30
Oswestry Disability Index (0–100)	12 (0–78)	28 (8–64)	0.12
EQ5D	0.76 (−0.23–1.00)	0.69 (−0.18–1.00)	>0.30
Zung Depression Scale	34 (20–64)	40 (24–61)	0.13

Fisher's permutation test

had fair/poor result after surgery compared to only 20% for those with postero-lateral herniations. In another retrospective study, strictly central herniations were chosen as a subgroup for analysis (40 patients out of 3,150). The size of the central herniation was not shown to be of any importance with regard to outcome, but the group with central herniations demonstrated a lower success rate than the total study group (65% and 98%, respectively) [2]. The classification used in these studies provided only two-dimensional grading of the disc herniation, were not reliability tested and the studies were retrospective.

The results from our prospective study, using a new three-dimensional classification system with reliability testing for lumbar disc herniation, could not verify that patients with centrally localised, large or the combination of large and centrally localised herniations had a less favourable outcome compared to the total study group.

Milette [7] presented what he called a patho-anatomic model to classify lumbar disc herniations, where the degree of disc degeneration and the type of disc lesion were assessed together. He suggested that the use of classifications, where radiological findings are assessed by the categorisation of findings related to the clinical presentation of the disease, give better guidance in determining treatment compared to classifications that just describe the contour of the herniation. Milette's classification was not applied to the population of our study, but the compromise of dura and nerve root, disc height and Modic changes were evaluated. We found that patients in whom the radiologist could not verify nerve root compromise on pre-operative images had significantly less improvement in leg and back

pain 2 years post-operatively compared to patients with nerve root compression. This may indicate that the pain was not radiculopathy.

In 15% of the patients, the surgeon reported disagreement between the radiological findings and the findings at surgery. The difference could probably be explained by shrinking or absorption of the disc herniation during the time between radiological examination and operation. This is supported by the long time interval that was noted between the radiographic examination and surgery in this group of patients. However, the post-operative results were not poorer in this patient group but, since all outcome measures were numerically inferior to patients with agreement between surgical and radiological findings, a type II error cannot be ruled out.

In patients with a surgical report of a true herniation, contained or not, the post-operative results were more favourable. This finding is in accordance with previous reports [10]. The distribution of disc herniations in the transverse plane was found to be increased with increasing age, which might reflect a higher degree of degeneration and bulging disc.

In our series of patients, only 4% (6/150) of patients were re-operated upon during the 2-year follow-up period, which makes subgroup-analysis for re-operated patients unreliable. The findings of significantly less large/central herniations, as well as disc height changes in this group, might, therefore, simply be explained by the low frequency of re-operations.

To our knowledge, this is the first study where morphological characteristics of lumbar disc herniations

Table 4 Comparison between surgical findings and clinical outcome measures

	Association between surgical findings and outcome, median (range)		<i>p</i> -value
	Sequestration or prolapse, <i>n</i> =126	Protrusion, normal disc or other pathology, <i>n</i> =24	
VAS leg pain (0–100)	17 (0–95)	38 (2–79)	0.046*
VAS back pain (0–100)	20 (0–95)	40 (2–74)	0.14
Oswestry Disability Index (0–100)	16 (0–78)	30 (0–64)	0.043*
EQ5D	0.76 (−0.24–1.00)	0.66 (−0.24–1.00)	0.035*
Zung Depression Scale	34 (20–64)	39 (23–63)	0.045*

Fisher's permutation test

have been studied in a prospective set-up and compared to follow-up data from both patients and an independent observer. Our study could not verify a previously reported correlation between central disc herniation and poor clinical outcome. Instead, the findings indicate that the localisation of the herniation in relation to the nerve root is of greater importance for outcome than the contour, size and position, as such. These aspects need to be considered when the predictive value of pre-operative radiological findings is studied.

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