THE EFFECTIVENESS OF THE SYSTEM FOR PREDICTING THE RESULTS OF SURGICAL TREATMENT OF PATIENTS WITH LUMBAR DISC HERNIATION

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Objective. To evaluate the effectiveness of a multivariate logistic regression model for the predicting surgical treatment results in patients with lumbar disc herniation.
Materials and Methods. Study design: monocentric retrospective study. The study included patients operated on for lumbar disc herniation at levels L4–L5, L5–S1, with a 3-year follow-up. Two groups were identified: Group I included 350 patients (their data served as a basis for creation of multivariate logistic regression predicting model), and Group II – 514 patients (in this group, the effectiveness of the model was evaluated). Group II was divided into two subgroups: Subgroup IIa (recurrence probability <50 %) included 497 (96.7 %) patients, and Subgroup IIb (recurrence probability >50 %) – 17 (3.3 %) patients. Patients in Subgroup IIa underwent microdisectomy, and in Subgroup IIb – spinal fusion. In order to obtain homogeneous pre-operative indicators of both group parameters, the PSM method was used. Statistical calculations were performed in the RStudio program.
Results. In Group II, significant differences in indicators in the subgroups were noted for the following parameters ($p < 0.05$): smoking, disc height index, segmental volume of movement, lumbar lordosis angle, type of intervertebral hernia (except for sequestration), Modic changes, and stage of intervertebral disc degeneration according to Pfirrmann. In Subgroup IIa, 8 (1.6 %) reoperations were performed, in Subgroup IIb – 2 (0.4 %). Using the PSM method, the data of groups I and II were flattened out for significantly different indicators. The sample size was 37 patients in each group. The number of reoperations in the groups differed statistically significantly: Group I – 35 % [22 %; 51 %]; Group II – 5 % [1 %; 18 %]. The risk of reoperation in Group II is 0.13 [0.03; 0.58] times lower than in Group I ($p = 0.002$).
Conclusions. The proposed system for predicting the results of surgical treatment of patients with intervertebral disc hernia can be used as a tool to determine the surgical tactics aimed at reducing the frequency of reoperations.
Key Words: intervertebral disc degeneration, microdiscectomy, prediction of surgical treatment, recurrence of lumbar disc herniation.
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Despite the effectiveness of conservative therapy in the treatment of patients with pain syndromes caused by lumbar disc herniation, the proportion of patients requiring surgical intervention does not decrease over time. Removal of intervertebral disc herniation is the most common neurosurgical procedure. Achievements in the field of spinal surgery do not contribute to a decrease in the frequency of revisions, while the frequency of reoperations for hernia remains 5–16 % [1–5]. Inadequate preoperative examination, which includes MRI, MSCT, and spinal radiography, in some cases is the cause of incorrect surgical strategy and, therefore, unsatisfactory outcome. Poor outcomes of microdiscectomy may be due to cicatricial-commissural changes in the epidural space, hypertrophic remodeling of the spinal canal, segmental instability, and recurrent disc herniation [3, 6]. Only half of the patients are satisfied with the results of reoperation. After the first revision surgery, the cumulative risk of hernia recurrence reaches 25 % [7].

A possible way to improve the results of lumbar microdiscectomy is preoperative identification and analysis of the risk factors of adverse outcomes followed by determining the choice of surgical approach. There are a large number of risk factors for hernia recurrence. The factors are quite heterogeneous: lifestyle (extensive physical exercise, body weight, bad habits), gender, patient's age, degenerative changes in the spinal motion segment, degree of mobility, herniation type, height of the intervertebral disc, comorbid factors (diabetes), etc. [4, 8–11]. In their meta-analysis on the risk factors for hernia, Huang et al. [10] found that diabetes, smoking, and the type of intervertebral disc herniation have a significant relationship with relapse. Thus, there are heterogeneous factors that have a significant correlation with hernia recurrence. However, the literature does not present any systematic guideline for their practical use. We attempted to eliminate this drawback in our previous study [12], where predictors of hernia recurrence were determined: body mass index, intervertebral disc height index, mobility of the spinal motion segment, lumbar lordosis angle, smoking, type of herniated disc, and the stage of intervertebral disc degeneration according to Pfirrmann. Further, a multivariate logistic regression model was proposed. The study showed the possibility of preoperative analysis of radiological parameters for predicting the risk of lumbar disc reherniation after microdiscectomy.

The aim of the study is to evaluate the effectiveness of a multivariate logistic regression model for predicting surgical treatment results in patients with lumbar disc herniation.

Material and Methods

The work presents a monocentric retrospective study.

The data of patients who underwent microdiscectomy for intervertebral disc herniation at two lower lumbar levels (L4–L5 and L5–S1) were analyzed. Group I included 350 patients operated on in the period of January 2009 to July 2012; in addition, the data on the same patients from our previous study, which served as the basis for a multivariate logistic regression prognostic model, was also used [12]. This group was included in the study in order to assess the comparability of the clinical and radiological parameters and surgery outcomes with the data on the patients from the current study, i.e. Group II, which included 514 patients operated on in the period of January 2013 to December 2014. All patients had radicular pain syndrome resistant to conservative therapy and lasting for more than 6 weeks. At the preoperative stage, clinical data (body mass index (BMI), smoking) and radiological parameters of the lumbar spine and the affected spinal motion segment (intervertebral disc height index (DHI), sagittal segmental range of motion, lumbar lordosis, herniation type, and Pfirrmann disc degeneration grade) were analyzed. Using a multivariate logistic regression model [12], we evaluated the probability of lumbar disc reherniation for each patient. The calculations were carried out by two doctors independently of each other. In case of the discrepancy between the two results, calculations were repeated until identical values were obtained.

The surgical strategy in Group II depended on the probability of recurrent disc herniation, which was the reason to divide the group into two subgroups. Subgroup IIa included patients with a low risk of recurrence (less than 50 %); these patients underwent open microdiscectomy. Subgroup IIb consisted of patients with a recurrence risk of more than 50 % who underwent spinal fusion according to the TLIF or PLIF technique combined with transpedicular fixation, which excluded recurrent intervertebral disc herniation of the operated spinal motion segment. All operations were performed by neurosurgeons specializing in spinal surgery with a five-year experience. The patients were followed up for a period of three years after surgery.

The inclusion criterion was intervertebral disc herniation at the L4–L5 or L5–S1 level.

Exclusion criteria were the following: intervertebral disc herniation in combination with hypertrophied yellow ligament and (or) zygapophyseal joints, various types of spondylolisthesis, nondegenerative lesions of the lumbar spine, and previous surgical interventions on the lumbar spine.

Next, data of the two groups of patients were compared. In order to obtain uniform preoperative parameter values, the Propensity Score Matching (PSM) method was used [13].

Prior to statistical evaluation, an exploratory analysis of the data was performed in order to check the normality of the parameter distribution in the groups, identify extreme values, and determine the degree of correlation between the variables in the groups. The Shapiro–Wilk test showed that all continuous variables were not normally distributed, except for the parameter “lumbar lordosis” in Group I after PSM application. A weak correlation was found between the DHI and the sagittal segmental range of motion (Spearman’s correlation coefficient $r = 0.30$, $p < 0.001$).

Continuous variables are presented as a median [first quartile; third quartile]; binary indicators are presented as quantity, percentage [95 % confidence interval (CI) of the percent], CI limits were calculated using the Wilson formula, categorical variables are presented as the number and percentage of patients in each category.

Continuous variables in the groups were compared by the unpaired Mann–Whitney U test, with calculation of the distribution shift and construction of the 95% confidence interval for the shift. To compare binary and categorical variables in the groups, Fisher exact two-tailed test was used.

Initially, the following preoperative parameters differed statistically significantly between the groups: gender ($p = 0.027$), proportion of smokers ($p < 0.001$), DHI ($p < 0.001$), sagittal segmental range of motion ($p < 0.001$), lumbar lordosis angle ($p < 0.001$), Modic changes ($p < 0.001$), and type of hernia ($p < 0.001$). In order to eliminate the possible effect of the identified heterogeneities on the number of reoperations in the groups, the PSM method was used (the nearest neighbor method with a caliber of 0.1 and a 1:1 group ratio), which allowed excluding the patients that did not met the criteria in the set of significantly different preoperative values (Table 1).

Comparison of freedom from repeated operation between the groups was carried out using log rank test with the construction of Kaplan – Meier survival curves and calculation of the risk ratio using the Cox proportional hazards model.

Statistical hypotheses were tested with a critical significance level of $p = 0.05$, i.e. the difference was considered statistically significant at $p < 0.05$. Statistical calculations were performed using a freely distributed RStudio software based on the statistical programming language R [14].

Results

The data of descriptive statistics, correlation analysis of Group I and on obtaining multivariate logistic regression model are presented in our previous study [12].

Multifactor logistic regression model was used to determine the likelihood of recurrence in each Group II patient at the preoperative stage, which then determined the surgical strategy. This served as a criterion for dividing the patients into two subgroups: Subgroup IIa (with less than 50 % probability of relapse) including 497 (96.7 %) patients and Subgroup IIb consisting of 17 (3.3 %) patients. A total of 459 (92.9 %) individuals from Subgroup IIa and 15 (88.2 %) individuals from Subgroup IIb were available for examination three years after surgery.

The results of statistical analysis of the clinical parameters of Group II are presented in Table 2. One can conclude from these data that patients with a high risk of recurrence are more likely to be smokers. There were no significant differences in the BMI and age structure.

The results of a comparative analysis of preoperative MRI and radiography data in Subgroups IIa and IIb are presented in Table 3. Significant differences were found for DHI, segmental range of motion, lumbar lordosis angle, type of intervertebral hernia (except for sequestration), changes in the end plates and bone marrow of the adjacent vertebrae according to Modic, and the stage of intervertebral disc degeneration according to Pfirrmann.

Among Subgroup IIa patients, 8 (1.6 %) cases of recurrent disc herniation that required revision surgery were noted. In Subgroup IIb, one patient had repeated surgery for a superior adjacent segment pathology 16 months after spinal fusion, and another patient underwent reoperation for deep surgical site infection 12 days after primary surgery.

The studied parameters of the patients in both groups were not comparable. The groups significantly differed by gender, percentage of smokers, DHI, parameters of lumbar lordosis, Modic changes, and type of hernia. Using the PSM method, the datasets for both groups were aligned for all statistically significantly different values. The sample size of the groups, which showed no significant difference in the variables between them, amounted to 37 patients in each (Table 1).

As it can be seen from Table 1, before applying the PSM method to achieve compatibility between the groups, the frequency of reoperations was 14 % [11 %; 18 %] in Group I versus 2 % [1 %; 4 %] in Group II. Since the groups differed significantly in a number of preoperative parameters, the data obtained could be false-positive. The PSM method allowed aligning the parameters. However, at the same time, the proportion of reoperations remained statistically significantly different between the groups: 35 % [22 %; 51 %] in Group I versus 5 % [1 %; 18 %] in Group II.

We evaluated the dynamics of freedom from reoperation. As it can be seen from the Figure, the last reoperation was performed after 16 months in Group II and after 30 months in Group I. The discrepancy in the freedom from reoperation in the groups occurred as late as one month after the patient's discharge, the risk of reoperation in Group II was 0.13 [0.03; 0.58] times lower than in Group I ($p = 0.002$).

Discussion

Recent studies have shown that the frequency of reoperations after microdiscectomy in patients with lumbar disc herniation averages 9.1 % but can reach as high as 19.0 % [5, 15–17]. The use of endoscopic techniques does not contribute to a significant reduction in the number of revision surgeries [16]. Studies with a long period of postoperative observation showed that the main cause of reoperations is the same-level recurrent disc herniation [18]. In our pervious study, we evaluated the results of microdiscectomy at L4–L5 and L5–S1 in 1,368 patients [12]. Reoperations for reherniation were performed in 50 (3.7 %) cases, which is lower than in the literature. This may be due to analysis of the recurrence of intervertebral disc herniation of the same disc and a three-year postoperative follow-up period. In this study, taking into account the altered surgical approach, recurrent hernias requiring reoperation amounted to 8 (1.6 %) cases.

Analysis of the data on the issue under consideration allowed us to identify the following factors that significantly contribute to the adverse outcome of microdiscectomy: diabetes mellitus [10, 17, 19], smoking [12], body weight [16], DHI [5], segmental range of motion [20], intervertebral disc degeneration [20], Modic criteria [16], type of intervertebral hernia [10], and the size of the annular defect [2].

The most objective factors that can be determined at the preoperative stage include parameters evaluated by neuroimaging (MRI) and radiography. Previously [12], we found a significant correlation between lumbar disc herniation recurrence and DHI, segmental range of motion, parameters of lumbar lordosis, herniation type, and disc degeneration grade according to Pfirrmann.

Most researchers have determined that disc degeneration is one of the main factors responsible for recurrent herniation of the lumbar disc. However, the question of at which stage of degeneration the risk is higher remains open. Cinotti et al. [21] concluded that men with severe degenerative lesions of the intervertebral disc have a high probability of hernia recurrence. Other authors argue that patients with an early stage of degeneration are at greater risk [22]. In this study, significant differences in the parameter "intervertebral disc degeneration" were noted for Subgroups IIa and IIb. In Subgroup IIb with a high risk of relapse, patients with Pfirrmann degeneration grade III prevailed, while grade IV patients prevailed in Subgroup IIa with a low probability of recurrence ($p < 0.001$).

Some researchers consider that intervertebral disc height and mobility of the spinal motion segment significantly affect the outcome of microdiscectomy. Kim et al. [4] revealed a significant correlation between reherniation and such parameters as DHI and sagittal segmental range of motion in a cohort of 171 patients. These parameters also significantly differed for the high and low probability of relapse in the Group II of our study ($p < 0.001$).

Flattened lumbar lordosis and especially its decrease at the L4–L5 and L5–S1 levels comprises 66 % of the total lordo-

Table 1
Results of statistical analysis of the patient data before and after applying the PSM method

Parameter	Before applying PSM				After applying PSM			
	Group I (n = 350)	Group II (n = 514)	Difference	Criterion	Group I (n = 37)	Group II (n = 37)	Difference	Criterion
Calculation method	*MED [IQR]*	*MED [IQR]*	*Pseudo-median of pairwise differences [95 % CI]*	*Mann–Whitney U test, p*	*MED [IQR]*	*MED [IQR]*	*Pseudo-median of pairwise differences [95 % CI]*	*Mann–Whitney U test, p*
Age, years	42 [34; 50]	42 [35; 52]	1 [0; 3]	0.147	47 [38; 54]	41 [37; 50]	-4 [-9; 2]	0.153
BMI, kg/m^2	26.705 [23.9; 29.78]	27 [24.2; 30.3]	0.24 [-0.37; 0.84]	0.453	28.76 [25.73; 30.39]	25.95 [23.5; 30.1]	-2.1 [-4.22; 0.15]	0.065
DHI	0.26 [0.23; 0.29]	0.29 [0.26; 0.32]	0.02 [0.02; 0.03]	<0.001*	0.27 [0.25; 0.31]	0.27 [0.25; 0.33]	0 [-0.03; 0.03]	0.970
Sagittal segmental range of motion, deg.	8 [6; 9]	4 [3; 5]	-4 [-4; -4]	<0.001*	9 [6; 10]	7 [5; 9]	-1 [-3;0]	0.066
Lumbar lordosis, deg.	44.2 [39.12; 50.75]	47 [43; 52]	3.2 [2.2; 4.2]	<0.001*	42.1 [36.9; 46.3]	43 [40; 48]	1.6 [-1.7; 5.7]	0.315
Calculation method	*Category: n (%)*	*Category: n (%)*	*Pseudo-median of pairwise differences [95 % CI]*	*Two-tailed Fisher's exact test, p*	*Category: n (%)*	*Category: n (%)*	*Pseudo-median of pairwise differences [95 % CI]*	*Two-tailed Fisher's exact test, p*
Gender, n (%)	Female: 189 (54); Male: 161 (46)	Female: 238 (46); Male: 276 (54)	Method not applicable	Method not applicable	Female: 20 (54); Male: 17 (46)	Female: 21 (57); Male: 16 (43)	Method not applicable	>0.999
Modic type (I/II, III, 0)	0 – 188 (53.7); I – 68 (19.4); II, III – 94 (26.9%)	0 – 277 (53.9); I – 49 (9.5%); II, III – 188 (36.6)	Method not applicable	<0.001*	0 – 18 (48.6); I – 11 (29.7); II,III – 8 (21.6)	0 – 20 (54.1); I – 6 (16.2); II, III – 11 (29.7)	Method not applicable	0.350
Pfirrmann disc degeneration grade (III, IV), n (%)	III – 86 (24.6); IV – 264 (75.4)	III – 112 (21.8); IV – 402 (78.2)	Method not applicable	0.365	III – 10 (27.0); IV – 27 (73.0)	III – 15 (40.5); IV – 22 (59.5)	Method not applicable	0.326
Herniation type	Protrusion: 120 (34.3); extrusion: 223 (63.7); sequestration: 7 (2)	Protrusion: 95 (18.5); extrusion: 395 (76.8); sequestration: 24 (4.7)	Method not applicable	<0.001*	Protrusion: 18 (48.6); extrusion: 17 (45.9); sequestration: 2 (5.4)	Protrusion: 16 (43.2); extrusion: 19 (51.4); sequestration: 2 (5.4)	Method not applicable	0.927
Level 1 –L4–L5; Level2 – L5–S1, n (%)	1 – 173 (49.4); 2 – 177 (50.6)	1 – 253 (49.2); 2 – 261 (50.8)	Method not applicable	Method not applicable	1 – 17 (45.9); 2 – 20 (54.1)	1 – 20 (54.1); 2 – 17 (45.9)	Method not applicable	0.642
Calculation method	*n; % [95 % CI]*	*n; % [95 % CI]*	*OR [95 % CI]*	*Two-tailed Fisher's exact test, p*	*n; % [95 % CI]*	*n; % [95 % CI]*	*OR [95 % CI]*	*Two-tailed Fisher's exact test, p*
Smoking	116; 33 % [28 %; 38 %]	89; 17 % [14 %; 21 %]	0.4 [0.3; 0.6]	<0.001*	12; 32 % [20 %; 49 %]	8; 22 % [11 %; 37 %]	0.6 [0.2; 1.8]	0.433
Reoperations	50; 14 % [11 %; 18 %]	10; 2 % [1 %; 4 %]	0.1 [0.1; 0.2]	<0.001*	13; 35 % [22 %; 51 %]	2; 5 % [1 %; 18 %]	0.1 [0.0; 0.5]	0.003*

*statistically significantly different variables.

Table 2

Results of a statistical analysis of Group II clinical parameters

Parameter	Subgroup IIa (n = 497)	Subgroup IIb (n = 17)	Difference	Criterion
Calculation method	*MED [IQR]*	*MED [IQR]*	*Pseudo-median of pairwise differences[95 % CI]*	*Mann – Whitney U test, p*
Age, years	42 [35; 52]	44 [38; 50]	1 [-4; 7]	0.646
BMI, kg/m^2	27.00 [24.20; 30.20]	28.35 [24.12; 31.38]	0.9 [-1.5; 3.5]	0.456
Calculation method	*n, % [95 % CI]*	*n; % [95 % CI]*	*OR [95 % CI]*	*Two-tailed Fisher's exact test, p*
Smoking	82; 16 % [13 %; 20 %]	7; 41 % [22 %; 64 %]	3.5 [1.1; 10.6]	0.016*

*statistically significantly different variables.

sis, it is associated with high stress on the anterior column of the spine. These biomechanical changes significantly increase the risk of intervertebral disc degeneration, its progression, and herniation [23]. In Subgroup IIb, lumbar lordosis angle was significantly less than in patients with a low risk of relapse ($p < 0.001$).

Special attention is devoted to the type of disc herniation as a factor that has a significant correlation with relapse [10, 24]. It has been noted that patients with protrusion herniation types have a significantly higher risk of reoperation than those with extrusion or sequestration [24]. Huang et al. [10] conducted a meta-analysis where they determined the high importance of the type of hernia as a risk factor for recurrence. Thus, there is a reason to believe that mechanical stability, the stage of intervertebral disc degeneration, the severity of lumbar lordosis, and the type of herniation play the main role in hernia recurrence after microdiscectomy. Since the mid-1990s, the studies were mainly focused on revealing the correlation between individual factors and the recurrence of lumbar hernias; however, to date, there are relatively few studies devoted to the evaluation of preoperative radiological predictors of relapse. Our previous work was the first study that proposed a prognostic system based on the assessment of a number of radiological parameters [12]. For the convenience of calculating the probability of an adverse outcome, a calculator has been created that estimates the risk based on the defined preoperative variables. By using this tool to correct the surgical strategy and perform statistical alignment of groups, one can judge the feasibility of the prediction system, which allow significantly reducing the frequency of reoperations (14 % [11 %; 18 %] versus 2 % [1 %; 4 %]).

Study limitations. The study has a series of limitations. Only parameters that can be assessed by MRI and radiography before surgery were considered in the study. Analysis of such parameters as the size of the annular defect and the amount of disc material removed, which are also the predictors of hernia recurrence, is not presented in the current work [25]. These parameters cannot be known prior to surgical intervention, while their intraoperative assessment may require correction of the surgical approach. The study presents data on the patients who underwent microdiscectomy at the L4–L5 and L5–S1 levels, since intervertebral disc hernias of these segments are the most diagnosed ones. Extrapolation of the data on patients undergoing surgery at other spinal motion segments should be carried out with extreme caution.

The study duration was limited to a three-year follow-up period, which does not exclude the recurrence of intervertebral hernias at a later date. A total of 92.9 % patients of Subgroup IIa and 88.2 % patients of Subgroup IIb were available by the end of the study for evaluation of the surgery results.

Conclusion

The following seven (clinical and radiological) parameters are significant predictors of the results of microdiscectomy: BMI, smoking, intervertebral disc height, sagittal segmental range of motion, lumbar lordosis angle, type of intervertebral hernia, and Pfirrmann grade III of intervertebral disc degeneration. The proposed prediction system based on these parameters can be used as a tool for determining the surgical strategy for treating patients aimed at reducing the frequency of reoperations.

The study had no sponsorship. The authors declare no conflicts of interest.

Table 3

Results of a statistical analysis of group II clinical parameters

Parameter		Subgroup IIa (n = 497)	Subgroup IIb (n = 17)	Difference	Criterion
Calculation method		*MED [IQR]*	*MED [IQR]*	*Pseudo-median of pairwise differences [95 % CI]*	*Mann – Whitney U test, p*
DHI		0.29 [0.26; 0.32]	0.34 [0.33; 0.38]	0.06 [0.04; 0.08]	<0.001*
Sagittal segmental range of motion, deg.		4 [3; 5]	9 [7; 10]	5 [4; 6]	<0.001*
Lumbar lordosis, deg.		47 [43; 52]	42 [38; 44]	-7 [-10; -4]	<0,001*
Calculation method		*Category: n (%)*	*Category: n (%)*	*Pseudo-median of pairwise differences [95 % CI]*	*Two-tailed Fisher's exact test, p*
Modic changes		0 – 272 (54.7 %); I – 40 (8.1 %); II, III – 185 (37.2 %)	0 – 5 (29.4 %); I – 9 (52.9 %); II, III – 3 (17.6 %)	Method not applicable	<0.001*
Pfirrmann disc degeneration grade III, IV, n %		III – 101 (20.3 %); IV – 396 (79.7 %)	III – 11 (64.7 %); IV – 6 (35.3 %)	Method not applicable	<0.001*
L4–L5/L5–S1 level		L4–L5 – 246 (49.5 %); L5–S1 – 251 (50.5 %)	L4–L5 – 7 (41.2 %); L5–S1 – 10 (58.8 %)	Method not applicable	0.624
Calculation method		*n, % [95 % CI]*	*n; % [95 % CI]*	*OR [95 % CI]*	*Two-tailed Fisher's exact test, p*
Herniation type	Protrusion	83; 17 % [14 %; 20 %]	12; 71% [47%; 87%]	11.9 [3.8; 44.2]	<0.001*
	Extrusion	391; 79 % [75 %; 82 %]	4; 24 % [10 %; 47 %]	0.1 [0; 0.3]	<0.001*
	Sequestration	23; 5 % [3 %; 7 %]	1; 6 % [1 %; 27 %]	1.3 [0; 9]	0.562

*statistically significantly different variables.

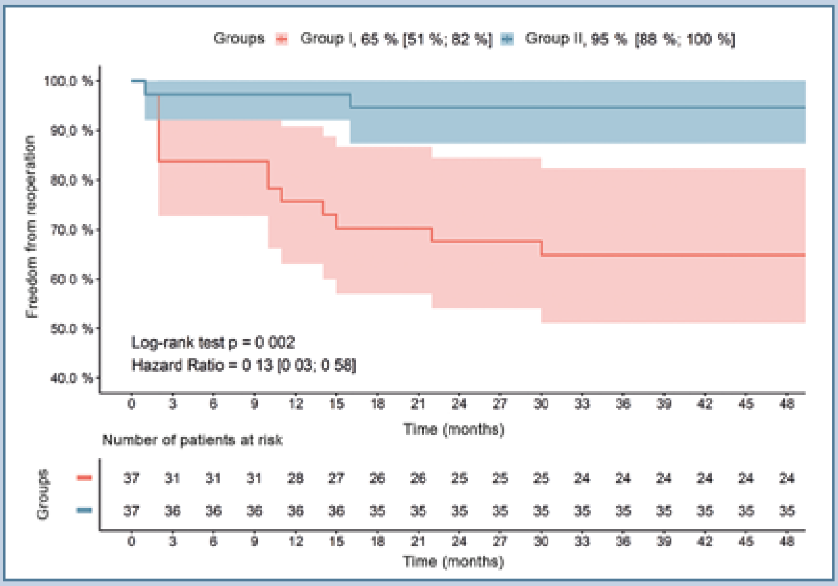

Fig.
Kaplan – Meier curves of freedom from reoperation after applying the Propensity Score Matching method

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