Formulation and Validation of Equation Predicting Amount of Disc Removed Before Microscopic Discectomy

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Summary

Purpose: During microscopic discectomy, knowing how much disc remains can be difficult if the ruptured disc has migrated upward or downward because of a limited microscopic field resulting from minimal laminotomy. The purpose of this study is to formulate and validate a primary linear equation that can predict the amount of herniated disc to be removed prior to surgery.

Methods: Sixty patients (35 males and 25 females) who had radiculopathy by extruded, ruptured, or migrated disc from May 2010 to December 2012.Each patient underwent microscopic hemilaminotomy and discectomy on lumbar levels. Volumes of herniated discs were ascertained using MRI and a picture analysis communication system. The surgically removed part of the herniated disc was weighed using an electronic scale in the operation theater. A distribution chart was constructed using measured weights (Y axis) and volumes (X axis). Using a regression analysis model, the primary linear equation was calculated. A prospective study was conducted on 30 patients (22 males and eight females) to statistically validate the equation using the Wilcoxon matched pairs sign rank test.

Results: The primary linear equation was $Y=1.220X$, where Y=predictable weight of removed disc and X=measured volume of herniated disc on MRI. The predictable weight of removed disc closely correlation with the measured volume of herniated disc on MRI ($R^2=0.818$). Validation of this equation was excellent (Wilcoxon matched pairs signed rank test by Null hypothesis).

Conclusions: The derived primary linear equation can predict the amount of disc to be removed prior to surgery.

Key words:, Microscopic discectomy, MRI, Validation Equation

Mikroskopik Diskektomiden Önce Alınan Disk Miktarının Tahmin Eden Denklemin Formulasyonu ve Validasyonu

Özet

Amaç: Mikroskopik diskektomi sırasında minimal laminotomi sonucu oluşan kısıtlı mikroskopik alan nedeniyle rüptüre olmuş disk yukarı ya da sağa kaydıysa ne kadar diskin kalıntısının kaldığını bilmek zor olabilir. Bu çalışmanın amacı cerrahiden önce ne büyüklükte herniye disk kaldığını tahmin edebilen primer lineer denklemi formüle ve valide etmektir.

Yöntem: Çalışmaya mayis 2010 ve aralik 2012 tarihleri arasında izlenen ekstrüde, rüptüre ya da migrate olmuş diske bağlı radikulopatisi olan 60 hasta (35 kadın ve 25 erkek) dahil edilmiştir. Herniye olmus disklerin hacimleri MRG ve resim analizi iletişim sistemi

kullanılarak belirlenmiştir. Herniye olmuş disklerin cerrahi olarak alınan parçaları operasyon salonunda elektronik bir skala kullanılarak tartılmıştır. Ağırlıklara (Y aksisi) ve hacimlere (X aksisi) bakılarak dağılım grafiği hazırlanmıştır. Regresyon analiz modeli kullanılarak primer lineer denkem hesaplanmıştır. 30 hastada (22 erkek, 8 kadın) istatistik validasyon için Wilcoxon matched pairs sign rank testi ile prospektif bir çalışma yürütülmüştür.

Sonuçlar: Primer lineer equasyon $Y=1.220X$ `tir (Y= alınan diskin tahmin edilen ağırlığı ve X= MRG´de ölçülen herniye diskin hacmi). Alınan diskin tahmini ağırlığı MRG'de herniye olmuş diskin ölçülen hacmiye yakın korelasyon göstermektedir ($R^2=0.818$). Bu denklemin validasyonu mükemmeldir

Sonuç: Primer lineer denklem cerrahiden önce alınan diskin miktarini tahmin edebilir.

Anahtar kelimeler: Mikroskopik diskektomu, MRG, validasyon, denklem

INTRODUCTION

Surgical treatment for lumbar disc herniation tends to be done using a minimally invasive microscopic technique. Long-term studies have reported the effectiveness of the approach in treating lumbar disc herniation (1). However, a microscopic field is limited when compared to a classical hemilaminectomy for a herniated disc. Furthermore, if the disc material migrates upward or downward to the pedicle level, it is difficult to completely remove the fragmented or ruptured disc material because of the limited microscopic field by laminotomy. If the surgeon could predict the optimal amount of herniated disc material before surgery, it would aid in the subsequent exploration for residual fragments, or could enable ending probing during operation. Both could lead to successful surgery.

There has been no study on the prediction on the amount of herniated disc to be removed pre-operatively. This study formulated and validated a primary linear equation predicting the amount of herniated disc to be removed prior to surgery.

MATERIAL AND METHODS

Materials

From January 2010 to December 2011, a retrospective study was conducted on 60 patients (35 males and 25 females) who had suffered lower back pain, sciatica, tingling sensation, and hyperesthesia (mean visual analog scale, VAS, score 7.8), who and had been definitively diagnosed with herniated disc by MRI, and had not responded to at least 6 weeks of conservative treatment. Exclusion criteria were recurrent disc herniation, infection, and traumatic disc herniation.

All patients had undergone partial laminotomy (1-2 mm removal of lamina using burr) and discectomy though a minimal invasive approach using microscopy. Thirty one patients were older than 50 years of age, and 15 were older than 70 years of age. Only 7 patients were younger than 30 years of age. 86% of patients were diagnosed to have herniated discs on L4-5 and L5-S1 levels (L4-5, 25 patients; L5-S1, 27 patients), 65% of patients with extrusions, and 35% of patients with sequestrations. Nine of the 21 patients with sequestrated type displayed upward migration and 12 had downward migration (5) (Table 1).

Diagnostic and Imaging Measurement

All patients had undergone preoperative imaging studies consisting of anterior-posterior and lateral, flexion-extension x-ray of lumbar spine, and contrasted MRI of the lumbar spine. An Achiva 3.0 Tesla MR system (Philips, Eindhoven, Netherlands) was used for all studies. All MRI evaluations were obtained at the facility on single system. The MRI sequences include

axial and sagittal T1 and T2 images from which the measurements were obtained. The images were 3 mm of thickness. The matrix was 256 x 192. The field was 14 cm for the sagittal images and 18 cm for the axial images. All MRI interpretations and measurements were conducted using the Picture Analysis Communication System (PACS)/Marosis view image system (2). In all cases, MRIs were read by a board certified orthopedic spine surgeon and radiologist who documented the disc types and levels of involvement.

Surgical Technique

All patients underwent a single-level discectomy by a single orthopedic spine surgeon using an OPMI VARIO/S88 microscope (Carl Zeiss, Oberkochen, Germany). Intra-operative cross table lateral radiography was used for the identifications of appropriate levels. A 2-3 cm posterior midline incision was centered over the appropriate disc space. A limited partial laminotomy was performed using a burr between approximately 1 and 2 mm of the hemilamina as previously (3). The fragments of discs were removed as previously described (4). The canal was inspected and the foramen probed for residual disc material or bony pathology, which were removed using a 3-5 mm hook after removing the herniated disc though canal, and ensuring that the nerve roots were completely decompressed and mobile (3-7). The extent of removal of the herniated fragments was measured using both pre-operative and post-operative MRI.

Measurement Technique

The weight of surgically removed disc fragments was measured by a MW i-3000, electronic scale (CAS, 2001). The measured volume of disc herniation in pre-operative MRI was calculated, except for that of the remanent herniated disc on post-operative MRI, using the calculation tool of the aforementioned PACS. On each axial MRI, the areas of herniated discs were measured and added. Heights of herniated discs measured on sagittal MRI,

represented the length between the top and the bottom of the axial images. The height of each slice was 3 mm. Measurements were made by three orthopedic spine surgeons using the PACS system. Each herniated fragment of disc was displayed as eight image slices, from which the areas of herniated fragments were measured using the region of interest curve tool on the MRI device. The eight areas were summed and multiplied by 3 mm. This allowed the calculation of the volumes of the herniated fragments, for example: 14.83 mm2 (slice 1) + 7.91 mm2 (slice 2) + 48.94 mm2 (slice 3) + 28.18 mm2 (slice 4) + 57.35 mm2 (slice 5) +60.31 mm2 (slice 6) + 86.50 mm2 (slice 7) + 57.84 mm2 (slice 8) x 3 mm). Figure 1(A) displays a representative axial pre-operative MRI image and Figure 1(C) displays a representative sagittal post-operative MRI image.

Statistical Analyses

Correlation between the measured volumes in MRI and weights of surgically removed herniated discs in the 63 patients was expressed by a primary linear equation (Y=1.220X, where Y=expected weight of removed disc and X=volume of disc in MRI using the regression analysis model. The coefficient of determination of the linear equation was expressed by R^2. R square (0< R^2 <1) is valid when it approaches 1. To evaluate the effectiveness of this equation, a prospective study was conducted with 30 patients (20 males and 10 females) between January 2012 and December 2012. The volumes of the herniated discs were measured preoperatively using the PACS system, and the weights of the removed discs were predicted using the primary linear equation. Effectiveness of each determination value was evaluated using the Wilcoxon matched pairs signed rank test by Null hypothesis. The results of measurements made independently by three observers were entered into the Statistical Package for Social Science

(SPSS) for PC version 10.01. ?-statistics were used to determine the degree of intra-observer and inter-observer agreement after correction for the agreement expected by chance.

Table 1. Demographic retrospective data of the patients.

		L2-3	L3-4	L4-5	L5-S1	Total
Male		0	1	16	18	35
Female		3	4	9	9	25
Less than 30 years old		1	1	2	3	7
30 to 50 years old		0	1	11	10	22
More than 50 years old		2	3	12	14	31
Each levels		3	5	25	27	60
Extruded type		2	3	17	17	39
Sequestration type	Upward	1	1	4	3	9
	Downward		1	4	7	12
Weight of removed	Maximum	0.7	0.7	1.5	2.1	
disc (g)	Minimum	0.6	0.4	0.2	0.2	
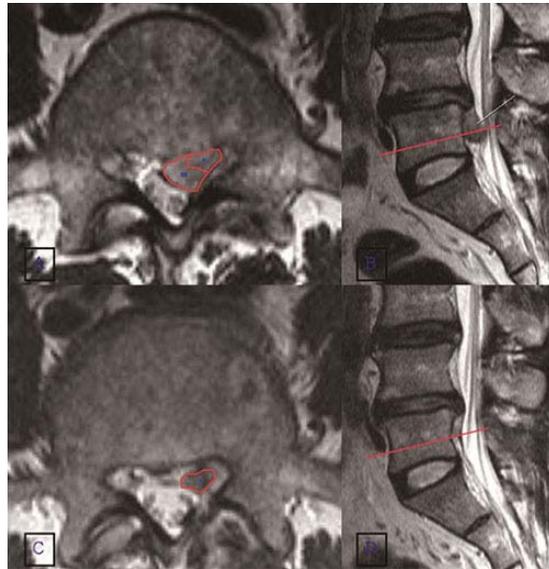
Figure 1: *Preoperative T2 weighted axial (A) and sagittal (B) MRI shows sequestrated disc herniation and downward migration. Postoperative T2 weighted axial (C) and sagittal (D) MRI shows minimal remnant of disc material. The amount of disc herniation was measured using a PACS system. The square denotes the amount of removed herniated disc. The star denotes the amount of the remnant herniated disc.*

RESULTS

Surgical outcome

Back and radiating pain improved from preoperative VAS (mean 7.8) to postoperative VAS (mean 1.4). Motor function was recovered after surgery. Furthermore, it was confirmed that the volume of almost herniated disc was removed on postoperative MRI.

Primary equation on expected amount of removed disc

Using the regression analysis model, measured volumes and weights were expressed through the aforementioned primary linear equation. $R2=0.818$, indicating the effectiveness of the correlation (Figure 2).

Validation

The Null hypothesis of the prospective was that when the difference in median value between the measured volume and the calculated weight is 0, the significance level is 0.575. The calculated and measured weights of fragment were significantly correlated. Therefore, the primary linear equation is amenable for preoperative use in when a surgeon anticipates the weight of fragment to be removed in an operation (Table 2).

Intraobserver and interobserver agreement

Pearson correlation coefficients for intraobserver agreement were 0.87 ($p < 0.01$), 0.73 ($p < 0.01$), and 0.84 ($p < 0.01$) for observers 1, 2, and 3, respectively. Pearson correlation coefficients between two observers were 0.79 (observers 1 and 2, $p <0.01$), 0.77 (observers 1 and 3, $p < 0.01$), and 0.73 (observers 2 and 3, $p < 0.01$). These results indicated good to excellent intraobserver and interobserver agreement of volume measurement.
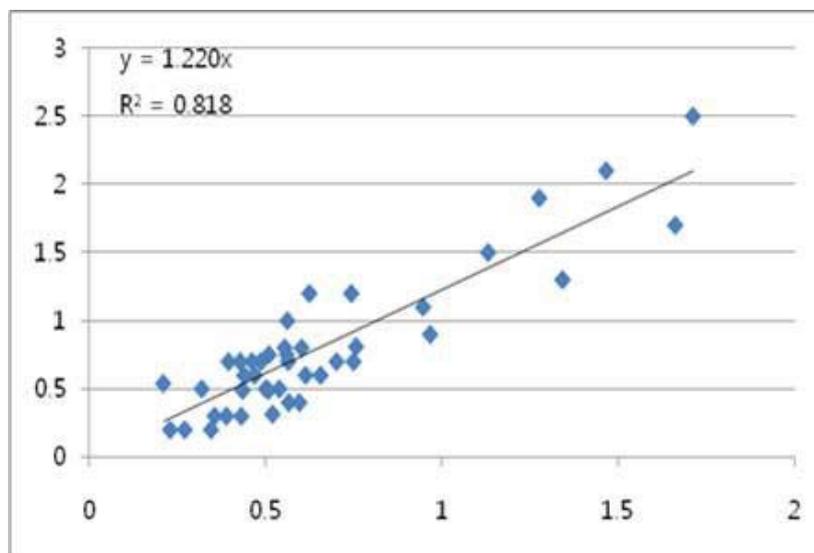
Figure 2: *Primary linear equation and scattered of real amount of removed disc material. Y=1.220X (Y= expected weight of removed disc, X= volume of disc in MRI). R2=0.818*

Table 2. Demographic prospective data of the patients.

		L2-3	L3-4	L4-5	L5-S1	Total
Male		2	1	10	7	20
Female		0	2	4	4	10
Less than 30 years old		1	0	2	1	4
30 to 50 years old		0	2	5	4	11
More than 50 years old		1	1	7	6	15
Each levels		2	3	14	11	20
Extruded type		2	1	11	9	13
Sequestration type	Up ward	0	0	2	1	3
	Down ward	0	2	1	1	4
Weight of removed	Maximum	0.7	0.8	0.7	1.5	
disc (g)	Minimum	0.6	0.3	0.4	0.2	

Table 3. Statistical test of correlation between measured and calculated weights.

Null hypothesis	Test	Significance level	Decision making
when the difference of medial value at between measured and calculated weight is 0	Wilcoxon matched pairs signed rank test	0.575	null hypothesis is validated

Approximate significance level is 0.05

DISCUSSION

Surgical treatment of lumbar disc herniation has been traditionally accomplished by removing the herniated fragments as well as an aggressive decompression of the disc spaces. The approach has produced low rates of recurrences. On the other hand, minimal invasive approaches with removal of only the herniated disc fragment have been effective in treating lumbar disc herniation. Studies of the outcomes of lumbar micro-discectomy in a young, active population reported an overall high success rate, patient satisfaction, and return to physically demanding activities compared to the traditional aggressive discectomy (8-11). While debate remains on which of the two approaches should be favored, it is notable that the recurrence rate of the two approaches is not significantly different (5,7).

Previous studies have suggested that limited micro-discectomy at lumbar disc herniation was considered to be effective approaches and would bring good outcomes, but there has been no suggestion on the amounts of disc fragments herniated

to be removed. This study shows an important issue of optimal amount of herniated fragment of disc leading minimal invasive surgery as well as no remnant of herniated disc effects satisfying post-surgical symptoms (12). Further discussion concerning the anticipation of an accurate amount of herniated disc fragment to be removed at pre-surgical state is necessary.

This study provides evidence that a patient with a herniated disc at single lumbar level can have an optimum amount of disc fragment removed when the extrusion and sequestration of the herniated disc are calculated using the primary linear equation. This facilitates a minimally invasive, precise approach that involves minimal incision and no residual herniated disc.

The retrospective phase of the study involved 63 patients who had improved from their preoperative symptoms. Weights of the removed disc fragments were measured using an electronic scale and herniated (extruded or sequestrated) discs were calculated in sagittal and axial images of MRI in a PACS system. The measured weight and calculated volume of discs were significantly correlated using the primary linear equation. This indicates the necessity of a surgeon to determine the weight of the herniated fragment of disc to be removed prior to surgery. In addition, in the intra-operative state, surgeons would be able to acknowledge whether the removal of herniated disc fragment would be sufficient to complete the surgery. The minimal invasive, microscopy-oriented approach is limited in the surgical field. Thus, a surgeon would not be able to predict whether the herniated disc had migrated upward or downward, or were hidden. For such reasons, the approach describe here may enable accurate surgery that provides symptom relief.

The prospective phase of the study involved 30 patients with neurologic symptoms, back pain, and a definite herniated disc established by MRI. Pre-operatively, MRI was used to calculate the volumes of herniated discs and the weights of the herniated discs prior to removal were obtained using the derived primary linear equation. The approach was statistically valid (significance level .575).

There are several limitations in our study. The first is the paucity of studies concerning predictions of herniated discs to be removed, which limited comparison with prior data. Another limitation was inaccuracy of the calculated data from the primary linear equation when the volume or weight of the herniated disc to be removed was small. In addition, as the discs destined to be removed contained fluid, the measured weights would be inaccurate. On the other hand, due to insufficient quantity of sliced images by MRI, accurate measurement on volumes of herniated discs would not be available.

CONCLUSION

In this study, it is suggested to predict the amount of disc fragment to be removed in prior to a surgery using a primary linear equation. A retrospective study established this equation from the correlation between measuring volume and weight by a regression analysis model. In a prospective study, the validity of this equation was confirmed by the correlation between the measurements and the calculated weights. Necessarily, the calculated values using this equation do not suggest optimal weight of herniated disc fragments to be removed, but with experience a surgeon will be able to anticipate the proper weight to be removed during an operation.

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