Objective: We aimed to retrospectively analyze clinical and surgical outcomes following posterior lumbar interbody fusion with concomitant pedicle screw fixation, midline lumbar fusion, and decompressive laminectomy in patients aged 80 years or older with degenerative lumbar spine disease.

Methods: The study group comprised 94 patients aged 80 years or older who received degenerative lumbar spinal surgery at our spine center from January 2011 to December 2020. Among them, 28 patients underwent decompressive laminectomy, 19 underwent posterior lumbar interbody fusion with pedicle screw fixation, and the remaining 47 underwent midline lumbar fusion.

Results: No significant intergroup differences were found regarding age, sex ratio, follow-up duration, and surgical level. The visual analog scale for lower back pain on postoperative day 7 was significantly different among the groups (P < 0.05). The Oswestry disability index was significantly different among the groups after 1 week of follow-up (P < 0.05). The estimated blood loss and operation time also showed significant differences among the groups (P < 0.05). There was a statistically significant difference among the groups in postoperative morbidity (P < 0.05).

Conclusion: Although the clinical outcomes were not significantly different among the three groups, perioperative morbidity was more favorable in the decompression and midline lumbar fusion groups. Therefore, we suggest that midline lumbar fusion is not inferior to posterior lumbar interbody fusion with pedicle screw fixation, if there is a need for fusion in elderly patients over 80 years of age.

Keywords: Lumbar vertebrae; Aged, 80 and over; Laminectomy; Spinal fusion; Retrospective studies

Introduction

Developments in modern medical science have significantly increased lifespan, and the resulting population aging has led to spine surgeons being increasingly confronted with older patients with degenerative lumbar spine disease [1–3]. Spine surgery should be considered when conservative therapy fails to improve degenerative lumbar spine disease symptoms, and decompressive laminectomy (DL) with or without fusion is the standard surgical treatment for patients with degenerative lumbar spinal disease.

DL alone has been used to treat degenerative lumbar spinal disease [4,5]. However, DL alone can induce lumbar instability and aggravate the symptoms after surgery. DL with fusion effectively ensures spinal stability but causes significant adverse events, such as instrument failure and adjacent segment degeneration (ASD). With the development in surgical techniques, minimally invasive spine surgery has recently become popular, and endoscopic decompression and fusion are being performed, from midline lumbar fusion (MIDLF) with cortical bone screws to minimal invasive surgery (MIS)-transforaminal lumbar interbody fusion. Therefore, considering the advantages and disadvantages of surgery, performing it according to appropriate indications is essential.
With the increase in the elderly population and the development of geriatric medicine, the elderly patient group is classified as a separate patient group in research and clinical trials [6]. Some studies have performed comparative analyses of fusion and decompression alone for patients over 60 and 70 years of age. It was reported that surgery according to the indication was helpful compared with avoiding fusion due to age [7,8].

However, comparative studies of MIDLF and conventional surgery in aging patients are rare. Additionally, unlike the 60 to 70 years old group, in the super-aged patient group over 80 years old, we hypothesized that differences in operating time and bleeding volume during decompression or fusion surgery could be prognostic factors.

Therefore, we aimed to retrospectively analyze clinical and surgical outcomes following posterior lumbar interbody fusion plus pedicle screw fixation (PLIF+PS), MIDLF, and DL alone in elderly patients (80 years or older) with degenerative lumbar spine disease.

**Material and Method**

**Patients**

The study groups comprised 94 patients aged 80 years or older who received degenerative lumbar spinal surgery at our spine center from January 2011 to December 2020. Overall, 2,583 cases were selected for this study. Three spine surgeons participated in this study (Table 1).

The clinical indications for surgery were radiating leg pain and/or radiculopathy, with or without low back pain (LBP), resistant to conservative therapy. Magnetic resonance imaging was used to confirm the diagnosis of central, lateral, or foraminal stenosis. The selection of surgical methods depended on each surgeon’s clinical impression, which would result in a better outcome based on symptoms, general condition, patient history, and the degree of osteoporosis. If needed, the degree of osteoporosis was evaluated by subjective judgment based on imaging studies or dual-energy X-ray absorptiometry.

The general indications for decompression alone were overwhelming main symptoms of radiating pain or NIC rather than LBP, in cases where successful fusion was not expected due to severe osteoporosis, and patients with intolerable general conditions to fusion surgery. The general indications for fusion were relatively severe LBP suspected to be mechanical back pain due to degeneration without overt segmental instability, successful fusion expected due to tolerable bone marrow density, and tolerable general conditions to fusion surgery. Patients who did not undergo fusion surgery were excluded, such as those with definite segmental instability [9] or severe spondylolisthesis (grade II or higher).

The study included 39 men and 55 women, and the mean age was 80.3 years. The mean follow-up was 29.6 months (range, 12–114). A total of 94 patients underwent surgery: 44 at one level, 37 at two levels, and 13 at three levels.

**Outcome parameters**

Preoperative conditions were assessed using the American Society of Anesthesiologists (ASA) classification of physical status [10], and clinical outcomes were assessed using a visual analog scale (VAS) for LBP, a VAS for leg pain, and the Oswestry disability index (ODI) [11]. VAS scores were determined using a 0 to 10-point scale, where a score of 0 meant symptom-free, and a score of 10 indicated the most serious symptom. The VAS and ODI were scored at 1 week preoperatively and 1 year postoperatively.

The surgical methods were compared regarding estimated blood loss (EBL), operation time, and hospital stay. Postoperative morbidities (e.g., neurologic deterioration, cerebrospinal fluid leakage, wound infection, pneumonia, heart problems, urinary difficulty, epidural hematoma, screw malposition, and deep vein thrombosis) were checked. In addition, reoperation and development of postoperative degenerative changes (e.g., recurrence, instability, subsidence, screw loosening, nonunion, and ASD) were documented. Fusion rate was assessed using the Bridwell grading system and computed tomography and radiographic findings at 1-year postoperatively (Table 2).

**Table 1. Surgical strategies for each surgeon**

| Surgeon   | DL | PLIF+PS | MIDLF |
|-----------|----|---------|-------|
| Surgeon 1 | 18 | 10      | 47    |
| Surgeon 2 | 8  | 6       | 0     |
| Surgeon 3 | 2  | 3       | 0     |
| Total     | 28 | 19      | 47    |

DL, decompressive laminectomy; PLIF+PS, posterior lumbar interbody fusion with pedicle screw fixation; MIDLF, midline lumbar fusion.

**Table 2. Bridwell interbody fusion grading system**

| Grade | Description                                      |
|-------|-------------------------------------------------|
| I     | Fused with remodeling and trabeculae present    |
| II    | Graft intact, not fully remodeled and incorporated, but no lucency present |
| III   | Graft intact, potential lucency present at top and bottom of graft |
| IV    | Fusion absent with collapse/resorption of graft |
Surgical technique
All operations were performed in the prone position. In cases of DL alone, subtotal laminectomy, ligamentectomy, and bilateral medial facetectomy were performed at each symptomatic lumbar level after a median vertical incision. Based on the symptoms and radiologic findings, additional unilateral foraminotomy, bilateral foraminotomy, or unilateral partial hemilaminectomy was performed. In cases of fusion, after decompression, discectomy, and PLIF, a traditional pedicle screw was used, followed by transpedicular screw fixation or cortical bone trajectory (CBT) by cortical screw fixation according to stenotic levels (Fig. 1).

Statistical methods
IBM SPSS ver. 26.0 (IBM Corp., Armonk, NY, USA) was used to analyze all data. One-way analysis of variance was used, depending on the characteristics of the variables being compared, and a post-hoc Bonferroni analysis was performed. Fisher’s exact test was used to analyze contingency tables, which showed a tabular representation of categorical data. Freeman–Halton extension was applied, and the test yield probability value was defined as the probability of the observed array of cell frequencies plus the sum of the probabilities of all other cell-frequency arrays (such as would be consistent with the observed marginal totals) that are smaller than the probability of the observed array. Statistical significance was accepted for $P < 0.05$ and $P < 0.016$ in the post-hoc analysis with Bonferroni correction among the three groups.

Ethics statement
We collected data from hospital records, including sex, date of birth, type of surgery, medical histories, body mass index, EBL, and date of death. The date of death was verified by records from the National Health Insurance Corporation. The Institutional Review Board of National Health Insurance Service Ilsan Hospital approved this study (No. 2022-01-027), and the requirement of informed consent was waived due to the retrospective nature of the study.

Results
Demographic and preoperative data
The patients were divided into three groups according to the surgical method. Of the 94 patients, 28 (29.8%) were allocated to the...

Fig. 1. Anterior–posterior radiograph of the lumbar spine showing each surgical method. (A) decompressive laminectomy, (B) posterior lumbar interbody fusion with pedicle screw fixation, (C) midline lumbar fusion.
DL group, 19 to the PLIF+PS group (20.2%), and 29 (50.0%) to the MIDLF group. No significant intergroup differences were found regarding age, sex ratio, follow-up duration, or surgical level (Table 3); there were no significant differences in ASA classification and Charlson comorbidity index (CCI) [12]. Additionally, preoperative ODI and VAS scores for LBP and leg pain were not significantly different between the three groups.

**Clinical outcome**

The VAS scores for LBP and leg pain sequentially decreased with follow-up in each group. In the decompression group, the VAS score for LBP improved from 3.4 to 1.2, while in the PLIF+PS group, it improved from 4.5 to 0.6. In the MIDLF group, the VAS score for LBP was improved from 3.6 to 1.0. At the last follow-up visit, the VAS score for leg pain decreased from 5.4 to 2.0 in the DL group, from 5.3 to 1.6 in the PLIF+PS group, and from 5.6 to 1.0 in the MIDLF group. The VAS scores were significantly different in each group after 1 week of follow-up (Table 4).

The VAS score for LBP on postoperative day (POD) 7 was significantly different between the groups (P < 0.05) (Fig. 2A). VAS for LBP on POD 7 was not significantly different between DL alone and PLIF+PS (P = 0.102). It was significantly different between PLIF+PS and MIDLF (P = 0.010) and was not significantly different between DL alone and MIDLF (P = 1.000).

### Table 3. Patients’ demographics and preoperative characteristics of the three groups

| Characteristic                  | Surgical strategy | P-value |
|---------------------------------|-------------------|---------|
|                                | DL (n = 28)       | PLIF+PS (n = 19) | MIDLF (n = 47) |       |
| Male:female                     | 10:18             | 10:9     | 19:28           | 0.131 |
| Age (yr)                        | 82.5 ± 2.5        | 81.1 ± 1.6 | 81.8 ± 1.9     | 0.084 |
| Height (cm)                     | 157.5 ± 9.1       | 157.8 ± 9.7 | 155.5 ± 9.4   | 0.560 |
| Weight (kg)                     | 58.3 ± 10.6       | 59.7 ± 9.5 | 59.0 ± 9.0     | 0.871 |
| BMI (kg/m²)                     | 23.4 ± 3.1        | 24.0 ± 2.9 | 24.4 ± 3.4     | 0.412 |
| ASA classification              | 2.1 ± 0.5         | 2.1 ± 0.6 | 2.0 ± 0.5      | 0.618 |
| CCI                             | 4.4 ± 0.8         | 4.8 ± 1.5 | 4.7 ± 1.0      | 0.282 |
| Follow-up duration (mo)         | 31.6 ± 27.7       | 31.1 ± 30.7 | 27.1 ± 21.7   | 0.615 |
| Operated levels                 |                   |          |                 |       |
| 1 Level                         | 9 (32.1)          | 8 (42.1) | 27 (57.4)       |       |
| 2 Level                         | 9 (32.1)          | 9 (47.4) | 19 (40.4)       |       |
| 3 Level                         | 10 (35.7)         | 2 (10.5) | 1 (2.1)         |       |

Values are presented as mean±standard deviation or number (%). DL, decompressive laminectomy; PLIF+PS, posterior lumbar interbody fusion with pedicle screw fixation; MIDLF, midline lumbar fusion; BMI, body mass index; ASA, American Society of Anesthesiologists; CCI, Charlson comorbidity index.

### Table 4. Postoperative patient characteristics of three groups

| Characteristic                  | Surgical strategy | P-value |
|---------------------------------|-------------------|---------|
|                                | DL (n = 28)       | PLIF+PS (n = 19) | MIDLF (n = 47) |       |
| VAS for low back pain           |                   |          |                 |       |
| Preop                           | 3.4 ± 3.1         | 4.5 ± 2.5 | 3.6 ± 3.0       | 0.266 |
| POD 7                           | 1.3 ± 2.1         | 2.6 ± 2.5 | 1.0 ± 1.5       | 0.013* |
| 1 Year f/u                      | 1.2 ± 2.2         | 0.6 ± 1.3 | 1.0 ± 1.8       | 0.746 |
| VAS for leg pain                |                   |          |                 |       |
| Preop                           | 5.4 ± 2.8         | 5.6 ± 2.2 | 5.6 ± 2.2       | 0.766 |
| POD 7                           | 2.4 ± 2.6         | 1.9 ± 2.6 | 1.9 ± 2.6       | 0.374 |
| 1 Year f/u                      | 2.0 ± 3.0         | 1.6 ± 2.2 | 1.0 ± 1.9       | 0.177 |
| ODI                             |                   |          |                 |       |
| Preop                           | 52.0 ± 12.4       | 52.0 ± 16.5 | 52.0 ± 16.5   | 0.899 |
| POD 7                           | 22.6 ± 15.7       | 14.8 ± 15.5 | 14.8 ± 15.5 | 0.024* |
| 1 Year f/u                      | 19.1 ± 22.1       | 14.9 ± 18.2 | 14.9 ± 18.2   | 0.394 |
| Bridwell grade one fusion       |                   |          |                 |       |
| 1 Year f/u                      | -                 | 79%      | 82%            | 0.188 |

Values are presented as mean±standard deviation or percentage. DL, decompressive laminectomy; PLIF+PS, posterior lumbar interbody fusion with pedicle screw fixation; MIDLF, midline lumbar fusion; VAS, visual analog scale; ODI, Oswestry disability index; Preop, pre-operation; POD, post-operative day. *P < 0.05.
Functional aspects were assessed using ODI scores. The ODI decreased during follow-up. The ODI scores were significantly different in each group after 1 week of follow-up (*P < 0.05) (Fig. 2B). Between the DL alone and PLIF+PS groups, the ODI at POD 7 was not significantly different (P = 1.000). It was significantly different between the PLIF+PS and MIDLF groups (P = 0.044) and was not significantly different between the DL alone and MIDLF groups (P = 0.148). Bridwell fusion rate was not significantly different in each group after 1 year of follow-up.

Comparison of surgical methods and complications
The EBL and operation time were significantly different between the groups (P < 0.05). It was observed that the EBL and operation time increased in the following order: DL, PLIF+PS, and MIDLF. Between the DL alone and PLIF+PS groups, EBL was significantly different (P = 0.001). It was also significantly different between the PLIF+PS and MIDLF groups (P = 0.027) and was not significantly different between the DL alone and MIDLF groups (P = 0.406) (Fig. 3A). The operation time was statistically significantly different between the DL alone and PLIF+PS groups (P = 0.001). It was also statistically significantly different between the PLIF+PS and MIDLF groups (P = 0.001) and between the DL alone and MIDLF groups (P = 0.001) (Fig. 3B).

There was no postoperative mortality or neurological deterioration. There was a statistically significant difference in postoperative morbidities (P < 0.05). Postoperative morbidity was noted in one patient (3.6%) in the DL alone group, six patients (31.6%) in the PLIF+PS group, and two (4.3%) patients in the MIDLF group. In the DL alone group, pulmonary edema occurred in one patient. In the PLIF+PS group, pneumonia occurred in two patients. There was pulmonary edema in one patient, pleural effusion in one patient, angina in one patient, and cerebral infarction in one patient. In the MIDLF group, pneumonia was observed in one patient, and pleural effusion was observed in one patient.

Postoperative complications were significantly different among the three groups (P = 0.003). In the post-hoc analysis, Fisher’s ex-

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*Fig. 2.* The statistically significant changes in outcome parameters. (A) The visual analog scale (VAS) for lower back pain (LBP) at postoperative day 7 was significantly different between each group (*P < 0.05). There was a statistically significant difference between the PLIF+PS and MIDLF groups (P = 0.013). (B) Oswestry disability index (ODI) scores were significantly different between the groups after the 1-week follow-up (*P < 0.05). There was a statistically significant difference between the PLIF+PS and MIDLF groups (P = 0.024). Preop, pre-operation; DL, decompressive laminectomy; PLIF+PS, posterior lumbar interbody fusion with pedicle screw fixation; MIDLF, midline lumbar fusion.

*Fig. 3.* The estimated blood loss (EBL) and operation time were significantly different between the groups. (A) Between the DL alone and PLIF+PS groups, EBL was statistically significantly different (**P = 0.002). There was a statistically significant difference between the PLIF+PS and MIDLF groups (P = 0.027). (B) The operation time was significantly different between the DL alone and PLIF+PS groups (**P = 0.001). There was a statistically significant difference between the PLIF+PS and MIDLF groups (P = 0.001) and between the DL alone and MIDLF groups (P = 0.001). DL, decompressive laminectomy; PLIF+PS, posterior lumbar interbody fusion with pedicle screw fixation; MIDLF, midline lumbar fusion.

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act test between the DL only and PLIF+PS groups was statistically significantly different \((P = 0.013)\). It was also statistically significantly different between the PLIF+PS and MIDLF groups \((P = 0.006)\) but was not statistically significantly different between the DL alone and MIDLF groups \((P = 0.688)\).

There were no statistically significant differences in the postoperative degenerative changes between the groups. Regarding morbidities, in the DL alone group, three patients \((10.7\%)\) developed postoperative degenerative changes (two instabilities and one ASD), all of whom underwent reoperation. In the PLIF+PS group, two patients \((10.5\%)\) developed postoperative degenerative changes (one subsidence and one ASD), and one ASD patient underwent reoperation. In the MIDLF group, three patients \((6.4\%)\) developed postoperative degenerative changes (three ASD) and underwent reoperation \((Table 5)\).

Although the postoperative degenerative changes were not statistically different between the three groups, it is not reasonable to compare the late complication rates between the three groups because the complications were different.

### Discussion

This study investigated 94 consecutive cases of DL, with or without fusion, for degenerative lumbar spinal disease in patients 80 years of age or older and demonstrated favorable outcomes in this patient population. The goal of MIS is to limit tissue damage. This is especially advantageous in elderly patients, in whom intraoperative EBL, postoperative mobilization, and wound healing have more profound implications \([13]\).

MIDLF is an MIS fusion technique that consists of posterior lumbar interbody arthrodesis and posterior instrumentation using CBT screws \([14]\). Being inserted in a divergent trajectory has advantages in small wounds and hard screw fixation. First, CBT does not require dissection of the facet joints for insertion \([14,15]\). Second, Matsukawa et al. studied biomechanical research and reported a higher insertion torque of CBT screws than that of traditional pedicle screws \([16]\). This may be especially important when performing lumbar fusion in elderly patients with poor bone density. In addition, CBT has less EBL than conventional pedicle screw insertion and requires only pars interarticularis dissection without extended dissection of the mammillary body; thus, the operation time is reduced.

Increased blood loss during lumbar spinal fusion has been correlated with increased muscle injury and dissection boundary \([17]\). Another theoretical advantage of decreased blood loss is the subsequent decreased risk of blood transfusion and other complications in patients with comorbid conditions, who are more sensitive to lower postoperative hemoglobin levels. We believe that fusion is more likely to cause higher complications, including cerebral infarctions and pulmonary complications because it shows a difference in operation time compared with decompression alone. Similar to this hypothesis, this study showed that longer surgeries led to greater amounts of bleeding, which increased the risk of postoperative complications and delayed functional pain relief.

The difference in EBL remained significant after adjusting for this factor. This was expected because traditional PS insertion requires extensive exposure of the facet joints. This difference has also been observed in other studies \([18–20]\). We believe that the

### Table 5. Perioperative morbidities and late complications of the three groups

| Variable                        | Surgical strategy | P-value |
|---------------------------------|-------------------|---------|
| Estimation of blood loss        | DL (n = 28)       | 320.0 ± 342.1 | 0.698 |
|                                 | PLIF+PS (n = 19)  | 886.1 ± 613.2 |       |
|                                 | MIDLF (n = 47)    | 507.5 ± 567.2 |       |
| Operation time (min)            | DL (n = 28)       | 105.6 ± 44.8  | 0.594 |
|                                 | PLIF+PS (n = 19)  | 266.8 ± 78.4  |       |
|                                 | MIDLF (n = 47)    | 161.9 ± 56.0  |       |
| Hospital stay (day)             | DL (n = 28)       | 14.5 ± 6.6    | 0.002** |
|                                 | PLIF+PS (n = 19)  | 17.4 ± 8.4    |       |
|                                 | MIDLF (n = 47)    | 14.8 ± 12.5   |       |
| Postoperative complications     | DL (n = 28)       | 1 (3.6)       | 0.003** |
|                                 | PLIF+PS (n = 19)  | 6 (31.6)      |       |
|                                 | MIDLF (n = 47)    | 2 (4.3)       |       |
| Pulmonary complications         | DL (n = 28)       | 1             | 0.003** |
|                                 | PLIF+PS (n = 19)  | 4             |       |
|                                 | MIDLF (n = 47)    | 2             |       |
| Cerebral infarction             | DL (n = 28)       | 0             | 0.698  |
|                                 | PLIF+PS (n = 19)  | 1             |       |
|                                 | MIDLF (n = 47)    | 0             |       |
| Angina                          | DL (n = 28)       | 0             | 0.003** |
|                                 | PLIF+PS (n = 19)  | 1             |       |
| Postoperative degenerative changes | DL (n = 28)     | 3 (10.7)      | 0.698  |
|                                 | PLIF+PS (n = 19)  | 2 (10.5)      |       |
|                                 | MIDLF (n = 47)    | 3 (6.4)       |       |
| ASD                             | DL (n = 28)       | 1             | 0.003** |
|                                 | PLIF+PS (n = 19)  | 1             |       |
|                                 | MIDLF (n = 47)    | 3             |       |
| Dynamic instability             | DL (n = 28)       | 0             | 0.003** |
|                                 | PLIF+PS (n = 19)  | 0             |       |
|                                 | MIDLF (n = 47)    | 0             |       |

Values are presented as mean ± standard deviation or number (%).

DL, decompressive laminectomy; PLIF+PS, posterior lumbar interbody fusion with pedicle screw fixation; MIDLF, midline lumbar fusion; ASD, adjacent segmental degeneration.

**P < 0.01, ***P < 0.001.

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difference in the screw insertion method of fusion surgery is the reason for the difference in the ODI and VAS for LBP values on the seventh day after fusion surgery between the groups.

Complications were divided into postoperative complications and degenerative changes, and there was a significant difference between the three groups. According to a study by Kobayashi et al., preoperative motor deficits, operative time, EBL, and fusion surgery with instrumentation were found to be significant risk factors for major complications (cerebral infarction, pulmonary embolism, coronary heart disease, and angina) after lumbar surgery in patients over 90 years of age [21]. In this study, pulmonary complications increased in the order DL, MIDLF, and PLIF+PS in postoperative complications.

In addition, in the case of PLIF+PS, one case of cerebral infarction required rehabilitation treatment due to motor weakness. Therefore, for elderly patients requiring fusion, selecting MIDLF, which has advantages in EBL and operative time, would be a way to reduce major complications. Previous studies have also found that the amount of bleeding and operation time are related to the occurrence of complications [22]. Regarding postoperative degenerative changes, ASD in one patient and iatrogenic spondylolytic spondylolisthesis in two patients were required to implement lumbar fusion; therefore, careful attention is required during DL surgery.

The selection of DL or fusion depends on numerous factors, such as symptoms, age, general condition, presence of osteoporosis, number of segments involved, and instability. The most important factor is radiographic instability of the lumbar spine because fusion is the therapy of choice for definite instability. However, in mild or ambiguous instabilities, fusion selection is occasionally problematic. For example, in elderly patients or those with a poor general condition, who are vulnerable to major surgery, protracted surgery, heavy bleeding, and extensive soft tissue injury can cause severe perioperative morbidities, such as cardiopulmonary complications, wound infections, or even death. In addition, in patients with osteoporosis, transpedicular screw fixation or interbody fusion can cause instrument-related complications, such as subsidence, screw failure, or nonunion. Accordingly, DL alone can be a better choice for patients with advanced age, poor preoperative condition, or osteoporosis if there is no severe instability [23].

In a previous study, the authors suggested that decompression or fusion should be performed as needed without significant differences in complications [7,8]. However, there may be biological differences in super-aged people over 80 years old. Oldridge et al. showed an overall mortality rate of 0.5% in 34,418 Medicare patients who underwent lumbar spine surgery. For patients older than 80 years, the mortality rate for spinal fusions was greater than 10%. They concluded that the 80 to 85 years age group faced the highest risk of a significant increase in morbidity and mortality for spinal fusion [24]. Therefore, MIDLF with less bleeding is advantageous when complications are considered.

The mean ASA and CCI values tended to increase with age, which was confirmed to increase the likelihood of perioperative complications [25]. However, in our study, in the MIDLF group, the surgical wound was relatively small, the amount of bleeding was small, and the surgery time was short, which could lower the risk of complications and secure sufficient fixation at the same time. No statistically significant differences were observed in complications according to ASA and CCI. We believe a significant difference can be found if the number of cases is higher.

Regarding the limitations of this study, first, since it is limited by the retrospective observation and analysis of 10 years of research conducted in a single institution, surgical indications in the three study groups were not exactly the same, and patients’ preoperative conditions varied between groups. This is because we could not randomly assign the study participants to the three groups. Thus, the basic characteristic variables may be different. Nevertheless, the conditions of the three groups before the operation were not significantly different. Also, three spinal surgeons were involved in this study, and differences between the surgical techniques could have influenced the outcomes. Additionally, due to the lack of the number of cases, it is difficult to compare the results for each level, so the average of all levels of surgery was compared. Finally, the lack of long-term clinical follow-up is a concern because the risk of recurrence is generally assessed over 5 years after surgery in elderly patients [26].

**Conclusion**

Advanced age did not increase the morbidity associated with the operation because the results reported in this study are comparable with those from other studies of younger populations. Also, advanced age did not decrease patient contentment or return to activities. Although the clinical outcomes were not significantly different among the three groups, perioperative morbidity and late complications were better in the decompression and MIDLF groups. We suggest MIDLF rather than PLIF+PS if there is a need for fusion in elderly patients over 80 years of age.

**Conflicts of interest**

No potential conflict of interest relevant to this article was reported.
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