



# RETROSPECTIVE ANALYSIS OF CLINICAL, NEUROLOGICAL AND DEGENERATIVE CHANGES IN PATIENTS WITH SINGLE-LEVEL CERVICAL SPINAL STENOSIS BASED ON THE USE OF THE INDI SCALE

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**Objective.** To evaluate the ability of the Index of Neurological and Degenerative Impairments (INDI) to reliably stratify patients with single-level cervical spinal stenosis depending on treatment tactics, through a retrospective analysis of clinical, neurological, and neuroimaging data.

**Material and Methods.** A total of 176 patients with single-level cervical spinal stenosis treated in a neurosurgical hospital were screened. Of these, 77 patients were included in the study based on predefined criteria: Group 1 – conservative treatment ( $n = 22$ ), Group 2 – surgical treatment ( $n = 41$ ), and Group 3 – patients who received conservative treatment but were discharged without improvement and placed under observation ( $n = 14$ ). Patients were treated strictly in accordance with the current Russian Clinical Guidelines for Degenerative Spinal Diseases. A statistical analysis of differences between the groups was performed using the INDI scale, and its prognostic significance was assessed. The INDI scale was used retrospectively, and the scale data did not influence treatment decisions.

**Results.** Group 1 had an average INDI score of  $2.58 \pm 1.46$ , Group 2 –  $6.30 \pm 1.36$ , and Group 3 –  $2.90 \pm 0.36$ . Patients in Group 2 were younger ( $46.12 \pm 10.65$  vs.  $53.90 \pm 10.66$  years in Group 1;  $p < 0.05$ ), had more pronounced paresis ( $2.92 \pm 0.46$  vs.  $1.63 \pm 1.50$ ;  $p < 0.05$ ) and more severe degenerative changes ( $p = 0$ ). Discriminant analysis confirmed significant differences between the groups (Wilks' lambda = 0.279;  $p = 0$ ), with INDI score and total neurological impairment score being the most discriminating factors ( $F = 92.78$  and  $92.47$ , respectively). The stratification accuracy was 93.5%.

**Conclusion.** The INDI scale allows for a unified assessment of the severity of neurological disorders and degenerative changes of the spinal motion segment based on neuroimaging data. It demonstrated a good ability to differentiate between groups in a retrospective sample, however, further prospective studies are required to validate the method.

**Key Words:** single-level cervical spinal stenosis; degenerative spinal diseases; neuroimaging; Index of Neurological and Degenerative Impairments (INDI); spinal surgery.

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More than a third of the world's population suffers from persistent cervical pain for more than three months [1]. Degenerative pathology of the cervical spine is the primary cause of cervical pain, injury to the nerve roots and adjacent spinal cord [2].

The incidence of degenerative changes in the spine in our country is 51.2 per 1,000 population [3], increasing with age in both men and women, most commonly in the age of 3rd to 5th decade of life [4, 5]. According to data from the world literature, degenerative changes in the cervical spine (CS), namely spinal canal stenosis, are multisegmental in nature in 65.5% of cases and occur at the C5–C6 or C6–C7

segments [6, 7]. The strong correlation between age and the number of affected levels ( $r = 0.77$ ;  $p < 0.0001$ ) indicates that degeneration more often becomes multi-level with the years passing. It can be concluded that single-level CS stenosis is a disease that predominantly affects the working-age population, making it a socially significant challenge [8].

There is no single, universally accepted definition of single-level degenerative CS stenosis in the literature. There are varying criteria, which depend on the combination of clinical, neurological, and MRI findings. For this study, we use the definition established in the current clinical guidelines of the Russian Federation. According to

this definition, degenerative single-level cervical spinal canal stenosis in the cervical spine is a condition characterized by a mismatch between the capacity of the bony-fibrous spinal canal and the space required by its neurovascular contents at a single spinal motion segment (SMS). This mismatch results from a pathological narrowing of the central canal, lateral recess, or intervertebral foramen because of invasion of bony, cartilaginous, or soft-tissue structures. It manifests clinically with symptoms of compression and ischemia of the nerve roots and/or spinal cord [9].

There are a large number of clinical and neurological scales as well as

neuroimaging scales for degenerative changes in the CS. For example, the VAS is used to evaluate pain syndrome, the Neck Disability Index is used to determine functional status in degenerative changes in the CS, the European Myelopathy Score is used to evaluate cervical myelopathy and the Neck Pain and Disability Scale is used to evaluate functional outcomes.

The use of these scales in clinical practice to standardize neurological syndromes and neuroimaging data is a relevant issue. Thus, the authors of this article present the Index of Neurological and Degenerative Impairments (INDI) of SMS.

The objective is to evaluate the ability of the Index of Neurological and Degenerative Impairments (INDI) to reliably stratify patients with single-level cervical spinal stenosis depending on treatment tactics through a retrospective analysis of clinical, neurological, and neuroimaging data.

## Material and Methods

Study design: a retrospective, observational, single-cohort uncontrolled study, without randomization or blinding.

The study was conducted at Irkutsk City Clinical Hospital No. 3 from 2019 to 2024. The study included 176 patients with diagnosis of single-level stenosis of the CS whose clinical and neurological data were retrospectively analyzed (using medical records) and assessed according to the INDI scale. Patients with comorbidities (spinal cord injury at any stage, history of central and peripheral nervous system disorders such as tumors, infectious and demyelinating diseases, polyneuropathies of various origins, etc.) were excluded, and patients with multisegmental degenerative changes in the spine or incomplete medical records were not included. The final sample consisted of 77 patients who received effective conservative ( $n = 22$ ) and surgical ( $n = 41$ ) treatment, as well as those who received conservative treatment but were discharged without improvement to follow-up care ( $n = 14$ ). The patients got both surgical

and conservative treatment in the hospital. The choice of treatment was in line with the clinical guidelines for the treatment of degenerative spinal diseases [9].

### Methods of assessment

The INDI was used to assess neurological and degenerative changes. The index is the authors' patented invention (priority reference No. 2024136118/14 (080205) "Method for assessment of degenerative changes in the spinal canal"). Neurological examination and neuroimaging (MSCT, MRI) were performed, and the data were summarized by INDI scores (Table 1). The INDI was used only retrospectively for research stratification and was not used in the selection of treatment strategies. The groups were selected after analysis of the documentation and statistical processing.

### Statistical analysis

The data were processed in Microsoft Excel 2019 and Statistica 10. The Mann-Whitney U test was used to compare groups, and discriminate function analysis was used to identify predictors of patient classification into one of three groups within the discriminant model and stratification accuracy. Statistical power was 80% at  $p = 0.05$ .

No ethical review was conducted because of the retrospective nature and compliance with clinical guidelines.

## Results

A total of 176 medical records of patients with degenerative pathology of the cervical spine were reviewed. Using the above criteria, 99 (56.24%) medical records were excluded. The study included 77 patients with single-level degenerative stenosis of the cervical spine. Two groups were retrospectively formed with conservative and surgical treatment (groups 1 and 2): 36 and 41 patients, respectively.

The mean age of patients in groups 1 and 2 was  $53.16 \pm 10.09$  and  $46.12 \pm 10.65$  years, respectively. Group 1 consisted of 14 men and 22 women, while Group 2 consisted of 27 men and 14 women.

During the nonparametric analysis, a significant statistical difference was found between the groups on a number of characteristics (Table 2).

A statistically significant difference was found between the groups in terms of age ( $53.16 \pm 10.09$  and  $46.12 \pm 10.65$  years;  $p < 0.05$ ) and gender (predominance of men in the group of surgically treated patients, see above;  $p < 0.05$ ), severity of neurological and degenerative changes according to the INDI: in Group 2, patients more often reported radicular pain and changes in reflexes ( $1.55 \pm 0.84$  and 2, respectively;  $p < 0.05$ ), and sagittal stenosis also dominated in this group ( $0.01333 \pm 0.01910$  and  $0.02341 \pm 0.01995$ , respectively;  $p < 0.05$ ).

Furthermore, a significant statistical difference ( $p = 0$ ) was observed in the following characteristics: presence of motor impairments ( $0.16 \pm 0.69$  and  $2.92 \pm 0.46$ , respectively), total neurological changes ( $2.66 \pm 1.17$  and  $6.24 \pm 1.35$ ), the predominance of disc bulges in Group 1 ( $0.005 \pm 0.050$  and 0) and herniation (for example, osteochondral nodes) in Group 2 ( $0.01 \pm 0.01$  and 0.02), total degenerative changes ( $0.04 \pm 0.01$  and  $0.06 \pm 0.01$ ), as well as the INDI scale ( $2.71 \pm 1.16$  and  $6.30 \pm 1.36$ , respectively).

Group 3 was defined empirically and included patients who received conservative treatment in accordance with current clinical guidelines. However, the effect of treatment was not as expected; therefore, the question of further treatment strategy remained undecided.

A discriminant analysis was performed, which statistically confirmed the existence of a third group of patients that differs significantly from the other two groups. The composition of this group is influenced by the following factors:

- discriminant analysis revealed that among the total sample of patients, there is a cluster (additional group) that cannot be clearly classified as either the conservative treatment group or the surgical treatment group;

Table 1

Index of neurological and degenerative impairments in the spinal motion segment

| A   |       | B  |       |
|---|-------|--|-------|
| Neurological changes  | Score | Degenerative changes   | Score |
| No pain   | 0     | Changes within the disc; Schmorl's nodes   | 0     |
| Local pain in the spine   | 1     | Intervertebral disc bulge  | 0.01  |
| Radicular pain (radiating to an extremity) and/or sensory impairment and/or changes in reflexes | 2     | Herniated disc   | 0.02  |
| Motor impairment (paresis, paralysis)   | 3     | Lateral stenosis of 2.7 mm or less in the oblique sagittal plane in the cervical spine, and 3 mm or less in diameter in the lumbar spine | 0.03  |
| Pelvic disorders, polyradicular syndrome  | 4     | Sagittal stenosis of 12 mm or less in the cervical spine, 12 mm or less in the lumbar spine  | 0.04  |

– it was found that such informative parameters ( $p = 0$ ) as total neurological changes, frequency of sagittal and foraminal stenosis, as well as the INDI score, significantly discriminate (distinguish) between the above three groups (mean Wilks' lambda distribution = 0.279374). Meanwhile, the most significant are INDI scores and total neurological changes ( $F = 92.78$  and  $92.47$ , respectively; Table 3).

The contribution of the identified characteristics to intergroup dispersion was found to be significant ( $p = 0$ ; Table 4).

These differences indicate that Group 3 is an empirically selected sample of patients that is statistically different from the other two groups (Tables 3, 4). Patients in this group received conservative treatment (including epidural blocks) and were under ongoing follow-up; the question of surgery remained unresolved for them and was beyond the scope of this retrospective analysis.

The separation of Group 3 is not a subjective decision but is confirmed by formal mathematical methods (discriminant analysis).

An additional statistical analysis revealed significant differences between this group and the two main groups, which eliminates the possibility of its formation being random.

The identification of Group 3 is a logically relevant and statistically

confirmed step. This cluster of patients requires separate analysis, as it differs in a number of characteristics and may represent a special category with controversial indications for surgical or conservative treatment.

Therefore, Group 1 was subdivided into two: the final group consisted of 122 patients who were effectively treated conservatively, and the group of patients ( $n = 14$ ) in whom the question of surgical treatment remained undecided after therapy (hereinafter referred to as Group 3).

After secondary analysis, the following results were obtained. In groups 1 and 2, a statistically significant difference in age was found ( $53.90 \pm 10.66$  and  $46.12 \pm 10.65$  years;  $p < 0.05$ ); disc bulges prevailed ( $0.008 \pm 0.003$  and  $0$ ;  $p = 0$ ) in Group 1, while in Group 2, radicular pain and reflex changes ( $1.27 \pm 0.98$  and  $2$ ;  $p = 0$ ), motor impairments ( $1.63 \pm 1.50$  and  $2.92 \pm 0.46$ ;  $p = 0$ ), totally more pronounced neurological changes according to the INDI ( $2.54 \pm 1.47$  and  $6.24 \pm 1.35$ ;  $p = 0$ ), a predominance of herniation and osteochondral enlargements ( $0.003 \pm 0.007$  and  $0.020$ ;  $p = 0$ ), total degenerative changes ( $0.04 \pm 0.01$  and  $0.06 \pm 0.01$ ;  $p = 0$ ), and a higher index value ( $2.58 \pm 1.46$  and  $6.30 \pm 1.36$ ;  $p = 0$ ) were more often noted.

In Group 1, compared with Group 3, radicular pain was less frequent ( $1.27 \pm 0.98$  and  $2.00$ ;  $p < 0.05$ ); disc bulges were more frequent ( $0.008 \pm 0.003$  and  $0.000$ ;

$p = 0$ ); disc herniation was significantly less frequent ( $0.003 \pm 0.007$  and  $0.020$ ;  $p = 0$ ); in Group 3, the total degenerative changes were more pronounced ( $0.040 \pm 0.010$  and  $0.050 \pm 0.004$ ;  $p < 0.05$ ), statistically significantly higher INDI score – 3 ( $2.58 \pm 1.46$  and  $2.90 \pm 0.36$ ;  $p < 0.05$ ).

A comparison of groups 2 and 3 showed that there were statistically more men in Group 2 than in Group 3 (27 men and 14 women versus 4 men and 10 women, respectively;  $p < 0.05$ ); in Group 2, paresis and paralysis were more frequent ( $2.92 \pm 0.46$  and  $0.00$ ;  $p = 0$ ), and the total neurological disorders according to the INDI were more pronounced ( $6.24 \pm 1.35$  and  $2.85 \pm 0.36$ ;  $p = 0$ ), as well as more pronounced degenerative changes ( $0.060 \pm 0.010$  and  $0.050 \pm 0.004$ ;  $p < 0.05$ ) and higher INDI values ( $6.30 \pm 1.36$  and  $2.91 \pm 0.36$ ;  $p = 0$ ).

During the discriminant analysis, the tolerance of predictors and possible multicollinearity issues were evaluated (Table 4). Four variables were used to calculate the classification functions:  $X1$  – neurological changes according to INDI;  $X2$  – lateral stenosis;  $X3$  – sagittal stenosis;  $X4$  – total INDI score.

The analysis showed that the coefficients of the classification functions (Table 5) have different importance values, which means that the predictors make different contributions to the classification (Table 4). Subsequently,

Table 2

Nonparametric analysis of groups 1 and 2

| Parameter                  | Total rank 1 | Total rank 2 | U   | Z (corrected) | p value (corrected) | N1 | N2 | Two-tailed (exact p) |
|----------------------------|--------------|--------------|-----|---------------|---------------------|----|----|----------------------|
| Age                        | 1701         | 1302         | 441 | 3.03          | 0.0024              | 36 | 41 | 0.0022               |
| Gender                     | 1603         | 1400         | 539 | 2.34          | 0.0190              | 36 | 41 | 0.0422               |
| No pain                    | 1404         | 1599         | 738 | -0.05         | 0.9900              | 36 | 41 | —                    |
| Local pain                 | 1417         | 1586         | 725 | 0.30          | 0.7650              | 36 | 41 | 0.8990               |
| Radicular pain / reflexes  | 1240         | 1763         | 574 | -3.16         | 0.0016              | 36 | 41 | 0.0952               |
| Motor impairments          | 725          | 2278         | 59  | -8.03         | 0.0000              | 36 | 41 | 0.0000               |
| Pelvic disorders           | 1332         | 1671         | 666 | -1.90         | 0.0576              | 36 | 41 | 0.4676               |
| Total neurological changes | 719          | 2284         | 53  | -7.49         | 0.0000              | 36 | 41 | 0.0000               |
| Intervertebral disc bulge  | 1773         | 1230         | 369 | 5.13          | 0.0000              | 36 | 41 | 0.0001               |
| Herniated disc             | 1035         | 1968         | 369 | -5.13         | 0.0000              | 36 | 41 | 0.0001               |
| Lateral stenosis           | 1400         | 1603         | 734 | -0.035        | 0.9660              | 36 | 41 | 0.9700               |
| Sagittal stenosis          | 1218         | 1785         | 552 | -2.19         | 0.0284              | 36 | 41 | 0.0579               |
| Total degenerative changes | 975          | 2028         | 309 | -4.68         | 0.0000              | 36 | 41 | 0.0000               |
| INDI                       | 683          | 2320         | 17  | -7.45         | 0.0000              | 36 | 41 | 0.0000               |

the correlation between variables was additionally reviewed. The correlation coefficients between predictors did not exceed the critical value of 0.7, indicating the absence of significant multicollinearity. The total score of the INDI scale ( $X_4$ ) correlated with individual neurological changes ( $X_1$ ), but their simultaneous inclusion in the model was clinically justified.

This means that there are no multicollinearity issues, and the included variables can be regarded as independent predictors in the model.

Based on the coefficients of the linear functions shown above, the values of functions  $F_1$ ,  $F_2$ , and  $F_3$  for groups 1, 2, and 3, respectively, are calculated using the following formulas:

$$F_1 = -25.66 - 3184.18 \times X_1 - 3047.86 \times X_2 - 3102.82 \times X_3 + 3187.33 \times X_4;$$

$$F_2 = -80.87 - 5706.83 \times X_1 - 5569.42 \times X_2 - 5634.36 \times X_3 + 5713.55 \times X_4;$$

$$F_3 = -62.89 - 5295.48 \times X_1 - 5158.93 \times X_2 - 5242.93 \times X_3 + 5299.93 \times X_4,$$

where  $X_1$  is the total neurological changes according to INDI (maximum 10 points);  $X_2$  is lateral stenosis (0.03);  $X_3$  is sagittal stenosis (0.04); and  $X_4$  is the total INDI score.

If  $F_1$  is more than  $F_2$  and  $F_3$ , the patient receives conservative treatment (Group 1). If  $F_2$  is more than  $F_1$  and  $F_3$ , surgical treatment is indicated (Group 2). If  $F_3$  is more than  $F_1$  and  $F_2$ , the patient receives conservative treatment accompanied by follow-up and consideration of surgical treatment if conservative treatment remains unsuccessful.

#### Additional research findings

During verification using linear classification functions of the

preliminary classification of objects into three groups, the grouping accuracy was 93.5%. The accuracy of diagnosis using the decision rules is 81.8% for Group 1, 97.5% for Group 2, and 100.0% for Group 3. The insufficient accuracy of diagnosis is attributed to the intersection of these groups.

Brief example: the patient suffers from local back pain – 1 point; radicular pain – 2 points; arm paresis – 3 points; pelvic disorders – 4 points; disc herniation – 0.02 points; lateral stenosis – 0.03 points; sagittal stenosis – 0.04 points. Total – A (10 points) + B (0.09 points) = 10.09 points according to INDI.

According to the formula:  $X_1 = 10$ ;  $X_2 = 0.03$ ;  $X_3 = 0.04$ ;  $X_4 = 10.09$ .

$$F_1 = -25.66 - 3184.18 \times 10 - 3047.86 \times 0.03 - 3102.82 \times 0.04 + 3187.33 \times 10.09 = 77.13.$$

Table 3

Parameters of discriminant analysis for assessing the factor significance

| Parameter                  | Wilks' lambda | Lambda partial | F excluded | p value  | Tolerance | 1-Tolerance (R <sup>2</sup> ) |
|----------------------------|---------------|----------------|------------|----------|-----------|-------------------------------|
| INDI                       | 0.304793      | 0.276735       | 92.781750  | 0.000000 | 0.000002  | 0.999998                      |
| Total neurological changes | 0.304069      | 0.277394       | 92.476880  | 0.000000 | 0.000002  | 0.999998                      |
| Sagittal stenosis          | 0.264680      | 0.318675       | 75.898650  | 0.000000 | 0.009295  | 0.990705                      |
| Lateral stenosis           | 0.243954      | 0.345748       | 67.175820  | 0.000000 | 0.015718  | 0.984282                      |

Table 4

Statistical indicators of canonical discriminant analysis

| Function | Characteristic value | Canonical R | Wilks' lambda | $\chi^2$   | Degree of freedom | <i>p</i> value |
|----------|----------------------|-------------|---------------|------------|-------------------|----------------|
| 1        | 6.544202             | 0.931369    | 0.0843470     | 179.279300 | 8                 | 0.000000       |
| 2        | 0.571512             | 0.603051    | 0.636330      | 32.772800  | 3                 | 0.000000       |

Table 5

Coefficients of linear classification functions

| Parameter                  | Group 1<br>( <i>p</i> = 0.28571) | Group 2<br>( <i>p</i> = 0.53247) | Group 3<br>( <i>p</i> = 0.18182) |
|----------------------------|----------------------------------|----------------------------------|----------------------------------|
| INDI                       | 3187.33                          | 5713.55                          | 5299.93                          |
| Total neurological changes | 3184.18                          | 5706.83                          | 5295.48                          |
| Sagittal stenosis          | 3102.82                          | 5634.36                          | 5242.93                          |
| Lateral stenosis           | 3047.86                          | 5569.42                          | 5158.93                          |
| Constant                   | 25.66                            | 80.87                            | 62.89                            |

$F2 = -80.87 - 5706.83 \times 105569.42 \times 0.03 - 5634.36 \times 0.04 + 5713.55 \times 10.09 = 108.03$ .

$F3 = -62.89 - 5295.48 \times 10 - 5158.93 \times 0.03 - 5242.93 \times 0.04 + 5299.93 \times 10.09 = 94.05$ .

$F2$  is more than  $F1$  and  $F3$ . It means that the patient requires surgical treatment in accordance with the INDI scale. The example illustrates the model classification of group assignment based on function values.

The treatment plan was selected independently of INDI. It was made in accordance with clinical guidelines; in this case, it is only a research demonstration of the model's operation.

## Discussion

During the study, we were able to identify various characteristics specific to each of the groups examined.

Firstly, it was found that patients who underwent surgery were younger than those who received conservative treatment. This phenomenon can be explained by the following pattern: with age, the degree of neurological manifestations of degenerative spinal pathology, including single-level lesions of the CS, decreases [10]. This is explained by

various factors causing degeneration of nerve structures: circulatory disorders, metabolic disorders, aging, etc.

Secondly, men were statistically more likely to undergo surgery, while women were more likely to receive conservative treatment. The middle-aged male population is most involved in labor activities, including physical labor, and therefore represents the most common group of patients requiring surgical treatment.

Thirdly, in the group of patients who were indicated for surgery, neurological symptoms were statistically more frequently detected, including radicular pain, changes in reflexes, and motor impairments (paresis, paralysis). Furthermore, disc bulges (including osteochondral enlargements) complicated by sagittal stenosis of the spinal canal were found significantly more often, while in Group 1, mild compression of the spinal canal contents (disc bulges) was more common. All these signs contributed to the decision to perform surgery, which is consistent with current clinical guidelines.

The separation of an additional Group 3 from Group 1 resulted from statistical data processing. Moreover, the existence of a group of patients for whom the choice of treatment is still controversial has been

confirmed by clinical practice. Based on clinical guidelines, these patients need to be treated conservatively. If this approach is ineffective, surgical intervention is recommended.

Following secondary data processing, the general trends between the conservative and surgical treatment groups were still the same: in Group 2, patients were 7 years younger and had more severe neurological (including motor impairments) and degenerative symptoms. The INDI score was significantly higher in Group 2. Nevertheless, the previous gender-based differences within the groups were no longer observed.

Statistical differences were also found between the groups given fully conservative treatment and Group 3, in which the question of further treatment strategy remained controversial. Patients in Group 3 were more often experienced radicular pain and disc bulges compared to Group 1, where disc bulges and less severe neurological symptoms were more common. The INDI score was higher in Group 3. There were no significant differences in age and gender between the groups.

Patients who underwent surgery also had a number of differences in comparison with those patients who received conservative treatment, but for whom the question of further strategy remained unresolved. In this case, there were more men in Group 2, with a marked prevalence of paresis and paralysis, which was significantly less common in Group 3. The total value of degenerative changes and INDI score was also statistically higher in Group 2.

Therefore, groups 1 and 2 are significantly differentiated by the age gap between patients and the degree of the neurological and degenerative changes that are the main indicators for surgical treatment. Group 3 is separated by two indicators: the severity of radicular pain and degenerative changes compared to Group 1; significantly less severe motor deficit and degree of spinal canal stenosis compared to Group 2.

The INDI score was statistically significantly different in all three groups, which also defines them.

Discriminate function analysis was conducted to determine the accuracy of patient classification into groups. It was revealed that the values of sagittal and foramen stenosis, as well as the INDI score, significantly discriminate (distinguish) between the three groups. The contribution of these characteristics to intergroup dispersion is verified by the statistical calculations indicated above. Using the aforementioned formulas, we calculated the values of functions  $F1$ ,  $F2$ , and  $F3$  for each specific patient. Using the highest  $F$  value, we were able to divide patients into corresponding groups: the highest  $F1$  – Group 1 (conservative treatment);  $F2$  – Group 2 (surgical treatment);  $F3$  – Group 3 (conservative treatment with subsequent decision on treatment strategy if unsuccessful).

The overall accuracy of patient categorization was 93.5%. The accuracy was approximately 82% for Group 1; 97.5% for Group 2; and 100% for Group 3. We believe that the slight decrease in diagnostic accuracy, which was mostly pronounced in Group 1, was associated with the fact that some patients had boundary scores on the INDI scale, complicating their accurate classification. There were some cases when the clinical data (for example, the intensity of pain) did not match the classification algorithm, requiring further clarification of the scale's threshold values.

The use of a new algorithm for selecting treatment strategies based on INDI may be difficult in case of manual cal-

culations. Nevertheless, if this method is implemented as a calculator program or mobile application, it will be convenient and easy to apply in clinical practice. The introduction of such a system will automate the patient assessment process, reduce the subjectivity of data interpretation, and simplify decision-making for physicians.

The obtained data indicate that INDI scale accurately distinguishes between groups in the retrospective sample. These results seem promising from a research point of view. However, prospective studies, external validation, and comparison with recognized scales (e.g., mJOA/Nurick) are required before discussing their potential practical application.

*Limitations of the study.* This study has a number of limitations that should be considered when interpreting the obtained data. The retrospective design of the study limits its level of evidence because of possible errors or incomplete data in medical records. The fact that the study was performed at a single hospital limits the generalizability of the findings, since regional characteristics may have influenced treatment strategy. The INDI scale used in the analysis has not undergone prospective validation and has not been compared with other evaluation methods, such as Nurick or mJOA, complicating confirmation of its prognostic value. Small sample sizes and the lack of  $p$ -value correction for multiple comparisons may confound statistical conclusions. Furthermore, the influence of

comorbidities such as osteoporosis or diabetes, as well as differences between surgical approaches, was disregarded, which requires further study.

## Conclusion

The study showed that the INDI scale reliably stratifies patients with single-level stenosis of the CS. A retrospective analysis highlighted three groups of patients (those who underwent conservative treatment, surgery, and those with an undefined treatment strategy), differing in clinical and neuroimaging characteristics. The accuracy of stratification was 93.5%, confirming the diagnostic and clinical significance of INDI. This approach combines neurological and degenerative data into a single evaluation, making it easier to choose treatment options. Additional prospective studies are required for final validation and widespread application of INDI scale in clinical practice.

*The study had no sponsors.*

*The authors declare that they have no conflict of interest.*

*The study was approved by the local ethics committee of the institution.*

*All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.*

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