A new classification for spinal epidural hematoma following microendoscopic decompressive laminotomy: A prospective clinical and magnetic resonance imaging study of 245 patients

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ABSTRACT

Objective: The aim of this study was to develop a new radiological classification system for postoperative spinal epidural hematoma (SEH) using magnetic resonance imaging (MRI) and to determine the correlation of this classification system with clinical and radiological outcomes.

Methods: This prospective study included a total of 245 consecutive patients (126 females, 119 males; mean age=72 years; age range=39-91 years) with single level spinal stenosis who were treated by microendoscopic decompressive laminotomy (MEDL). MRI was performed for all patients 24 hours postoperatively and at 12 months. SEHs were categorized into four grades using our new MRI-based classification system based on the measurement of dural sac area: Grade A, small hematoma with a round shape; grade B, small hematoma that show no round shape; grade C, moderate hematoma; grade D: severe hematoma. Patients were then divided into four groups according to their hematoma grades, Group A, 107 patients with grade A hematomas; group B, 47 with grade B; group C, 67 with grade C; group D, 24 with grade D. Also, patients who had neurological deterioration or who were resistant to medical treatment were treated surgically, and those were assigned to group H+ (14 patients). The study, therefore, contained five groups. Clinical evaluation was done using Japanese Orthopaedic Association (JOA) score preoperatively and at 12 months postoperatively.

Results: No significant difference existed among groups in the preoperative median measurement of the dural sac area, which were 0.90 cm² in group A, 0.80 cm² in group B, 0.70 cm² in group C, 1.1 cm² in group D, and 0.80 cm² in group H+ (p=0.076). At the postoperative 12-month measurement, no significant difference was noted among groups A (2.05 cm²), B (1.80 cm²), and H+ (1.90 cm²) but the difference reached a statistical significance (p=0.078). In preoperative JOA scores, there were no significant differences among groups (p=0.05). At 12-month JOA scores, no significant difference was observed between groups A and B (p=0.061) and between groups C and D (p=0.513). The scores were higher in groups A and B than in groups C and D (p=0.05).

Conclusion: It seems that the narrower the preoperative dural sac area, the better the clinical symptoms of the patients with SEHs based on our new MRI-based classification system. This classification may be useful to predict the clinical status of these patients at one-year follow-up.

Level of Evidence: Level IV, Diagnostic study

Introduction

Postoperative spinal epidural hematoma (SEH) is a condition which can lead to neurological deficits or severe postoperative pain requiring revision surgeries. Symptoms can emerge in the first hours after the operation or may develop later (1, 2).

In the literature, hematomas are generally classified as symptomatic or asymptomatic. Retrospective studies have reported the incidence of symptomatic SEH to be 0.1%-0.2% (3, 4), and asymptomatic SEH was reported to be as high as 33%-100% (5-7). Previous studies of SEH were mostly carried out among patients who underwent open surgery. However, Ikuta et al. investigated the clinical and radiological recovery of postoperative hematoma among 30 patients who underwent microendoscopic decompressive laminotomy (MEDL), and the patients were grouped as symptomatic and asymptomatic, and the patients with symptomatic hematoma were reported to have slower recovery and worse clinical scores at the final follow-up compared to patients with asymptomatic hematoma. It was also reported radiologically that the dural sac of these patients had expanded less, and even with a resolution of the hematoma, the formation of fibrotic tissue occurred, which could have prevented the dural sac re-expansion (5).

The likelihood of SEH was higher in MEDL technique because the area of dissection was smaller, and effective haemostasis could not be achieved due to poor visualization in the surgical field. In addition, adequate post-operative drainage could not be achieved (6).

The aim of the current study was to develop a radiological classification that was simple and suitable for universal use and to prospectively investigate the correlation...
between this classification and the clinical and radiological outcome in 245 patients who underwent MEDL at their one-year follow-up.

Materials and Methods

In this prospective study, the patients selected had spinal stenosis treated with the MEDL technique between 2014 and 2016. The study inclusion criterion was having single-level spinal stenosis. Exclusion criteria were previous history of lumbar surgery, Cobb angle >20˚, the presence of vertebral fracture, the presence of a coagulopathy, multiple level stenosis, and cases of intraoperative dural tear. All patients followed a similar postoperative protocol, and the same drain type was used in all patients (Jackson-Pratt silicone round drain, Cardinal Health, Waukegan, USA).

Magnetic resonance imaging (MRI) and computed tomography (CT) examinations were performed in all the patients 24 hours postoperatively and in the 12th month. The hematomas were divided into four categories using our newly-developed hematoma classification. In the MRI classification, measurements were taken of the cross-sectional area of the preoperative dural sac (Pre DS), cross-sectional area of the 24-hour postoperative dural sac (Po DS), and the hematoma cross-sectional area under the line drawn from the spinous process to the ventral surface of the facet joint on the laminotomy side. The measurements were made using a DICOM viewer [POP-net web server, Image ONE Co., Tokyo, Japan]. The measurements were performed by two spinal surgeons at the symptomatic disc level where the procedure was performed on T2-weighted axial images of MRI (Figure 1). Forty-nine of the 254 (20%) postoperative MRI images were randomly selected for repetitive review by both surgeons. The Pearson’s correlation coefficients were used to calculate inter- and intra-observer reliabilities with values of 0.93 and 0.95, respectively. According to this classification:

* Grade A: Po DS has a round shape. There could be a small hematoma but not compressing the dural sac.
* Grade B: Po DS is not round in shape because of a small hematoma, but Po DS area > Pre DS area > Hematoma area.
* Grade C: Moderate hematoma; Hematoma area > Po DS area > Pre DS area.
* Grade D: Severe Hematoma; Hematoma area > Pre DS area.

The patients were separated into 4 groups according to the hematoma classification stated above (Grade A=Group A, Grade B=Group B, Grade C=Group C, and Grade D=Group D). Hematoma evacuation surgery was performed in patients with neurological deterioration or in those with pain that could not be controlled with medical treatment. Those patients who needed hematoma evacuation surgery constituted a separate group, labelled H+; and thus, the study was conducted with 5 groups. In addition, MRIs were performed again at the end of the 12th month to observe final dural sac expansion.

**HIGHLIGHTS**

- Spinal epidural hematoma (SEH) negatively affects postoperative dural sac enlargement.
- According to our new SEH classification: As the grade of hematoma increases, clinical improvement is delayed, even if it is asymptomatic.
- The narrower the preoperative dural sac area of the patient, the less symptoms of spinal epidural hematoma that could develop.
Rates of clinical healing were compared between the groups using the Japanese Orthopaedic Association (JOA) score and the Visual Analog Scale (VAS) score applied preoperatively and in 1\(^{st}\), 3\(^{rd}\), and 12\(^{th}\) months postoperatively. The improvement rate of the JOA score was calculated and was based on the following formula: Improvement rate [%]=\((\text{postoperative JOA score-preoperative JOA score}) \times 100/\text{(preoperative JOA score)}\). The demographic data of the patients, operation levels, operating times, and amounts of bleeding were also examined.

Written informed consents were obtained from the patients, and the study was performed in accordance with the Declaration of Helsinki and was approved by the ethics committee with the decision number of İ8-534-20.

**Statistical analysis**

The IBM Statistical Package for Social Sciences version 25.0 (IBM SPSS Corp.; Armonk, NY, USA) and PAST 3 (Hammer, Ø., Harper, D.A.T., Ryan, P.D. 2001. Paleontological Statistics) were used to analyse the variables. The suitability of univariate data for normal distribution was evaluated by the Shene-Wilk test, and the homogeneity of variance by the Levene Test (Dornik and Hansen Omnibus), and variance homogeneity was evaluated with the Box-M Test. In a comparison of more than two groups according to quantitative data, the Jonckheere-Terpstra and the Kruskal-Wallis H tests, which are non-parametric tests, were used with the Monte Carlo Simulation Technique. The Dunn’s test was used for post hoc analysis. In the analysis of repeated quantitative measurements, the Friedman’s two-way test was used with the Monte Carlo Simulation Technique; and the Dunn’s test was used for post hoc analysis. In the comparison of categorical variables, the Chi-squared, the Fisher-Freeman-Halton, and the Pearson’s tests were used with the Monte Carlo Simulation Technique; and column ratios were compared with each other. The p value was expressed according to the Benjamini-Hochberg corrected results. Quantitative variables were expressed as mean±std (standard deviation) and median (minimum), and categorical variables were expressed as n (%). The variables were examined at 95% confidence level and p value was accepted significant when it was less than 0.05.

**Results**

A total of 245 patients were evaluated in this prospective study. The patients consisted of 126 females and 119 males with a mean age of 72.1 years (range: 39-91 years). The mean follow-up period was 12 months. The mean operating time was 94.3 min (range 29-169 min), and the mean blood loss was 49.7 cc (range: 10-350cc). The level of surgery was at L2/3 in 13 patients, L3/4 in 41, L4/5 in 182, and L5/S1 in 7 patients. No significant difference was determined between the groups in terms of age, gender, blood loss, and surgery level. The operation time was significantly lower in Groups A and B compared to those in Groups C and D. The demographic characteristics of the patients are shown in Table 1.

There were 107 patients in Group A, 47 in Group B, 67 in Group C, and 24 in Group D. All patients in Group D (100%) and 2 patients in Group C (20.9%) were symptomatic in terms of postoperative pain. Two patients in Group C (3%) and eleven patients in Group D (45.8%) had neurological deficits. There were 14 patients in Group H+; one patient in Group D who had pain that could not be controlled, and two patients in Group C and eleven patients in Group D had neurological deterioration.

**Dural sac area measurements**

The median preoperative dural sac area was 0.90 cm\(^2\) in Group A, 0.80 cm\(^2\) in Group B, 0.70 cm\(^2\) in Group C, 1.1 cm\(^2\) in Group D, and 0.80 cm\(^2\) in Group H+. No significant difference was determined between the groups with respect to preoperative dural sac area (p=0.076). On postoperative day 1, the median dural sac area was 2.23 cm\(^2\) in Group A, 1.85 cm\(^2\) in Group B, 1.30 cm\(^2\) in Group C, 0.61 cm\(^2\) in Group D, and 0.66 cm\(^2\) in Group H+. On the postoperative day

| Table 1. The demographic characteristics of the patients |
|-----------------------------------------------|
|                                | A          | B          | C          | D          | Pairwise Comparison |
| (n=107)                        | (n=47)     | (n=67)     | (n=24)     | p          | A→B | A→C | A→D | B→C | B→D | C→D |
| Postoperative Pain             |            |            |            |            | ns. | ns. | ns. | ns. | ns. | ns. |
| Absent                         | 107 (100)  | 47 (100)   | 53 (79.1)  | 0 (0)      | <0.001 | ns. |
| Present                        | 0 (0)      | 0 (0)      | 14 (20.9)  | 24 (100)   | ns. | ns. | ns. | ns. | ns. | ns. |
| Neurologic Impairment          |            |            |            |            | ns. | ns. | ns. | ns. | ns. | ns. |
| Absent                         | 107 (100)  | 47 (100)   | 65 (97)    | 13 (54.2)  | <0.001 | ns. |
| Present                        | 0 (0)      | 0 (0)      | 2 (3)      | 11 (45.8)  | ns. | ns. | ns. | ns. | ns. | ns. |
| Level                          |            |            |            |            | <0.001 | ns. |
| L2/3                           | 5 (4.7)    | 2 (4.3)    | 6 (9)      | 0 (0)      | 0.9191 | ns |
| L3/4                           | 18 (16.8)  | 6 (12.8)   | 11 (16.4)  | 6 (23)     | ns. | ns. | ns. | ns. | ns. | ns. |
| L4/5                           | 80 (74.8)  | 37 (78.7)  | 47 (70.1)  | 18 (75%)   | ns. | ns. | ns. | ns. | ns. | ns. |
| L5/S1                          | 5 (4.7)    | 0 (0)      | 1 (1.5)    | 0 (0)      | ns. | ns. | ns. | ns. | ns. | ns. |
| Sex                            |            |            |            |            | ns. | ns. | ns. | ns. | ns. | ns. |
| Female                         | 48 (44.9)  | 20 (42.6)  | 32 (47.6)  | 16 (66.7)  | 0.2292 | ns |
| Male                           | 59 (55.1)  | 27 (57.4)  | 35 (52.2)  | 8 (33.3)   | ns. | ns. | ns. | ns. | ns. | ns. |

**Table 5.1 Statistical analysis**

|                                | Median (Min /Max) | Median (Min /Max) | Median (Min /Max) | Median (Min/Max) |
|--------------------------------|-------------------|-------------------|-------------------|------------------|
| Age                           | 73 (48/91)        | 74 (48/84)        | 71 (39/90)        | 70 (61/86)       |
| Operation Time (min)          | 89 (29/169)       | 86 (55/146)       | 95 (63/156)       | 100.5 (65/145)   |
| Blood loss (cc)               | 30 (10/300)       | 30 (8/150)        | 30 (10/350)       | 30 (10/100)      |

\*Fisher Freeman Halton Test (Monte Carlo); Post Hoc test: Benjamini-Hochberg correction, \*Pearson Chi-Square Test (Monte Carlo); Jonckheere-Terpstra Test (Monte Carlo); Post Hoc Test: Dunn’s Test; ns: not significant.
1, dural sac area was smaller in Groups C, D, and H+ compared to Groups A and B (p<0.001). No significant difference was noted between Group A and Group B (p=0.472) in terms of the dural sac area on postoperative day 1 (Table 2).

Twelve months postoperatively, the median dural sac area was 2.05 cm² in Group A, 1.80 cm² in Group B, 1.80 cm² in Group C, 1.60 cm² in Group D, and 1.90 cm² in Group H+. No significant difference was noted between Groups A, B, and H+ (A→B: p=0.891, A→H+: p=0.089, B→H+: p=0.933). In Group A and Group B patients, the 12-month postoperative dural sac area was significantly greater compared to those in Groups C and D (p<0.05). The dural sac area in 12 months postoperatively was greater in Group H+ patients compared to those in Groups C and D, who did not undergo hematoma drainage (H-); however, the difference did not reach statistical significance (p=0.078) (Table 2, 3). In addition, in all groups except Groups A and B, the dural sac area was significantly wider on postoperative day 1 compared to an evaluation in the 12-month postoperative period (p<0.001). This may indicate that we cannot stop the degenerative process by decompression. The changes in the dural sac area over time is shown in Figure 2.

Clinical improvement

The median VAS scores from preoperative to the 12-month postoperative period are shown in Table 4. The median preoperative VAS score was 6.0 (range: 1-10). In the postoperative 1st month, the median VAS score of Groups C and D were found to be significantly higher than those in other groups (p<0.05). No difference was observed between Groups A, B, and H+ (Table 5). The one-month postoperative VAS scores of Group H+ were significantly lower than patients in Groups C and D (p=0.001). No significant difference was noted between Groups A and B (p=0.425) (Table 4, 5).

The median preoperative JOA score was 11.2 (range:2-24). No significant differences were noted between the groups in terms of preoperative period. The JOA scores of the patients in the 1st, 3rd, 6th, and 12th months postoperatively are shown in Table 6. The clinical improvement in Groups C and D was found to be significantly higher than in other groups (p<0.01). No difference was observed between Groups A, B, and H+ (Table 5). The clinical improvement period of Group H+ was significantly lower than patients in Groups C and D (p=0.001). No significant difference was noted between Groups A and B (p=0.425) (Table 4, 5).

### Table 2. Results of MRI evaluation on preoperative, Day 1 and year 1

|                  | A (n=47) | B (n=47) | C (n=67) | D (n=24) | Pairwise Comparison |
|------------------|----------|----------|----------|----------|---------------------|
| **MRI Tekal Sac** |          |          |          |          |                     |
| Preop            | 0.9 (0.3/1.6) | 0.8 (0.1/1.4) | 0.7 (0.1/1.7) | 1.1 (0.6/1.6) | 0.273 | ns | ns | ns | ns | ns | ns | ns |
| d 1.             | 2.2 (1.2/2.9) | 1.8 (1.1/2.7) | 1.3 (0.5/1.9) | 0.6 (0.2/1.1) | <0.001 | 0.472 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| y 1.             | 2 (1.1/2.7) | 1.8 (1.2/3.3) | 1.8 (1.3/2.2) | 1.6 (1/2) | <0.001 | 0.891 | <0.001 | <0.001 | <0.001 | <0.001 | 0.049 | 0.002 | 0.005 |
| **Improvement (Difference)** |          |          |          |          |                     |
| d 1. - Preop     | 1.3 (0.7/2.2) | 1.0 (0.4/1.8) | 0.6 (0.1/1.4) | -0.4 (0/0.9) | <0.001 | 0.079 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| y 1. - Preop     | 1.0 (0.6/1.9) | 1.0 (0.5/2.4) | 1.1 (0.3/1.7) | 0.6 (0/1.1) | <0.001 | 0.092 | 0.055 | <0.001 | 0.078 | <0.001 | <0.001 | <0.001 |
| y 1. - d 1.      | -0.1 (-0.6/0.1) | 0 (-0.4/1.4) | 0.5 (0/1) | 0.9 (-0.3/1.6) | <0.001 | 0.089 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Hematoma Size(cm²)** |          |          |          |          |                     |
| d 1.             | 0.9 (0/2.4) | 1.5 (1/2.6) | 2 (1.1/3.3) | 2.8 (1.2/3.5) | <0.0011 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **P (for intra group)** |          |          |          |          |                     |
| Preop→d 1.       | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Preop→y 1.       | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| d 1.→y 1.        | <0.001 | 0.680 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

### Table 3. Comparison of the Tekal Sac area with hematoma evacuation group (H+)

|                  | A (n=107) | B (n=47) | C (n=77) | D (n=14) | Pairwise Comparison |
|------------------|----------|----------|----------|----------|---------------------|
| **MRI Tekal Sac** |          |          |          |          |                     |
| Preop            | 0.9 (0.3/1.6) | 0.8 (0.1/1.4) | 0.7 (0.1/1.7) | 0.8 (0.3/1.3) | 0.076 | ns | ns | ns | ns |
| d 1.             | 2.2 (1.2/2.9) | 1.8 (1.1/2.7) | 1.2 (0.2/1.9) | 0.6 (0.1/1.5) | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 |
| y 1.             | 2 (1.1/2.7) | 1.8 (1.2/3.3) | 1.7 (1/2.2) | 1.9 (1.7/2) | <0.001 | 0.089 | 0.933 | 0.078 |
| **Improvement (Difference)** |          |          |          |          |                     |
| d 1. - Preop     | 1.3 (0.7/2.2) | 1.0 (0.4/1.8) | 0.5 (0.9/1.4) | -0.2 (0.6/0.6) | <0.001 | <0.001 | <0.001 | <0.001 | <0.033 |
| y 1. - Preop     | 1.2 (0.6/1.9) | 1.0 (0.5/2.4) | 1.4 (0.4/1.7) | 0.5 (0.5/1.6) | 0.001 | 0.026 | 0.552 | 0.677 |
| y 1. - d 1.      | -0.1 (-0.6/0.1) | 0 (-0.4/1.4) | 0.5 (0/1) | 1.2 (0.6/1.6) | <0.001 | <0.001 | <0.001 | 0.022 |
| **P (for intra group)** |          |          |          |          |                     |
| Preop→d 1.       | <0.001 | <0.001 | <0.001 | 0.059 | - | - | - | - |
| Preop→y 1.       | <0.001 | <0.001 | <0.001 | 0.002 | - | - | - | - |
| d 1.→y 1.        | <0.001 | 0.660 | <0.001 | <0.001 | <0.001 | - | - | - |

$^*$Jonckheere-Terpstra Test (Monte Carlo). $^1$Friedman Test (Monte Carlo). $^2$Post Hoc Test: Dunn’s Test. ns.: not significant.
and 12th months postoperatively are shown in Table 4. No statistically significant difference was noted for Groups A and B in terms of the 12-month postoperative scores (p=0.061). The 12-month postoperative JOA scores of Groups A and B were significantly higher than those in Groups C and D (p<0.05) (Table 4). No statistically significant difference was observed between Groups C and D (p=0.511).

When the 12-month postoperative JOA scores of Group H were compared with Groups A and B, no significant difference was observed (p>0.05). Groups C and D patients, who did not undergo hematoma evacuation (H-), had significantly lower scores than those in Group H+ (p<0.001) in all examinations (Table 5). The improvement in VAS and JOA scores over time is shown in Figure 3.

| VAS | Median (Min / Max) | Improvement (Difference) | JOA | Median (Min / Max) | Improvement (Difference) | Pairwise Comparison |
|-----|------------------|--------------------------|-----|------------------|--------------------------|---------------------|
| A   | [n=107]          |                          |     | [n=47]          |                          |                     |
| Preop | 6 (0 / 10)      | -4 (-9 / 4)              | Preop | 12 (0 / 23)     | -1 (-4 / 6)              | A→B                 |
| M 1. | 2 (0 / 8)        | -4 (-9 / 4)              | M 1.  | 12 (0 / 23)     | 0 (-5 / 2)               | A→C                 |
| M 2. | 2 (0 / 8)        | -4 (-9 / 4)              | M 2.  | 4 (0 / 4)       | 0 (-4 / 4)               | A→D                 |
| M 3. | 2 (0 / 9)        | -4 (-9 / 4)              | M 3.  | 10 (5 / 6)      | 1 (-4 / 6)               | B→C                 |
| M 4. | 2 (0 / 10)       | -4 (-9 / 4)              | M 4.  | 11 (1 / 2)      | 1 (-5 / 5)               | B→D                 |
| M 5. | 2 (0 / 10)       | -4 (-9 / 4)              | M 5.  | 12 (0 / 23)     | 0 (-3 / 5)               | C→D                 |
| M 6. | 2 (0 / 10)       | -4 (-9 / 4)              | M 6.  | 12 (0 / 23)     | 0 (-3 / 7)               |                     |
| M 7. | 2 (0 / 10)       | -4 (-9 / 4)              | M 7.  | 12 (0 / 23)     | 0 (-3 / 7)               |                     |
| M 8. | 2 (0 / 10)       | -4 (-9 / 4)              | M 8.  | 12 (0 / 23)     | 0 (-3 / 7)               |                     |
| M 9. | 2 (0 / 10)       | -4 (-9 / 4)              | M 9.  | 12 (0 / 23)     | 0 (-3 / 7)               |                     |
| M 10.| 2 (0 / 10)       | -4 (-9 / 4)              | M 10. | 12 (0 / 23)     | 0 (-3 / 7)               |                     |
| M 11.| 2 (0 / 10)       | -4 (-9 / 4)              | M 11. | 12 (0 / 23)     | 0 (-3 / 7)               |                     |
| M 12.| 2 (0 / 10)       | -4 (-9 / 4)              | M 12. | 12 (0 / 23)     | 0 (-3 / 7)               |                     |

Table 4. Clinical parameters results by the time in groups
Figure 3. Clinical parameters (VAS and JOA score) changes during the 12-month postoperative follow-up

Table 5. Comparison of the VAS and JOA scores with hematoma evacuation group (H+)

|     | A         | B         | C and D without Evacuation (H-) | C and D with Evacuation (H+) | Pairwise Comparison |
|-----|-----------|-----------|---------------------------------|-----------------------------|--------------------|
|     | (n=107)   | (n=47)    | (n=77)                          | (n=14)                      |                    |
| VAS |           |           |                                 |                             |                    |
| Preop | 6 (0 / 10) | 6 (1 / 10) | 6 (2 / 9)                       | 7 (4 / 9)                   | 0.429 ns ns ns     |
| M 1. | 2 (0 / 8)  | 2 (0 / 8)  | 4 (0 / 10)                      | 2 (1 / 3)                   | <0.001 0.894 0.690 <0.001 |
| M 3. | 2 (0 / 9)  | 2 (0 / 8)  | 4 (0 / 9)                       | 1 (0 / 2)                   | <0.001 0.159 0.124 <0.001 |
| M 12. | 1 (0 / 9) | 1 (0 / 7)  | 3 (0 / 9)                       | 1 (0 / 2)                   | <0.001 0.163 0.132 <0.001 |
| Improvement (Difference) |         |           |                                 |                             |                    |
| M 1. - Preop | -4 (-9 / 4) | -3 (-9 / 2) | -2 (-7 / 3)                    | -5 (-8 / 2)                 | <0.001 0.093 0.107 <0.001 |
| M 3. - Preop | -4 (-9 / 4) | -4 (-10 / 5) | -2 (-7 / 5)                    | -5 (-5 / 3)                 | <0.001 0.016 0.023 <0.001 |
| M 12. - Preop | -4 (-10 / 4) | -4 (-10 / 2) | -2 (-8 / 2)                    | -6 (-9 / 3)                 | <0.001 0.020 0.031 <0.001 |
| M (1 - 3) | 0 (6 / 5)  | 0 (-2 / 4)  | 0 (4 / 4)                       | -1 (-2 / 0)                 | 0.185 ns ns ns     |
| M (12 - 1) | 0 (5 / 4)  | -1 (-5 / 2) | -1 (-3 / 5)                    | 0.322 ns ns ns             |
| M (12 - 3) | 0 (5 / 2)  | 0 (-5 / 2)  | -1 (4 / 6)                      | 0 (2 / 0)                   | 0.602 ns ns ns     |
| P (for intra group) 2 |         |           |                                 |                             |                    |
| Pairwise Comparison | Preop→M 1. | <0.001    | <0.001                          | 0.004                        | - - -            |
| Preop→M 3. | <0.001    | <0.001    | <0.001                          | <0.001                      | - - -            |
| Preop→M 12. | <0.001   | <0.001    | <0.001                          | <0.001                      | - - -            |
| 1.M→M 3. | 0.459     | 0.604     | 0.318                           | 0.164                       | ns ns ns         |
| 1.M→M 12. | 0.004    | 0.046     | 0.001                           | 0.019                       | - - -            |
| 3.M→M 12. | 0.032    | 0.139     | 0.014                           | 0.341                       | - - -            |
| JOA |           |           |                                 |                             |                    |
| Preop | 12 (0 / 23) | 11 (2 / 24) | 10 (0 / 22)                    | 11 (-2 / 18)                | 0.589 ns ns ns    |
| M 1. | 19 (6 / 29) | 18 (7 / 28) | 14 (2 / 24)                    | 21 (-8 / 24)                | <0.001 0.293 0.166 <0.001 |
| M 3. | 21 (8 / 29) | 20 (6 / 29) | 15 (3 / 23)                    | 22 (19 / 25)                | <0.001 0.233 0.078 <0.001 |
| M 12. | 23 (8 / 29) | 21 (7 / 29) | 17 (3 / 27)                    | 23.5 (21 / 28)              | <0.001 0.583 0.149 <0.001 |
| Improvement (Difference) |         |           |                                 |                             |                    |
| M 1. - Preop | 8 (-1 / 23) | 9 (-2 / 15) | 3 (-6 / 13)                    | 9.5 (-6 / 22)               | <0.001 0.193 0.250 <0.001 |
| 3. M - Preop | 10 (5 / 27) | 9 (-2 / 18) | 4 (-6 / 16)                    | 11 (-6 / 23)                | <0.001 0.129 0.073 <0.001 |
| 12. M - Preop | 11 (4 / 28) | 10 (4 / 22) | 6 (-5 / 20)                    | 12.5 (-9 / 23)              | <0.001 0.253 0.053 <0.001 |
| (3 - 1) M | 1 (12 / 12) | 1 (9 / 7)  | 1 (5 / 11)                     | 1.5 (-3 / 1)                | 0.212 ns ns ns    |
| (12 - 1) M | 3 (-8 / 13) | 2 (-8 / 11) | 4 (-10 / 12)                   | 2 (-1 / 7)                  | 0.400 ns ns ns    |
| (12 - 3) M | 1 (-9 / 12) | 1 (5 / 6)  | 2 (-6 / 11)                    | 0.5 (-1 / 4)                | 0.188 ns ns ns    |
| Improvement (%) |         |           |                                 |                             |                    |
| M 1. - Preop | 47.4 (-9.1 / 100) | 47.8 (-13.3 / 93.3) | 15.4 (45.7 / 65) | 55.3 (38.9 / 72) | <0.001 0.279 0.280 <0.001 |
| M 3. - Preop | 57.1 (-45.5 / 100) | 51.6 (20 / 100) | 23.5 (71.4 / 72.7) | 62.3 (44.4 / 76) | <0.001 0.223 0.070 <0.001 |
| M 12. - Preop | 66.7 (-69.4 / 100) | 58.6 (-60 / 100) | 35.7 (263 / 90.9) | 69.4 (55.6 / 90.9) | <0.001 0.506 0.072 <0.001 |
| P (for intra group) 2 |         |           |                                 |                             |                    |
| Pairwise Comparison | Preop→M 1. | <0.001    | <0.001                          | <0.001                      | - - -            |
| Preop→M 3. | <0.001    | <0.001    | <0.001                          | <0.001                      | - - -            |
| Preop→M 12. | <0.001   | <0.001    | <0.001                          | <0.001                      | - - -            |
| 1.M→M 3. | 0.017     | 0.231     | 0.134                           | 0.019                       | ns ns ns         |
| 1.M→M 12. | <0.001   | 0.008     | <0.001                          | 0.001                       | - - -            |
| 3.M→M 12. | 0.004    | 0.150     | 0.001                           | 0.306                       | - - -            |

*Kruskal-Wallis H Test (Monte Carlo), Friedman Test (Monte Carlo), Post Hoc Test: Dunnet Test, ns not significant.*
Postoperative SEH is a condition that manifests with lumbar pain and radicular pain especially in the postoperative period and can cause deterioration in neurological status. This was related to compression within the spinal canal. It must be kept in mind that when the neurological status deteriorates in the early period, early intervention is of vital importance (9, 10). Several studies had reported the superiority of MRI in the determination of SEH as increased signal intensity is seen on T1 and T2-weighted images (11, 12). There were many studies in the literature on the prevention of SEH and determination of the risks. However, no consensus had been reached on the definition of all the risk factors (3, 13, 14).

SEH incidence had been reported at varying rates (33%-67.6%) in the literature (5, 7, 14, 15). In the current study, this rate was seen to be 100%. It can be considered that after any surgical intervention, there is a high likelihood of subsequent blood collection inside.

To date, all SEH classifications were based on whether patients were symptomatic or asymptomatic. Symptomatic patients were defined as patients who had severe pain at the incision site or extremities or who experienced worsening of the neurological status, generally within hours (16). In an MRI study of patients with symptomatic SEH by Ikuta et al., it was reported that a fibrotic band had formed preventing dural sac expansion at the final follow-up, and this resulted in worse clinical results compared to patients without hematoma. However, as the patients in the study underwent decompression at multiple levels, it was not possible to differentiate to what extent the clinical results were affected by the hematoma at each level. In the current study, the distribution of the groups was extremely homogeneous as the patients selected were those who underwent single-level decompression, and all the operations were performed by the same surgeon.

Moreover, to be able to classify the amount of each hematoma formed, detailed clinical evaluation was carried out for each grade of the hematoma. As previously stated by Ikuta et al., the dural sac area at 12 months postoperatively in patients who developed Grade C and D hematomas was observed to be smaller than that of the patients in Groups A, B, and H+. This finding supports the view that even if it is a resolution of the hematoma, there may be remaining adhesions and fibrosis. Mirzai et al. also reported that postoperative scar tissue originated from postoperative SEH and that SEH was responsible for fibrous tissue formation (7).

Sokolowski et al. compared the postoperative dural sac area to the preoperative dural sac area with MRI (17). A cut-off value was determined by showing that if the postoperative dural sac area on MRI was <20% of the preoperative area because of a hematoma, cauda equina syndrome developed; and when the ratio was in the range of 20%-50%, it caused pain (17). In the current study, no such relationship was found, and in 3% of Group C patients, the pain was experienced despite the postoperative dural sac area being larger than the preoperative area. Again, there was no such relationship in patients who developed neurological deficits. However, the narrower the preoperative dural sac area of the patient, the less symptoms of spinal epidural hematoma that could develop. In other words, despite the formation of large-diameter hematomas in patients with a small preoperative dural sac area, they were classified as Grade C rather than D and were determined as having a lower likelihood of symptoms or neurological deficits.

In the current study, the JOA and VAS score improvements in Group C and D patients were observed to be lower than those in other groups up to 12 months postoperatively. Furthermore, in the 12-month postoperative MRI examination, the dural sac area of patients in Groups C and D was lower than that of other groups.

A limitation of this study is that the hematoma may expand throughout the cranio-caudal axis; therefore, the cross-sectional measurements of hematoma may seem meaningless. However, in the literature, hematoma size has been usually measured using the cross-sectional area (5, 16, 17). As a matter of fact, we did not find any hematoma extending in the longitudinal plain in our study. This could be attributed to MEDL technique being minimally invasive; and therefore, the soft tissue remained largely intact and hematoma would not spread along the longitudinal axis.

In conclusion, the development of SEH affected the clinical and radiological results of patients. With this newly developed classification, it can be seen that in Grade C and D SEH, patients had poor clinical and radiological outcomes. In the current study, Group C and D patients, especially in the early postoperative period (first 3 months), had low JOA scores and high VAS scores. The authors recommend hematoma evacuation in case of persistent severe pain or neurological deficit due to hematoma in the early postoperative period in Group C and D patients since the patients who did not undergo hematoma evacuation (H-) in these groups had lower JOA scores than those in Group H+ in all examinations. The smaller the dural sac area in the preoperative period, the lower the chance of hematoma symptoms that could develop postoperatively. This classification is useful as the measurements can be made easily, and it can predict the 12-month postoperative outcomes of the patient.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethical Committee of Ankara University (18-534-20).

Informed Consent: Written informed consent was obtained from the patients.

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