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Comparison of Pain and Functional Outcomes Among Geriatric and Nongeriatric Adults Following Full Endoscopic Spine Surgery for Degenerative Lumbar Pathology

ALEXANDER A. CHERNYSH, BS[1*]; JANNIK LEYENDECKER, MD[2,3*]; OWEN P. LEARY, BS[1]; RAHUL A. SASTRY, MD, MPH[1]; ZIYA L. GOKASLAN, MD[1]; JARED S. FRIDLEY, MD[1]; PETER DERMAN, MD, MBA[4]; OSAMA KASHLAN, MD[5]; SANJAY KONAKONDLA, MD[6]; JOHN OGUNLADE, DO[7]; CHRISTOPH P. HOFSTETTER, MD, PHD[2]; AND ALBERT E. TELFEIAN, MD, PHD[1]

[1]*Department of Neurosurgery, Warren Alpert Medical School, Brown University, Providence, RI, USA;* [2]*Department of Neurological Surgery, University of Washington, Seattle, WA, USA;* [3]*Department of Orthopedics and Trauma Surgery, Faculty of Medicine and University Hospital Cologne, University of Cologne, Cologne, Germany;* [4]*Department of Orthopedic Spine Surgery, Texas Back Institute, Plano, TX, USA;* [5]*Department of Neurosurgery, University of Michigan, Ann Arbor, MI, USA;* [6]*Department of Neurosurgery, Geisinger Neuroscience Institute, Danville, PA, USA;* [7]*Department of Neurological Surgery, Washington University School of Medicine, St. Louis, MO, USA*

[*]Alexander A. Chernysh and Jannik Leyendecker contributed equally to the work.

ABSTRACT

Background: Full endoscopic spine surgery (FESS) champions a rapid recovery and a low rate of overall complications. However, its efficacy in geriatric patients that might yield additional benefits from minimized invasiveness remains underexplored.

Methods: A multi-institutional prospective cohort study was conducted involving patients undergoing elective lumbar FESS. Participants were categorized into nongeriatric (18–69 years old) and geriatric (≥70 years old) groups. Studied variables included demographics, medical comorbidities, operative details, visual analog scale (VAS) for back and leg pain, and Oswestry Disability Index (ODI). A mobile application was leveraged to collect real-time data pre- and postoperatively.

Results: One hundred and sixty-four patients were included and divided into nongeriatric ($N = 125$) and geriatric ($N = 39$) cohorts. No group differences were observed between sex ($P = 0.404$), body mass index ($P = 0.372$), procedure duration ($P = 0.350$), or blood loss ($P = 0.384$). Nongeriatric patients received discectomy more frequently ($P < 0.001$), while older patients underwent more decompressive procedures ($P < 0.001$). Characterization of pain and functional outcome revealed that nongeriatric and geriatric patients follow a similar recovery trajectory and both appreciate significant improvements from baseline to 3 months postoperatively ($P < 0.001$ for VAS back, VAS leg, and ODI). There were no differences in the rate of improvement between age groups at any time point ($P > 0.05$ for VAS back, VAS leg, and ODI).

Conclusions: FESS significantly improves pain and function in both geriatric and nongeriatric adults with degenerative lumbar conditions, with no difference in the degree of improvement between groups.

Clinical Relevance: These findings underscore the efficacy of FESS as a minimally invasive surgical option for elderly patients. Mobile application technology is useful for collecting patient-reported data in spine surgery clinical research.

Level of Evidence: 3.

Endoscopic Minimally Invasive Surgery

Keywords: minimally invasive surgical procedures, spine, spondylosis, aged, patient reported outcome measures

INTRODUCTION

Demographic predictions forecast a substantial increase in the elderly population amidst an unprecedented surge in global aging. According to the U.S. Census Bureau, the world's population of octogenarians in 2015 is expected to more than triple by 2050.[1] This phenomenon accentuates a compelling societal paradigm: an escalating desire among seniors to preserve both physical activity and quality of life deep into their golden years.[2] Unfortunately, degenerative spinal conditions commonly arise as the body ages and can be debilitating, at times requiring surgical management.[3] However, the confluence of biological senescence, increased frailty, and prevalent comorbidities often makes traditionally invasive spinal surgery particularly risky for elderly patients. Compared with their younger counterparts, older patients have been shown to experience longer recovery times and have higher rates of complications following open surgery.[4–8] These shortcomings highlight

the pressing need for surgical methodologies that are both effective and minimally burdensome for aging bodies.

Full endoscopic spine surgery (FESS) has emerged as an important innovation among minimally invasive methods for treating degenerative lumbar pathologies. Prior evidence shows that FESS offers desirable outcomes, particularly in terms of rapid recovery and overall low complication rates during and after elective spine surgery.[9–11] However, research examining the efficacy of FESS in geriatric patients is incomprehensive. Although several studies have demonstrated the utility of FESS in elderly patients compared with other surgical methods,[12,13] few directly assess the outcomes of geriatric patients as compared with younger adults.[14,15] The extrapolation of these findings to a broader, aging demographic necessitates a cautious approach, emphasizing the need for rigorous, prospective research to substantiate the effectiveness of FESS within this vulnerable group.

This study aims to build upon and validate existing evidence concerning the feasibility of FESS in geriatric patients older than 70 years by characterizing treatment outcomes following surgery. To the best of our knowledge, this is the first study to employ a prospective cohort design that includes a younger comparison group to elucidate the research question at hand. Additionally, we collected temporally granular outcomes data using a mobile application for documenting patient-reported outcome measures. We hypothesized that both geriatric and nongeriatric patients experience significant improvements in pain and function from baseline to 3 months postsurgery. Furthermore, we anticipated that both cohorts will appreciate similar rates of improvement in outcomes following FESS.

METHODS

Study Design and Patient Recruitment

A prospective observational cohort analysis of patients older than 18 years undergoing elective lumbar uniportal FESS between March 2021 and August 2023 was carried out. FESS is characterized as a surgical procedure involving a single endoscopic working port featuring an irrigation channel, light source, and camera. The specific types of surgeries performed encompassed discectomy (transforaminal endoscopic lumbar discectomy, interlaminar endoscopic lumbar discectomy, and extraforaminal endoscopic lumbar discectomy), lateral recess decompression (transforaminal endoscopic lateral recess decompression and interlaminar endoscopic lateral recess decompression), foraminotomy (transforaminal endoscopic lumbar foraminotomy and interlaminar contralateral endoscopic lumbar foraminotomy), and lumbar endoscopic unilateral laminotomy for bilateral decompression. These procedure types follow the AO Consensus definition for surgeries performed by working channel endoscopes.[16] Patient recruitment was carried out in the outpatient clinics of multiple experienced endoscopic spine surgeons across 6 high-volume U.S. surgical centers.

In this study, we defined geriatric patients as individuals older than 70 years old, consistent with prior research on older patients undergoing FESS. Specifically, Kim et al used this age threshold in a comparable patient population to examine pain and functional outcomes following discectomy or decompression via FESS.[17] By aligning our age definitions, we ensure consistency of reporting with existing studies, allowing for more direct comparisons within this group of elderly patients.

Upon study enrollment, patients provided informed consent to have their surgical baseline and follow-up data collected via a mobile application installed on their mobile devices preoperatively (Supplemental Figure. 1). This institutional review board (IRB)-approved smartphone application was implemented herein as described in prior studies.[18–21] Following preoperative baseline and operative data input, patients are notified to complete an asynchronous survey at specified time points assessing their recovery status postoperatively. Providers have access to the patient's user profile to virtually interface with them. This means of collecting data enabled a convenient and accessible way of gathering patient-reported outcomes while keeping patients engaged in care.

This study was approved by a central IRB and individual participating center IRBs. Written informed consent was obtained for all participants. Study activities were performed in agreement with the 1975 Declaration of Helsinki.

Study Inclusion/Exclusion Criteria

Adult study participants were included in this analysis based on their receipt of elective lumbar uniportal FESS due to a degenerative pathology. Consequently, patients undergoing surgery for tumor removal, trauma, or congenital reasons were excluded. Furthermore, instrumented cases, including fusion procedures, were not considered. Given the stratification of research patients according to age, records with incomplete age data were excluded. Finally, patients with any missing data at the primary endpoints for the study were excluded from the analysis.

Primary and Secondary Study Endpoints

In this study, a visual analog scale (VAS) was used to track back and leg pain outcomes, while the Oswestry Disability Index (ODI) was used to assess functional outcomes.[22] The specific primary endpoints were defined as VAS back, VAS leg, and composite ODI score preoperatively and postoperatively at 1 day, 4 days, 1 week, 2 weeks, and 3 months following surgery. The secondary endpoint for the study was patient satisfaction following operative intervention at 3 months, which was expressed as a binary choice indicating self-perceived surgical outcome as either "good" or "poor." Other variables of interest included patient demographics and baseline information (sex, age, race, ethnicity, smoking status, and body mass index), medical history (presence of diabetes, asthma, arthritis, and other cardiovascular comorbidities), and operative details (procedure type performed, surgical revision history, levels of operation, surgical laterality, dural tears, procedure duration, and estimated blood loss). All data were collected prospectively via the mobile application as described previously.

Statistical Methods

R (version 4.3.2) and R Studio (version 2023.12.0+369) were used for all statistical analyses and figure construction. A P value cutoff of $P < 0.05$ was used to represent statistical significance in this study. Descriptive statistics were computed to describe the sample population for the geriatric, nongeriatric, and combined age cohorts. Seventy years was used as the age cut-off to separate groups. All categorical variables were reported as frequencies represented by a percent value. Continuous variables were reported as medians for the evaluation of central tendency with a corresponding interquartile range to measure variability.

Univariate hypothesis testing was used to compare differences between the geriatric and nongeriatric cohorts. Categorical variables were assessed using either Pearson's χ^2 test or Fisher's exact test. Continuous variables were compared using the Wilcoxon rank sum test or Student's t test. The type of test used was determined by evaluating for any qualifying assumptions. Comparison across groups separated by age and procedure type was performed using a Kruskal-Wallis test, given the small sample sizes in some groups ($N < 10$). This nonparametric test provides a more reliable comparison between groups, as it does not rely on the assumption of normality—an assumption that can be difficult to validate with small samples. A Shapiro-Wilk test was used to assess the assumption of normality. P values were adjusted for multiple testing using a Benjamini-Hochberg correction when appropriate and denoted as a corresponding q value.

A nonparametric Friedman test was employed to compare overall differences within each age-stratified group for the interval time point outcomes. Post-hoc analyses were subsequently conducted to compare differences between individual time points using a Durbin-Conover test and reported as adjusted values for multiple testing.

RESULTS

Participant Inclusion, Demographics, and Medical History

Overall, 561 patients were enrolled across various sites for participation in using a mobile application to track their treatment outcome after spine surgery. Given our patient population of interest, a total of 164 patients met the inclusion criteria for this study, with $N = 125$ in the nongeriatric cohort (<70 years) and $N = 39$ in the geriatric group (≥70 years).

The median age for the entire cohort was 58.0 (44.8–69.0, interquartile range) years. The younger group (<70 years) had a median age of 52.0 (40.0–61.0) years, and the older group (≥70 years) had a median age of 75.0 (72.0–76.5) years ($P < 0.001$; $q < 0.001$). The median body mass index was 29.2 (25.8–35.1) for the younger group and 29.0 (25.9–32.1) for the older cohort ($P = 0.372$; $q = 0.628$; Table 1).

Notably, the older cohort reported a significantly higher rate of hypertension than the younger group (72% vs 29%, $P < 0.001$; $q < 0.001$). Furthermore, the older group had a slightly higher rate of hyperlipidemia than the younger group (21% vs 6%, $P = 0.025$). This difference was found to be nonstatistically significant after adjustment for multiple testing ($q = 0.126$). Other comorbidities showed no significant differences between groups, before or after adjustment (Table 1).

Operative Details

Patients were classified as having undergone discectomy (55%) or other decompressive FESS (45%). Our cohort showed that the younger group was significantly more likely to undergo discectomy than the older group ($P < 0.001$; $q < 0.001$). Among discectomies, this trend was evident for both transforaminal endoscopic lumbar discectomy ($P = 0.005$; $q = 0.019$) and interlaminar endoscopic lumbar discectomy ($P = 0.009$; $q = 0.029$) but not for extraforaminal endoscopic lumbar discectomy ($P > 0.999$; $q > 0.999$). In contrast, the older group was significantly

Table 1. Demographic, medical history, and procedure details for the total patient cohort and groups stratified by age.

Patient Characteristics	Total Cohort (*N* = 164)	Age <70 y (*N* = 125)	Age ≥70 y (*N* = 39)	*P*	*q*[a]
Demographic and Physical Details					
Sex, *n*/*N* (%)				0.404[b]	0.628
Men	100/164 (61%)	74/125 (59%)	26/39 (67%)		
Women	64/164 (39%)	51/125 (41%)	13/39 (33%)		
Age, median (IQR)	58.0 (44.8–69.0)	52.0 (40.0–61.0)	75.0 (72.0–76.5)	**<0.001**[c]	**<0.001**
Race, *n*/*N* (%)				0.648[d]	0.811
White	87/101 (86%)[e]	73/84 (87%)[e]	14/17 (82%)[e]		
Black or African American	8/101 (8%)[e]	6/84 (7%)[e]	2/17 (12%)[e]		
American Indian or Alaska Native	1/101 (1%)[e]	1/84 (1%)[e]	0/17 (0%)[e]		
Asian	2/101 (2%)[e]	2/84 (2%)[e]	0/17 (0%)[e]		
Self-reported unknown	3/101 (3%)[e]	2/84 (2%)[e]	1/17 (6%)[e]		
Ethnicity, *n*/*N* (%)				0.385[d]	0.628
Not Hispanic or Latino	78/101 (77%)[e]	66/84 (79%)[e]	12/17 (71%)[e]		
Hispanic or Latino	18/101 (18%)[e]	13/84 (15%)[e]	5/17 (29%)[e]		
Self-reported unknown	5/101 (5%)[e]	5/84 (6%)[e]	0/17 (0%)[e]		
Current smoker, *n*/*N* (%)	8/127 (6%)[e]	8/94 (9%)[e]	0/33 (0%)[e]	0.111[d]	0.415
BMI (kg/m^2), median (IQR)	29.2 (25.8–33.7)[e]	29.2 (25.8–35.1)[e]	29.0 (25.9–32.1)	0.372[c]	0.628
Medical History					
Diabetes, *n*/*N* (%)	23/164 (14%)	16/125 (13%)	7/39 (18%)	0.419[b]	0.628
Hypertension, *n*/*N* (%)	64/164 (39%)	36/125 (29%)	28/39 (72%)	**<0.001**[b]	**<0.001**
Hyperlipidemia, *n*/*N* (%)	16/164 (10%)	8/125 (6%)	8/39 (21%)	**0.025**[d]	0.126
Arthritis, *n*/*N* (%)	26/164 (16%)	22/125 (18%)	4/39 (10%)	0.273[b]	0.628
Asthma, *n*/*N* (%)	9/164 (5%)	7/125 (6%)	2/39 (5%)	>0.999[d]	>0.999
Chronic lung disease, *n*/*N* (%)	3/164 (2%)	2/125 (2%)	1/39 (3%)	0.560[d]	0.763
Heart attack, *n*/*N* (%)	2/164 (1%)	2/125 (2%)	0/39 (0%)	>0.999[d]	>0.999
Congestive heart failure, *n*/*N* (%)	1/164 (1%)	1/125 (1%)	0/39 (0%)	>0.999[d]	>0.999
Coronary artery disease, *n*/*N* (%)	3/164 (2%)	1/125 (1%)	2/39 (5%)	0.141[d]	0.423
Procedure Details					
Procedure type, *n*/*N* (%)					
Discectomy	90/164 (55%)	82/125 (66%)	8/39 (21%)	**<0.001**[b]	**<0.001**
TELD	51/164 (31%)	46/125 (37%)	5/39 (13%)	**0.005**[b]	**0.019**
IELD	38/164 (23%)	35/125 (28%)	3/39 (8%)	**0.009**[b]	**0.029**
EELD	1/164 (1%)	1/125 (1%)	0/39 (0%)	>0.999[d]	>0.999
Other decompression	74/164 (45%)	43/125 (34%)	31/39 (79%)	**<0.001**[b]	**<0.001**
LE-ULBD	57/164 (35%)	34/125 (27%)	23/39 (59%)	**<0.001**[b]	**0.002**
IE-LRD	8/164 (5%)	3/125 (2%)	5/39 (13%)	**0.019**[d]	0.055
TELF	6/164 (4%)	3/125 (2%)	3/39 (8%)	0.147[d]	0.326
ICELF	2/164 (1%)	2/125 (2%)	0/39 (0%)	>0.999[d]	>0.999
TE-LRD	1/164 (1%)	1/125 (1%)	0/39 (0%)	>0.999[d]	>0.999
Levels of operation,[f] *n*/*N* (%)					
L1/2	7/164 (4%)	3/125 (2%)	4/39 (10%)	0.056[d]	0.139
L2/3	18/164 (11%)	8/125 (6%)	10/39 (26%)	**0.002**[d]	**0.010**
L3/4	28/164 (17%)	21/125 (17%)	7/39 (18%)	0.868[b]	>0.999
L4/5	97/164 (59%)	73/125 (58%)	24/39 (62%)	0.728[b]	0.970
L5/S1	42/164 (26%)	35/125 (28%)	7/39 (18%)	0.209[b]	0.419
Surgical approach, *n*/*N* (%)				0.231[b]	0.421
Right	83/164 (51%)	60/125 (48%)	23/39 (59%)		
Left	81/164 (49%)	65/125 (52%)	16/39 (41%)		
Revision surgery, *n*/*N* (%)	36/164 (22%)	28/125 (22%)	8/39 (21%)	0.804[b]	>0.999
Dural tear, *n*/*N* (%)	4/113 (4%)[e]	3/94 (3%)[e]	1/19 (5%)[e]	0.526[d]	0.752
Procedure duration (min), median (IQR)	90.0 (60.0–120.0)	88.0 (60.0–120.0)	90.0 (67.5–120.0)	0.350[c]	0.583
Blood loss (mL), median (IQR)	5.0 (5.0–10.0)	5.0 (5.0–10.0)	5.0 (5.0–10.0)	0.384[c]	0.591

Abbreviations: BMI, body mass index; EELD, extraforaminal endoscopic lumbar discectomy; ICELF, interlaminar contralateral endoscopic lumbar foraminotomy; IELD, interlaminar endoscopic lumbar discectomy; IE-LRD, interlaminar endoscopic lateral recess decompression; IQR, interquartile range; LE-ULBD, lumbar endoscopic unilateral laminotomy for bilateral decompression; TELD, transforaminal endoscopic lumbar discectomy; TELF, transforaminal endoscopic lumbar foraminotomy; TE-LRD, transforaminal endoscopic lateral recess decompression.

Note: Boldface indicates statistical significance ($p < 0.05$).

[a]False discovery rate correction for multiple testing (corrections for "Demographic and Physical Details" and "Medical History" were performed independently from "Procedure Details").

[b]Pearson's χ^2 test.

[c]Wilcoxon rank sum test.

[d]Fisher's exact test.

[e]Denominator was adjusted to account for missing values.

[f]Levels of operation may span >1 spinal region; therefore, percentages sum to >100%.

more likely to undergo a decompressive procedure ($P < 0.001$; $q < 0.001$). Likewise, older patients were found to undergo a significantly greater rate of surgery at the L2/L3 spinal level compared with their younger counterparts (26% vs 6%, $P = 0.002$; $q = 0.010$). Frequency of operation at other spinal levels demonstrated no statistically significant differences between age groups. Median procedure duration was 88.0 (60.0–120.0) minutes for younger patients and 90.0 (67.5–120.0) minutes for older patients ($P = 0.350$; $q = 0.583$). Moreover, median blood loss was 5.0 (5.0–10.0) mL for both groups ($P = 0.384$; $q = 0.591$). Lastly, 3 intraoperative dural tears were noted

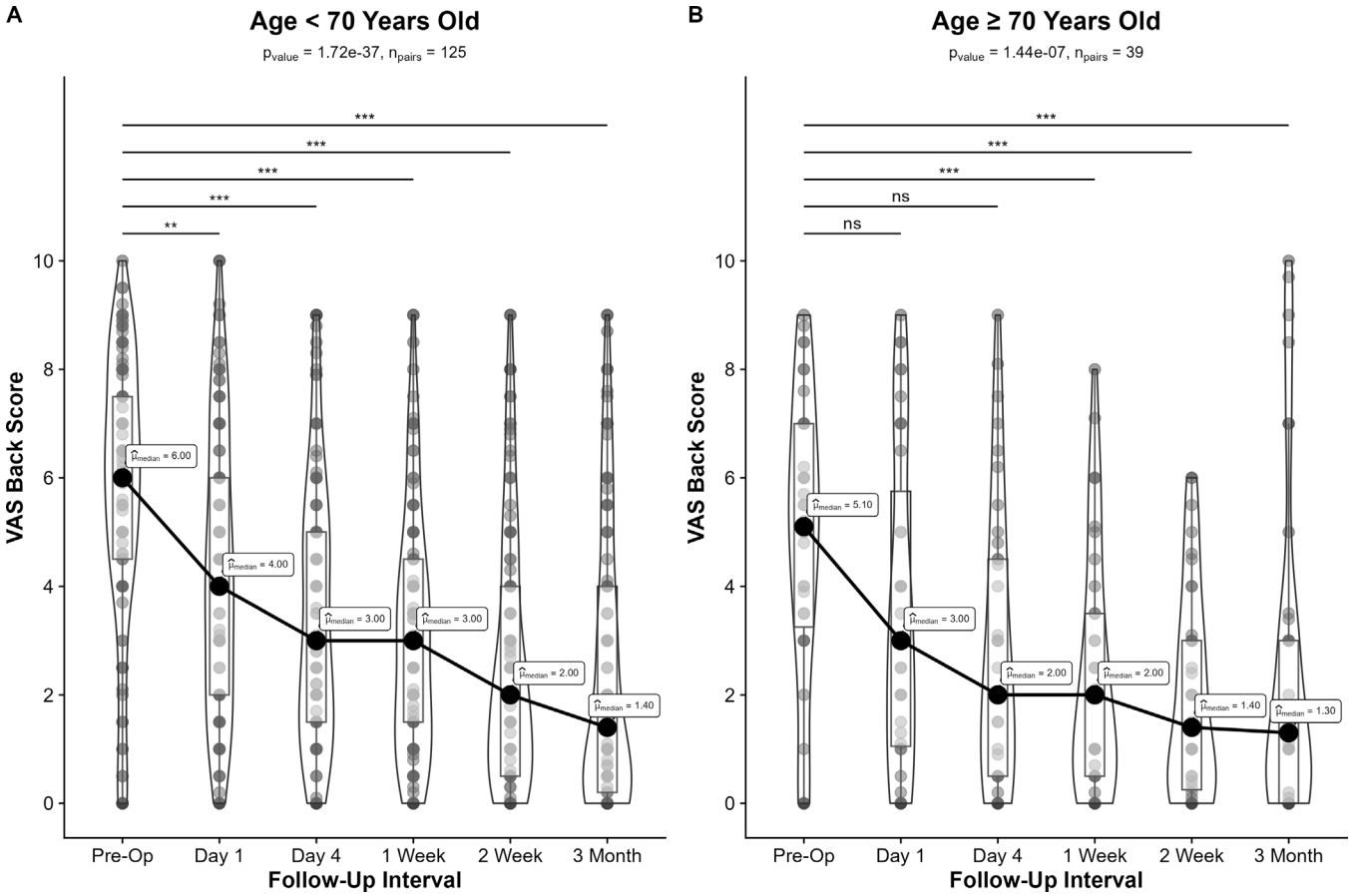

Figure 1. Representation of VAS back scores preoperatively and at various follow-up intervals for (A) patients younger than 70 years and (B) patients aged 70 years or older. Significant ("*" denotes $P < 0.05$; "**" denotes $P < 0.01$; "****" denotes $P < 0.001$) and nonsignificant values (denoted by "ns") comparing the preoperative score to each of the follow-up time points are visually represented. Additional statistically significant values were noted for group (A) between "day 1" and "day 4" ($P < 0.01$); "day 1" and "1 week" ($P < 0.001$); "day 1" and "2 weeks" ($P < 0.001$); "day 1" and "3 months" ($P < 0.001$); "day 4" and "2 weeks" ($P < 0.001$); "day 4" and "3 months" ($P < 0.001$); "1 week and 2 weeks" ($P < 0.01$); "1 week" and "3 months" ($P < 0.001$) as well as for group (B) between "day 1" and "2 weeks" ($P < 0.01$); "day 1" and "3 months" ($P < 0.05$); "day 4" and "2 weeks" ($P < 0.05$).

for the younger group vs 1 in the older group ($P = 0.526$; $q = 0.752$; Table 1).

Characterization of Pain and Functional Outcomes

Analysis of VAS back scores revealed significant Friedman test results for both geriatric and nongeriatric cohorts comparing pre- and postoperative scores ($P < 0.001$ and $P < 0.001$, respectively). For the younger cohort, VAS back was rated as a median of 6.0 (4.5–7.5) preoperatively, subsequently decreasing to 4.0 (2.0–6.0) by day 1, stabilizing at 3.0 (1.5–5.0) by day 4 and 3.0 (1.5–4.5) at week 1, reducing further to 2.0 (0.5–4.0) by 2 weeks, and finally reaching 1.4 (0.2–4.0) by 3 months. From baseline to each follow-up time point, a statistically significant improvement was observed (Figure 1a). The older group experienced a similar trend in VAS back score improvement over time, progressing from a score of 5.1 (3.3–7.0) preoperatively to 3.0 (1.1–5.8) at day 1, then to 2.0 (0.5–4.5) at day 4, 2.0 (0.5–3.5) at week 1, further decreasing to 1.4 (0.3–3.0) at 2 weeks, and ultimately arriving at 1.3 (0.0–3.0) by the 3-month mark. In contrast to the younger group, the older group did not experience significant improvement from baseline until 1 week and onward after surgery ($P < 0.001$; Figure 1b).

Analysis of VAS ipsilateral leg scores across time points also yielded statistically significant Friedman test results for both younger ($P < 0.001$) and older ($P < 0.001$) cohorts. A closer examination of the recovery trajectory for nongeriatric patients revealed a marked decrease in VAS from baseline after just 1-day postsurgery (6.4 [4.5–8.0] vs 1.5 [0.0–4.0]). The VAS score mildly increased to 2.0 (0.5–4.0) on day 4 but gradually declined thereafter, stabilizing at 1.0 (0.0–2.5) by the 3-month mark. Statistically significant improvements were noted between baseline and each subsequent follow-up interval ($P < 0.001$; Figure 2a). Similarly, geriatric patients experienced a significant improvement in

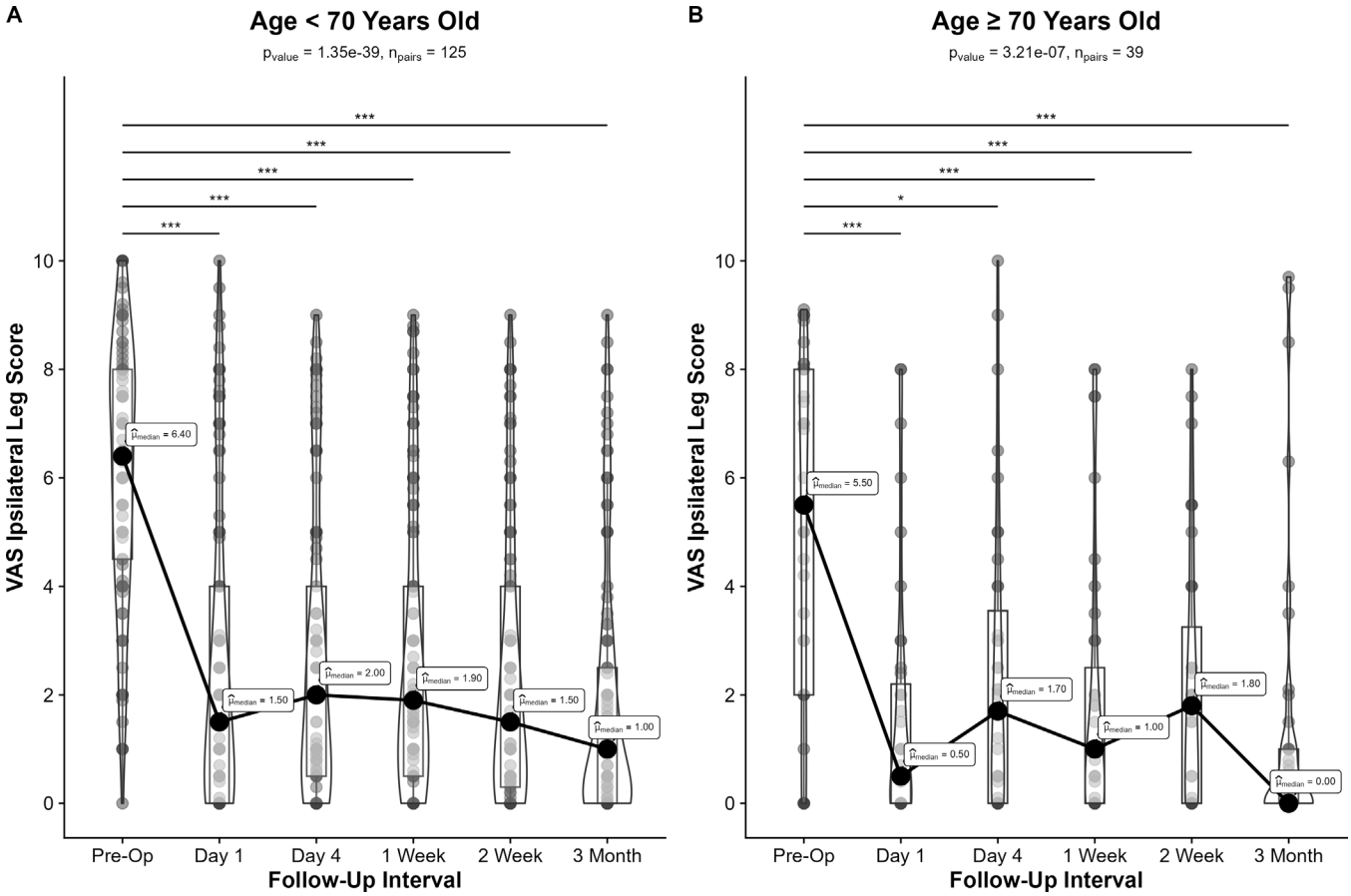

Figure 2. Representation of visual analog scale (VAS) ipsilateral leg scores preoperatively and at various follow-up intervals for (A) patients younger than 70 years and (B) patients aged 70 years or older. Significant ("*" denotes $P < 0.05$; "**" denotes $P < 0.01$; "****" denotes $P < 0.001$) and nonsignificant values (denoted by "ns") comparing the preoperative score to each of the follow-up time points are visually represented. Additional statistically significant values were noted for group (A) between "day 1" and "3 months" ($P < 0.01$); "day 4" and "2 weeks" ($P < 0.01$); "day 4" and "3 months" ($P < 0.001$); "1 week" and "3 months" ($P < 0.001$) as well as for group (B) between "day 4" and "3 months" ($P < 0.05$).

VAS leg scores just 1 day after surgery (5.5 [2.0–8.0] vs 0.5 [0.0–2.2]). Like their younger counterparts, the geriatric cohort saw a slight increase to 1.7 (0.0–3.6) at day 4, which was followed by a reduction to 1.0 (0.0–2.5) at week 1 and a minor fluctuation to 1.8 (0.0–3.3) at 2 weeks. By 3 months, the median VAS leg score reported by the older group reached 0.0 (0.0–1.0). Post-hoc analyses confirmed statistically significant differences between baseline and all follow-up endpoints for geriatric patients as well ($P < 0.001$ for day 1, week 1, week 2, and 3 months; $P < 0.05$ for day 4; Figure 2b).

Functional improvement as characterized by ODI score also improved overall from baseline to follow-up for both non-geriatric ($P < 0.001$) and geriatric ($P < 0.001$) groups. In contrast to pain outcomes, improvement in ODI was generally observed later in the postoperative course. Median preoperative ODI was 20.3 (15.5–27.0) for the younger cohort. The first statistically significant improvement from baseline is noted at week 1 following surgery, with a decrease to an ODI score of 19.0 (12.3–26.0, $P < 0.05$). ODI decreased more steadily thereafter to 15.8 (9.3–21.5) at 2 weeks and 7.0 (2.2–14.3) at 3 months (Figure 3a). Similarly, geriatric patients started with a median preoperative ODI of 20.0 (14.8–24.5) but did not improve as quickly. The first statistically significant improvement from baseline is noted at 3 months when ODI reached a value of 10.3 (3.9–14.2, $P < 0.001$; Figure 3b).

Dynamics of Pain and Functional Improvement Compared Between Groups

The rate of improvement was determined by calculating the difference in preoperative metrics to each subsequent follow-up time point. Changes in improvement at each measured interval were compared between the nongeriatric and geriatric groups. Pain assessment for VAS back showed no statistically significant differences between the younger and older groups at the initial assessment ($P = 0.060$), although the younger

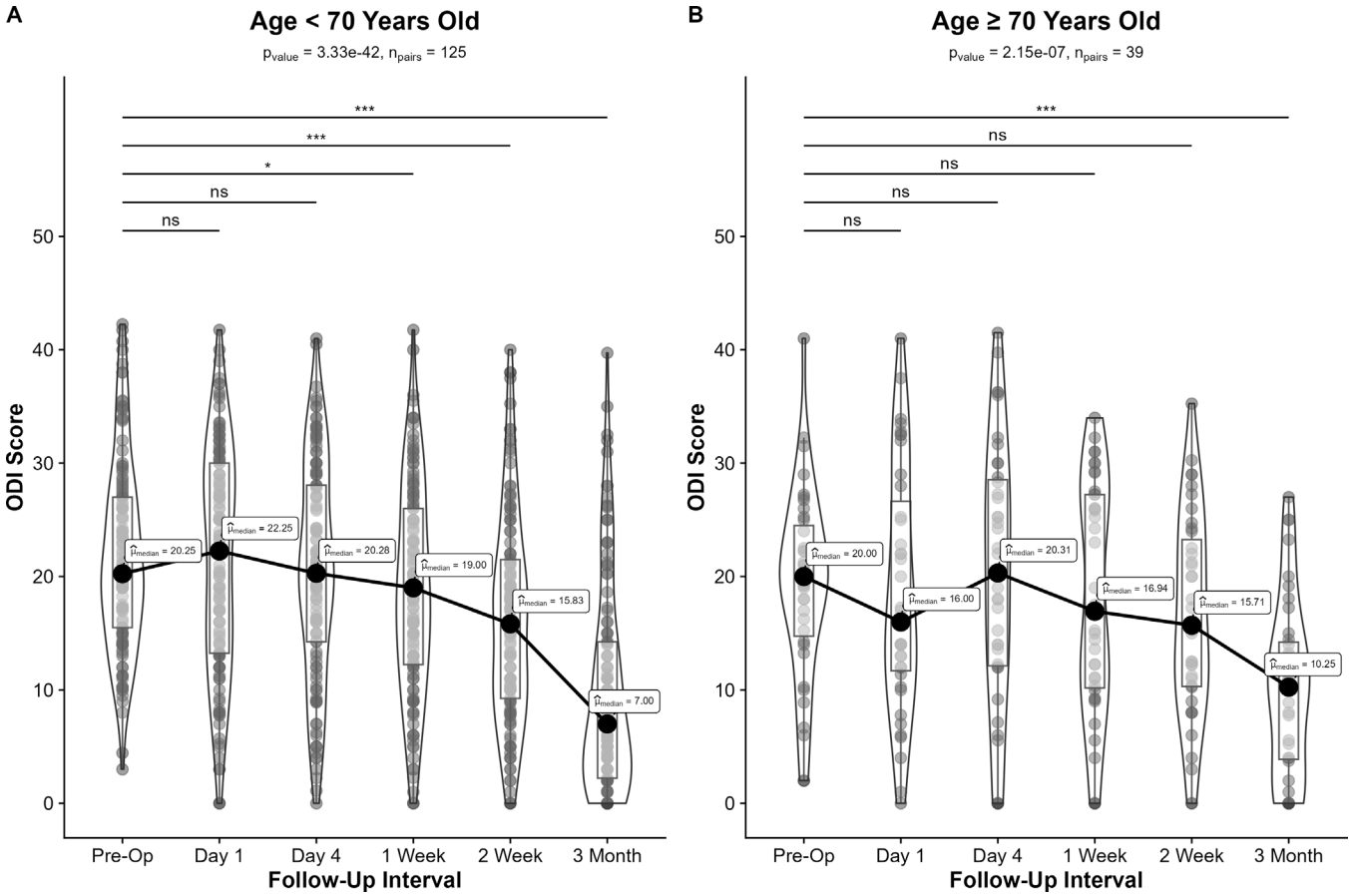

Figure 3. Representation of Oswestry Disability Index (ODI) scores preoperatively and at various follow-up intervals for (A) patients less than 70 years old and (B) patients greater than or equal to 70 years old. Significant ("*" denotes $P < 0.05$; "**" denotes $P < 0.01$; "***" denotes $P < 0.001$) and nonsignificant values (denoted by "ns") comparing the preoperative score to each of the follow-up time points are visually represented. Additional statistically significant values were noted for group (A) between "day 1" and "1 week" ($P < 0.001$); "day 1" and "2 weeks" ($P < 0.001$); "day 1" and "3 months" ($P < 0.001$); "day 4" and "1 week" ($P < 0.05$); "day 4" and "2 weeks" ($P < 0.001$); "day 4" and "3 months" ($P < 0.001$); "1 week" and "2 weeks" ($P < 0.001$); "1 week" and "3 months" ($P < 0.001$); "2 weeks" and "3 month" ($P < 0.001$) as well as for group (B) between "day 1" and "3 months" ($P < 0.001$); "day 4" and "3 months" ($P < 0.001$); "1 week" and "3 months" ($P < 0.001$); "2 weeks" and "3 months" ($P < 0.01$).

group demonstrated slightly higher preoperative pain levels (6.0 [4.5–7.5] vs 5.1 [3.3–7.0]). Comparisons of changes in improvement at day 1, day 4, 1 week, 2 weeks, and 3 months revealed no statistically significant differences between the cohorts at any time point ($P = 0.855$, $P = 0.658$, $P = 0.872$, $P = 0.699$, and $P = 0.199$, respectively). At the 3-month mark, the younger group demonstrated a median improvement of 3.5 (1.0–6.0), while the older group showed an improvement of 2.4 (0.0–5.3) points on the VAS back. Similarly, the analysis of VAS leg scores between the cohorts indicated no significant evidence to suggest that 1 group improved faster than the other. Both groups exhibited similar VAS leg scores at the outset ($P = 0.140$) and comparable rates of improvement at day 1 ($P = 0.780$), day 4 ($P = 0.547$), 1 week ($P = 0.580$), 2 weeks ($P = 0.135$), and 3 months ($P = 0.428$; Table 2). Further stratification of groups by age and procedure type for diagnosis pathology continued to support that no statistically significant differences were observed across groups for VAS back and leg scores ($P > 0.050$; $q > 0.050$; Supplemental Table 1).

Younger and older patients experienced similar rates of functional improvement as assessed by ODI. Preoperatively, there were no statistical differences between the groups in functional status ($P = 0.248$). Both cohorts observed modest short-term improvements and noted the most significant difference in improvement at 3 months (younger group improved by 12.0 [5.3–19.0] points from baseline; older group improved by 8.3 [3.4–15.3] points from baseline). The rate of ODI improvement, when compared between the 2 groups, did not reveal statistically significant differences at any measured interval (day 1, $P = 0.621$; day 4, $P = 0.325$; 1 week, $P = 0.405$; 2 weeks, $P = 0.099$; 3 months, $P = 0.428$; Table 2). Further stratification of groups by age and procedure type for diagnosis pathology revealed initial differences between groups for ODI improvement at

Table 2. Postoperative patient outcomes for the total cohort and groups stratified by age.

Outcome Measure	Total Cohort (N = 164)	Age <70 y (N = 125)	Age ≥70 y (N = 39)	P
VAS Back Outcomes, median (IQR)				
Preoperative	6.0 (4.0–7.5)	6.0 (4.5–7.5)	5.1 (3.3–7.0)	0.060[a]
ΔDay 1	1.5 (–0.5 to 3.6)	1.3 (-0.5–3.5)	1.5 (–0.8–3.5)	0.855[b]
ΔDay 4	2.0 (0.0–4.5)	2.0 (0.0–4.5)	1.5 (–0.3–4.9)	0.658[b]
Δ1 week	2.5 (0.5–4.5)	2.5 (0.5–4.6)	2.5 (0.0–4.2)	0.872[b]
Δ2 week	3.0 (1.0–5.0)	3.0 (1.0–5.5)	2.1 (1.0–4.8)	0.699[b]
Δ3 month	3.4 (0.8–5.8)	3.5 (1.0–6.0)	2.4 (0.0–5.3)	0.199[a]
VAS Ipsilateral Leg Outcomes, median (IQR)				
Preoperative	6.2 (4.0–8.0)	6.4 (4.5–8.0)	5.5 (2.0–8.0)	0.140[a]
ΔDay 1	3.5 (1.0–6.4)	3.5 (1.0–6.0)	3.0 (0.0–6.8)	0.780[b]
ΔDay 4	3.5 (1.0–6.0)	3.5 (1.5–6.0)	2.5 (0.0–6.4)	0.547[a]
Δ1 week	3.5 (1.0–6.0)	3.5 (1.5–6.0)	2.5 (0.3–6.8)	0.580[a]
Δ2 weeks	3.9 (1.5–6.0)	4.0 (2.0–6.0)	2.0 (0.0–6.3)	0.135[a]
Δ3 months	4.2 (2.0–7.0)	4.3 (2.9–6.5)	3.5 (0.0–7.4)	0.428[a]
ODI Outcomes, median (IQR)				
Preoperative	20.3 (15.2–26.3)	20.3 (15.5–27.0)	20.0 (14.8–24.5)	0.248[a]
ΔDay 1	–0.9 (–7.1–7.6)	–1.8 (–8.0–8.0)	1.0 (–5.4–5.0)	0.621[a]
ΔDay 4	–1.0 (–6.1–8.0)	0.0 (–6.3–9.0)	–2.3 (–5.0–6.1)	0.325[b]
Δ1 week	1.8 (–5.0–9.7)	2.0 (–5.0–10.5)	1.0 (–5.0–7.5)	0.405[b]
Δ2 weeks	4.3 (–3.0–10.1)	5.0 (–2.3–11.5)	4.0 (–4.5–6.6)	0.099[a]
Δ3 months	11.3 (4.9–18.1)	12.0 (5.3–19.0)	8.3 (3.4–15.3)	0.158[b]
Perceived Surgical Outcome at 3 mo, *n/N* (%)				0.623[c]
Good	130/164 (79%)	98/125 (78%)	32/39 (82%)	
Poor	34/164 (21%)	27/125 (22%)	7/39 (18%)	

Abbreviations: IQR, interquartile range; ODI, Oswestry Disability Index; VAS, visual analog scale.
Note: "Δ" Values are reported as the median change in score from preoperative evaluation to the indicated follow-up time point. Positive values represent an improvement and negative values represent a decline.
[a]Wilcoxon rank sum test.
[b]Two sample t test.
[c]Pearson's χ^2 test.

day 1 (P = 0.016), day 4 (P = 0.016), and 1 week (P = 0.028); however, these differences were no longer significant after adjustment for multiple testing (day 1, q = 0.144; day 4, q = 0.144; 1 week, q = 0.168). No significant differences were observed between groups at the final follow-up point of 3 months (Table S1).

Patient Satisfaction Following FESS

Self-perceived surgical outcomes were assessed in all patients who received FESS 3 months postprocedure. In the older group, 82% perceived their results as "good," while 18% considered them "poor." The younger cohort reported slightly worse perceptions, with 78% deeming the procedure "good" and the remaining 22% rating it as "poor." There was no statistically significant difference in responses between the groups (P = 0.623; Table 2).

To explore potential differences in outcomes based on patient satisfaction at 3 months, the cohort was stratified into 2 groups: those reporting a "good" outcome and those reporting a "poor" outcome. Changes in improvement from baseline for VAS back, VAS leg, and ODI were then compared between these groups. Results indicated that patients who perceived their outcome as "poor" at 3 months demonstrated significantly lower rates of improvement for VAS back (P = 0.002; q = 0.009), VAS leg (P = 0.001; q = 0.009) and ODI (P < 0.001; q < 0.001) compared with patients who perceived their outcome as "good" (Table 3).

DISCUSSION

This study illustrates the efficacy of FESS in managing degenerative spinal conditions across nongeriatric and geriatric age cohorts. Our investigation was grounded in the hypothesis that both younger and older groups would derive significant pain and functional benefit from FESS. By systematically analyzing outcomes such as pain scores (VAS back and leg) and functional status (ODI), we provide empirical evidence supporting the hypothesis. This analysis not only reaffirms the significance of the topic but also invites deeper scrutiny into the nuanced dynamics of postoperative recovery in older patients.

Both nongeriatric and geriatric patients demonstrated significant improvements from their baseline pain and functional measures following FESS. Notably, the younger cohort showed statistically significant improvements earlier than the older group for VAS back (postoperative day 1 vs day 7) and ODI (postoperative day 7 vs day 90). These findings align with reported

Table 3. Postoperative patient outcomes stratified by perceived surgical outcome at 3 months.

Outcome Measure	Good ($N = 130$)	Poor ($N = 34$)	P	q[a]
VAS Back Outcomes, median (IQR)				
Preoperative	6.0 (4.0–7.4)	6.0 (5.0–7.8)	0.243[b]	0.547
ΔDay 1	1.5 (–0.9–3.7)	1.1 (–0.1–3.2)	0.893[c]	0.966
ΔDay 4	2.0 (0–4.5)	2.2 (0–4.6)	0.953[d]	0.966
Δ1 week	2.5 (0.5–5.0)	2.5 (1.1–4.0)	0.864[c]	0.966
Δ2 weeks	3.0 (1.0–5.0)	3.0 (1.0–4.7)	0.890[d]	0.966
Δ3 months	3.5 (1.0–6.0)	1.7 (–0.7–3.9)	**0.002**[b]	**0.009**
VAS Ipsilateral Leg Outcomes, median (IQR)				
Preoperative	6.3 (4.0–8.0)	6.0 (4.1–8.0)	0.966[b]	0.966
ΔDay 1	3.8 (1.0–6.5)	2.5 (0–6.0)	0.170[b]	0.437
ΔDay 4	3.6 (1.0–6.0)	3.0 (–0.6–6.3)	0.334[b]	0.547
Δ1 week	3.6 (1.5–6.5)	2.5 (–0.4–4.4)	**0.016**[b]	0.058
Δ2 weeks	4.0 (2.0–6.5)	1.5 (–0.8–4.4)	**0.002**[b]	**0.009**
Δ3 months	4.5 (2.9–7.2)	2.5 (–0.9–5.1)	**0.001**[b]	**0.009**
ODI Outcomes, median (IQR)				
Preoperative	20.2 (15.1–26.0)	20.1 (16.1–28.0)	0.320[d]	0.547
ΔDay 1	0 (–6.0–7.7)	–2.5 (–10.8–5.8)	0.562[d]	0.806
ΔDay 4	–1.0 (–5.7–7.8)	0 (–9.0–8.2)	0.582[d]	0.806
Δ1 week	2.8 (–3.9–9.9)	0.9 (–7.9–8.8)	0.294[d]	0.547
Δ2 weeks	5.0 (–2.8–11.2)	2.1 (–4.9–7.6)	0.090[b]	0.270
Δ3 months	12.1 (6.8–19.0)	4.1 (–2.5–10.2)	**<0.001**[d]	**<0.001**

Abbreviations: IQR, interquartile range; VAS, visual analog scale.
Note: "Δ" Values are reported as the median change in score from preoperative evaluation to the indicated follow-up time point. Positive values represent an improvement and negative values represent a decline. Boldface indicates statistical significance ($p < 0.05$).
[a]False discovery rate correction for multiple testing.
[b]Wilcoxon rank sum test.
[c]Welch's t test.
[d]Two sample t test.

differences in recovery pace when comparing FESS discectomy and decompression and partially reflect the different pathologies of younger and elderly patients.[21] Furthermore, they provide unique insight of discrepancies in postoperative recovery patterns which is essential for comprehensive patient counseling. The younger cohort reported early functional benefits. On the other hand, functional improvement in patients older than 70 years may be more protracted on average, possibly necessitating ongoing assistive care in the early postoperative period.

The distinction between statistical and clinical significance is crucial in evaluating surgical treatments such as FESS. While statistical significance shows the likelihood that an observed numerical effect is not due to chance, it does not necessarily measure the effect's real-world importance. The minimum clinically important difference (MCID) addresses this gap by defining the smallest change in outcomes that patients or clinicians may consider valuable. Prior work has validated improvements of 1.2 points for VAS back, 1.6 points for VAS leg, and a 30% reduction in ODI as benchmarks for MCID in patients undergoing spine surgery.[23–25] Applying this standard to the median of our data for each respective outcome metric, we observe that both younger and older patients are able to appreciate clinically significant differences in VAS back and leg by the first day following surgery and onward (Figures 1 and 2). Meanwhile, younger and older patients first notice an MCID for ODI at 3 months following surgery (Figure 3). The gradual improvement in ODI compared with VAS supports the idea that functional recovery tends to follow pain relief.[21] Overall, our results extend beyond statistical significance and accentuate the clinically significant potential benefits of FESS in nongeriatric and geriatric patients alike.

Prior research exploring the efficacy of FESS in patients older than 70 years is limited. In their 2018 study, Kim et al retrospectively analyzed the postoperative outcomes of 53 geriatric (>70 years old) patients following FESS. They reported pain (VAS) and functional (ODI) outcomes at baseline, 3 months, and at a final follow-up mean of 17 months. At each time point, a statistically significant improvement was noted from baseline ($P < 0.0001$).[17] Telfeian et al expanded upon these findings, exhibiting the feasibility of FESS in the extremely elderly (>80 years old). They reported low rates of overall complications while still showing that most patients appreciated substantial improvements in VAS leg and ODI.[26] Although these results are compelling, the retrospective nature of both studies and the lack of a younger comparison group limit the internal and external validity of these findings. In the present study, we validate these conclusions with our own multicenter

data set and leverage a prospective study design with a younger comparator group. Furthermore, our contribution is the first to include virtually collected patient-reported outcomes at uniform time points, enriching the body of evidence with rigorous, longitudinally collected data. Lastly, the temporal resolution of our results is substantially higher as we highlight the understudied early postoperative pain and functional improvements that we believe are crucial for long-term recovery.[21]

A point of contention in the literature has been the purported higher reoperation rates among older patients undergoing endoscopic procedures. In a nationwide cohort study, Kim et al have proposed an age cut-off point of 57 years, past which they report an increased chance of reoperation in older patients undergoing FESS compared with open discectomy.[27] While our study did not specifically address reoperation rates, it is essential to consider this aspect within the broader context of surgical benefits and risks. A prevailing counterargument is that the reduced risk of complications and minimally invasive nature of FESS may offset the negatives of higher reoperation rates. FESS facilitates awake anesthesia that counteracts anesthetic complications which mainly affect the elderly.[28,29] Another recent study reports an eradication of feared surgical site infection following FESS, a complication affecting the elderly disproportionately.[11] Our findings contribute to this ongoing debate by highlighting the early statistically and clinically significant improvements in pain and function following FESS, suggesting that the benefits of this minimally invasive approach may indeed outweigh the risks, especially in older populations. Future prospective studies focusing on long-term outcomes and reoperation rates are necessary to fully understand the risk-benefit profile of FESS in different age groups.

The relationship between frailty and surgical outcomes is complex, with age often used as a surrogate marker for frailty. Our findings suggest that age, in isolation, may not be a definitive predictor of poorer outcomes following FESS. This observation prompts a broader discussion on the necessity of considering multifaceted assessments of frailty. While our study did not directly measure frailty, the comparable outcomes between younger and older patients challenge the assumption that older, potentially more frail individuals are at a disadvantage following FESS. In fact, the results indicate similar improvements following FESS, potentially irrespective of pathophysiological disparities, in the nongeriatric and geriatric cohorts. This highlights the need for further research to explore the impact of comprehensive frailty assessments as a potential modifier of surgical outcome following FESS.

Limitations

We acknowledge that there are several limitations in the present study. The relatively small number of participants in the geriatric cohort may not support the statistical power needed to detect a significant difference from the younger cohort and limit overall generalizability. Moreover, our study only reports treatment outcomes up to 3 months postsurgery, so it is unclear whether these trends will be observed in the longer term. Furthermore, this study was limited to the collection and analysis of pain and functional outcomes, as reported through a patient-facing self-report mobile application. Data on postoperative complications, such as epidural hematoma, infection, reoperation, and other postoperative complications beyond the noted dural tears were not systematically collected. Additionally, although most patients were discharged the same day as surgery, as is standard practice at the endoscopic spine specialty centers that participated in this study, granular information on length of stay was not collected. Future studies may benefit from incorporating comprehensive complication tracking, length of stay data, and longer follow-up periods to provide a fuller picture of patient outcomes.

We also acknowledge that the 2 cohorts are not entirely homogeneous in terms of baseline characteristics. Degenerative spinal pathology encompasses a wide range of maladies, and it is unsurprising to see that younger and older patients may vary with respect to surgical indication and the specific type of FESS procedure consequently performed. We recognize that this introduces potential selection bias, as most nongeriatric patients in our study primarily underwent surgery for herniated intervertebral discs, whereas geriatric patients typically required decompression. This variation in surgical indication may contribute to discrepancies in postoperative clinical outcomes between the 2 groups, potentially impacting the comparability of outcomes between age cohorts. We also recognize the possibility of selection bias in considering the types of patients for whom an individual provider may choose a FESS approach. However, our study may reduce the effects of this bias by drawing from a multi-institutional cohort across the clinics of 6 experienced endoscopic spine surgeons. Furthermore, loss to follow-up is a limitation of many prospective studies, including ours. In excluding patients with missing data at the defined project primary endpoints, we recognize the possibility

that these subjects may not be missing at random and may skew our results.

We employed a novel method for collecting prospective data using a mobile application with previous research indicating improved follow-up compliance to mitigate these effects.[30] Furthermore, research assistants and clinical staff familiar with the technology were continuously available, remotely and in person, to assist patients with installing and utilizing the mobile application. This support was especially important for geriatric patients who may experience accessibility challenges, such as limited familiarity with mobile devices, less frequent phone usage, and difficulties navigating app interfaces. By providing continuous assistance, we aimed to ensure that all participants could effectively engage with the mobile platform. However, despite prior studies having successfully leveraged this specific method of data collection in comparable instances, its relative novelty may be perceived as a limitation, and more research is needed to confirm its validity.[18–21]

CONCLUSION

In this prospective cohort study, we report that both geriatric (≥70 years) and nongeriatric adults experience statistically and clinically significant improvements in pain and function up to 3 months after undergoing FESS for degenerative lumbar conditions. Additionally, both groups exhibited comparable rates of improvement in their outcomes. Our findings indicate no statistically significant differences in VAS back, VAS leg, or ODI scores at any measured time points between the 2 groups, highlighting the effectiveness of FESS in the geriatric population. Endoscopic spine surgery represents a robust and efficacious option for geriatric patients seeking a minimally invasive surgical alternative.

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Corresponding Author: Alexander A. Chernysh, Department of Neurosurgery, Warren Alpert Medical School, Brown University, 593 Eddy St, APC-6, Providence, RI 02903, USA; alexander.a.chernysh@gmail.com

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