



The influence of age on the peri- and postoperative clinical course in patients undergoing minimally invasive transforaminal lumbar interbody fusion techniques of the lumbar spine



Wolfgang Senker^{a,*}, Harald Stefanits^a, Matthias Gmeiner^a, Wolfgang Trutschnig^b, Christian Radl^b, Andreas Gruber^a

^a Department of Neurosurgery, Kepler University Hospital, Neuromed Campus, Linz, Austria

^b Department of Mathematics, University of Salzburg, Austria

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ABSTRACT

Objective: As a result of continuously increasing life expectancy, the number of requests for surgery to treat degenerative diseases of the spine in the elderly population will increase. Since older age is associated with the occurrence of medical comorbidities, the demand for less extensive surgical approaches is growing. The aim of this study is to establish whether minimally invasive fusion techniques are a safe and adequate tool for use in elderly patients.

Patients and methods: We analyzed 187 patients who underwent minimally invasive surgery (MIS) in the form of one- to four-level fusion procedures. In 146 patients, additional widening of the spinal canal was performed. The subjects were grouped into four age categories of approximately equal size (33–56, 56–66, 66–74 and 74–85). The effect of age on the incidence of peri- and postoperative complications was investigated and compared between the age groups.

Results: Older age was not associated with the occurrence of perioperative complications, which include wound healing disorders, hematomas, wound traction-blisters and cerebrospinal fluid leakage. Fourteen patients (7.49%) encountered distinct surgical technique related complications, making surgical revision necessary in eight patients (4.28%). Furthermore, increasing age didn't elevate the risk of postoperative adverse events, i.e. pulmonary embolism, ischemic heart attack or pneumonia, among others. However, older patients were found to stay in hospital longer than younger patients, especially when more than one level was fused.

Conclusions: Minimally invasive surgery techniques are safe in elderly patients. The small-scale surgical approach guarantees a low incidence of infections and wound healing disorders. However, a longer hospital stay must be expected in older patients.

1. Introduction

In the last few decades, life expectancy has increased across Europe. In 2014, according to Eurostat, an 80-year-old EU resident was expected to live for another 9.5 years. Degenerative conditions of the spine are common among the elderly. Consequently, the number of patients referred to spine surgeons for fusion procedures will continue to rise. By the 1980s, the number of surgeries performed to treat spinal stenosis in US patients aged 65 years or older had already increased eight-fold [1]. As age increases, so does the occurrence of comorbidities, which can lead to further complications in spinal surgery. Despite

higher comorbidity and complication rates in geriatric patients, the outcomes of surgery are just as likely to be rated as good for up to two years post-surgery by older patients as they are by younger ones [2]. The aim of this prospective study, which investigated 187 patients, was to examine whether older patients undergoing minimally invasive fusion techniques of the spine experience higher peri- and postoperative complication rates compared to younger patients. Minimally invasive surgery (MIS) uses a smaller corridor to the spine and therefore results in less tissue injury. It is associated with reduced blood loss, faster recovery and lower perioperative morbidity rates, while still producing results similar to those achieved through open procedures [3–5]. Thus,

* Corresponding author at: Department of Neurosurgery, Kepler University Hospital, Neuromed Campus, Linz, Austria.

E-mail addresses: wolfgang.senker@kepleruniklinikum.at (W. Senker), harald.stefanits@kepleruniklinikum.at (H. Stefanits), matthias.gmeiner@kepleruniklinikum.at (M. Gmeiner), wolfgang@trutschnig.net (W. Trutschnig), christian.radl@kepleruniklinikum.at (C. Radl), andreas.gruber_1@kepleruniklinikum.at (A. Gruber).

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the purpose of this study was to investigate each MIS case in our daily routine practice and to compare the outcomes and complication rates in different age groups. Data on outcomes and complication rates in the elderly are scarce [6–8], and to our knowledge, this study is one of the largest single-center studies to address this topic.

2. Patients and methods

This study was approved by the ethics committee of the Federal State of Lower Austria. Written consent was obtained from all patients, and the study was registered at ClinicalTrials.gov (NCT01259960). A cohort of 187 patients (115 women, 72 men) who underwent MIS fusion for degenerative disorders of the lumbar spine in our daily routine practice between April 2010 and February 2016 were recruited for this prospective investigation. MIS lumbar fusion was performed using only transforaminal lumbar interbody fusion (TLIF) procedures and posterolateral fusion. In 146 patients suffering from spinal stenosis, additional widening of the spinal canal was performed. Data on patients' demographics (age, weight, comorbidities, medications, etc.), duration of surgery, length of stay in hospital and complications were collected. Complications were defined by their chronological sequence into surgical technique related complications, wound complications (e.g. wound healing disorder [WHD], hematoma, dehiscence, wound traction-blister [WTB]), and postoperative sequelae, which were divided into major and minor complications and classified according to Carreon [9].

All patients were treated by one-, two-, three- or four-level, minimally invasive fusion. They were divided into two groups, those with one-level fusions and those with multi-level ('two plus') fusions. Patients were divided into four age groups of approximately equal size (33–56, 56–66, 66–74 and 74–85).

2.1. Surgical technique

In instances where revision of the disc space or laminotomy for spinal stenosis were required, the Quadrant Tubular Retractor system (Medtronic Inc., Memphis, TN) was used. After identifying the relevant facet joint with fluoroscopy, an incision was made 1.5 cm off the midline. A tube was inserted subcutaneously and muscle tissue was sequentially dilated by producing a corridor to the facet joint, in a fashion similar to that described by Foley [10]. The facet joint and the yellow ligament were exposed and resected on one side. After identifying the disc space, we resected the disc and prepared the endplates with shavers to remove superficial layers of the cartilaginous endplates and to expose the underlying bleeding bone. With the help of distractors, the disc space was sequentially distracted until an adequate disc space height was obtained and an adequate foraminal size was restored. Next, we filled the disc space with local bone and a hydroxyapatite bone paste. An appropriate TLIF cage was then inserted. We used the Sextant II or Longitude (both Medtronic Inc., Memphis, TN) percutaneous screw/rod fusion systems for posterolateral fusion. In nine patients, we did not implant an interbody device at every level because the disc space was narrow and there was a risk of fracturing the corresponding endplates. In four two-level fusion cases, we fused only one vertebral segment with a TLIF cage. In four three-level fusion cases, we implanted two TLIF cages, and in one four-level fusion case we implanted three TLIF cages. In cases with spinal stenosis, the retractor was directed to the contralateral side of the spinal canal to enable laminotomy.

2.2. Statistics

Statistical analyses were performed using the R package (nrmv). The nonpartest [11] was used to test the null hypothesis that the underlying distributions in the groups under investigation were the same. A linear dependence of variables was determined by Pearson's correlation (ρ), while concordance was quantified by Spearman's rank

correlation (ρ_S). The *t*-test was used for testing for zero correlation. A *p*-value < 0.05 was considered to indicate statistical significance.

As the number of fused levels varied significantly between the age groups, the effects of age were analyzed separately for the group of patients with only one fused level and the group of patients with two or more fused levels ('two plus'). It should be noted that the seemingly natural option of applying a (generalized) linear mixed model to the data, which would set the number of fused levels to 'random', age to 'fixed effect', and the peri- and postoperative complication rate to 'response', is not appropriate because the resulting residuals do not follow a normal distribution.

3. Results

A total of 187 patients were included in the study, 115 of whom were female and 72 male. The mean age was 64.27 years (range: 33–85). Patients were grouped according to their age into four age groups of approximately equal size. Three of the age groups (33–56, 56–66 and 66–74) contained 45 individuals each, while the 74–85 age group contained 51 patients. The most frequent preoperative comorbidities were chronic obstructive pulmonary disease, primary chronic polyarthritis, hyperuricemia, and chronic renal insufficiency. We did not observe a higher preoperative comorbidity rate in the older patients.

3.1. Number of fused levels

As the number of fused levels influences the response variables, this potential bias was ruled out in every analysis before the effect of age on complication rates was quantified. The average age of patients with a one-level fusion, was 61.76 years (range: 33–85), whereas the average age of patients with a multi-level fusion was 66.79 years (range: 40–85). In both the female and male cohorts, patients with multi-level fusions were, on average, older. Not considering gender, the age distributions differed significantly between the one-level and 'two-plus' level subgroups ($p = .01$). Age distributions also varied slightly between the groups of patients with two-, three- and four-level fusions (Table 1). However, this difference was not statistically significant, possibly due to the much smaller sample size ($p = .65$). For a detailed statistical summary of age versus the number of fused vertebral segments, see Table 2.

3.2. Duration of surgery

The relationship between age and surgery duration varied between patients with single-level and patients with multi-level fusions. In the one-level group, no correlation between age and duration of surgery could be established ($\rho = .000044$ ($\rho_S = .0771$); $p = .99$ ($p = .52$)).

In the multi-level ('two plus') group, a weak positive correlation between age and surgery duration was observed ($\rho = .1460$ ($\rho_S = .1370$); $p = .17$ ($p = .20$)). However, the data indicated that older patients tend to undergo lengthier surgeries. Partitioning patients

Table 1

Age distribution for male and female genders, separated by the number of vertebral segments fused. m - male; f - female.

No. of Fused Levels	Gender	No. Patients	Mean Age	Median Age	Min. Age	Max. Age
2	m	31	66.35	68	43	85
3	m	5	67	65	58	83
4	m	2	69	69	64	74
2	f	30	65.77	66	40	85
3	f	17	69.06	73	47	82
4	f	5	66.8	67	60	74

Table 2

Age versus number of fused levels. Patients were divided into one-level (1) and multi-level (2+) fusion groups. m - male; f - female.

Fusion Group	Gender	No. Patients	Mean Age	Median Age	Min. Age	Max. Age
1	m	34	62.94	63	34	85
2+	m	38	66.58	67	43	85
1	f	62	61.11	64	33	82
2+	f	52	66.94	70	40	85

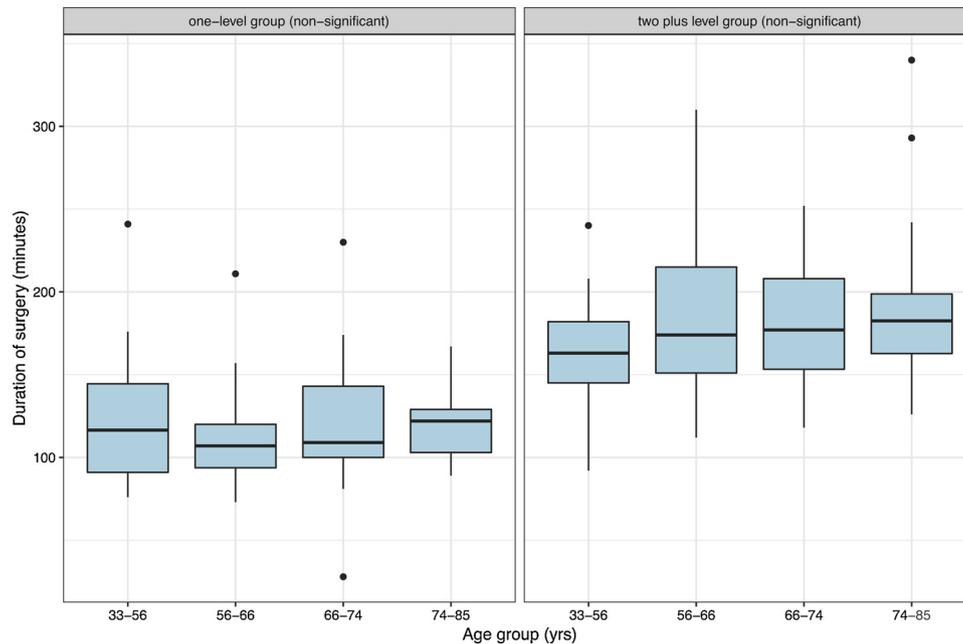


Fig. 1. Surgery duration distributions for the four age groups; the panel titles refer to the (aggregated) one-level and multi-level ('two plus') groups. 'Age groups' in years, 'duration surgery' in minutes. No statistically significant difference between the age groups was found.

Table 3

Distribution of wound complications by age group and fusion group. Patients were divided into one-level (1) and multi-level (2+) fusion groups.

Fusion Group	Age Group	WHD	Hematoma	WTB	Dehiscence	No. Patients
1	33-56	0 (0%)	1 (3.12%)	0 (0%)	0 (0%)	32
1	56-66	0 (0%)	1 (5%)	1 (5%)	0 (0%)	20
1	66-74	0 (0%)	0 (0%)	1 (4.76%)	0 (0%)	21
1	74-85	1 (4.35%)	1 (4.35%)	0 (0%)	0 (0%)	23
2+	33-56	0 (0%)	1 (7.69%)	0 (0%)	0 (0%)	13
2+	56-66	0 (0%)	1 (4%)	0 (0%)	0 (0%)	25
2+	66-74	0 (0%)	2 (8.33%)	0 (0%)	0 (0%)	24
2+	74-85	0 (0%)	2 (7.14%)	2 (7.14%)	2 (7.14%)	28

WHD - wound healing disorder; WTB - wound traction blister.

into the four age groups and distinguishing between the two fusion level subgroups yielded similar results (Fig. 1).

3.3. Surgical technique related complications

Fourteen patients had surgical technique related complications (7.49%), and eight of these had to undergo revision (4.28%). These complications were: one compression fracture of an L4 endplate in an L3-L5 fusion, one iatrogenic fracture of an S1 pedicle, one skin abrasion resulting from OP cloth removal, one extraforaminal hematoma with persisting neurological deficit, three epidural hematomas (of which one patient was revised on day two, one on day four and one on day five), one screw malposition, one case of glenohumeral arthritis caused by inadequate positioning of the patient on the OR table, and one loosened screw (due to osteoporosis) that occurred two months postoperatively and needed revision. One patient had to be revised because of a weakness of dorsiflexion of the foot due to a bone fragment in the spinal

canal, another needed revision because of a fracture of a pedicle of the vertebral arch which caused a space consuming lesion in the spinal canal, and one because of dislocation of a TLIF cage. Nine of the patients with complications were in the one-level group, and five were in the multi-level ('two plus') group. We saw no difference in the frequency of surgery-related complications between the age groups ($p = .46$ and $p = .38$, respectively). Moreover, we observed 22 patients with cerebrospinal fluid leakages (CSF), of which six were in the one-level group and sixteen were in the 'two plus' group. No statistically significant differences were evident between the age groups ($p = .49$ and $p = .34$, respectively).

3.4. Wound complications

Wound healing disorders (WHD), hematomas, wound dehiscence, and wound traction-blisters (WTB) after inadequate dressing application were considered together as wound complications (Table 3). We

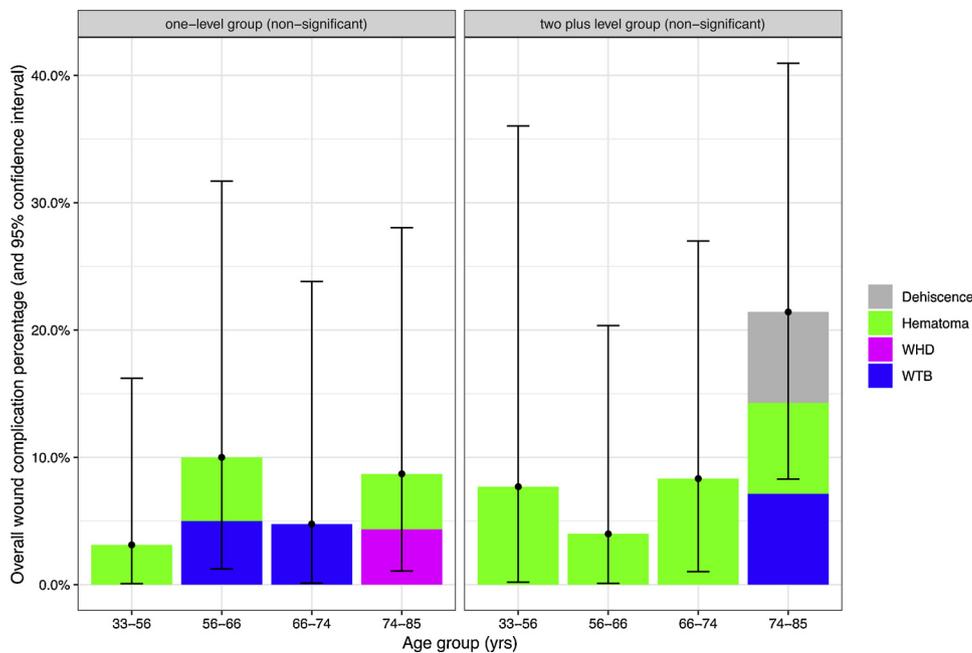


Fig. 2. Overall wound complication rate, 95% confidence intervals, and the complications constituting the overall rate (none of the patients had two or more different complications); the panel titles refer to the (aggregated) one-level and multi-level ('two plus') groups. No statistically significant difference between the age groups was found. WHD - wound healing disorder; WTB - wound traction-blister.

saw no statistically significant difference in the number of patients with WHDs between the age groups. Neither the one-level nor the multi-level ('two plus') fusion group showed a statistical difference in the number of patients with hematomas between the age groups ($p = .79$ and $p = .93$, respectively). None of these patients needed revision surgery.

Again, there was no statistically significant difference in the number of patients with traction blisters between the age groups (one-level group: $p = .43$; 'two plus' level group: $p = .21$). We did not observe a statistically significant difference in the number of patients with wound dehiscence between the age groups (no patients in the one-level group; 'two plus' level group $p = .21$). One patient needed a secondary suture.

Testing for equal proportions of all four complications in the four age groups in the one-level group ($p = .79$) and the 'two plus' level group ($p = .67$) also showed no statistically significant differences. Furthermore, the likelihood of at least one perioperative complication occurring in a patient didn't differ between the age groups in either the one-level group ($p = .72$) or the 'two plus' level group ($p = .20$). Nevertheless, we observed a tendency for older, 'two plus' fusion patients to experience an insignificantly higher rate of complications (Fig. 2).

3.5. Postoperative sequelae

A total of 16 possible minor and major postoperative sequelae were recorded. Twelve patients (6.45%) had major complications in the postoperative course: one case of fatal pulmonary embolism (0.5%), one transient ischemic attack (0.5%), and two patients with pneumonia (1.1%). Four patients had atrial fibrillation postoperatively (2.1%), two had cardiac ischemia (1.1%), and two had a myocardial infarction (1.1%). Minor complications included 45 patients (24.19%) with sub-febrile temperatures and 18 (9.68%) with fever. Seven patients (3.76%) had a urinary tract infection and six (3.22%) had anemia. Enteritis, urinary retention, reflux esophagitis, (pre-)ileus, and an attack of gout were each suffered by one patient (0.54%) (Table 4). A neurological deficit was recorded in 30 patients (16.13%). Two patients (1.07%) had a neurological deficit because of an epidural hematoma, and one patient (0.53%) had a weakness of dorsiflexion of the foot due to a bone fragment in the spinal canal. Another patient had a neurological deficit because of a fracture of a pedicle and one due to a malpositioned screw (0.53% each). All patients with neurological deficits recovered after revision surgery. One patient (0.53%) had a persisting neurological

deficit as a consequence of an extraforaminal hematoma. Twenty-four patients (12.83%) reported transient paraesthesias which disappeared within one week after surgery. In the one-level fusion group, testing for equality of proportions in the four age groups for each postoperative incident individually yielded no statistically significant differences between the age groups. There were also no statistically significant differences between the four age groups for each postoperative complication individually in the multi-level ('two plus') fusion group. The likelihood of at least one postoperative incident occurring did not differ between the four age groups in either the one-level group ($p = .15$) or the 'two plus' level group ($p = .28$). Subsequently, we combined wound complications and postoperative sequelae and tested for equal portions in all age groups. We saw no significant results ($p = .43$ in the one-level group and $p = .07$ in the 'two plus' level group).

3.6. Length of stay in hospital

A weak correlation between age and length of stay in hospital was observed in the one-level group ($\rho = .0477$ ($pS = .1480$); $p = .65$ ($p = .15$)). For the multi-level ('two plus') group, a significant positive correlation was noted between age and the length of stay in hospital ($\rho = .2639$ ($pS = .2320$); $p = .01$ ($p = .20$)) (Fig. 3).

4. Discussion

The topic of spinal fusion in elderly patients is becoming more relevant as life expectancy continues to increase. Despite the improved quality of life after spinal surgery [2,12], the risk of peri- and postoperative complications in the elderly continues to be much debated [9,13–15]. Carreon et al. reported a complication rate of 79.59% in 98 patients, aged 60 years or older, who underwent decompression and fusion surgery [9]. Ten percent of these patients had wound infections. Carreon et al. concluded that advanced age and the number of levels fused were the primary factors which resulted in such complications. They hypothesized that this is due to elderly patients being less able to tolerate major surgery because of their general medical condition and associated medical problems. Deyo et al. showed that surgery for spinal diseases, apart from herniated disc surgery, was associated with more complications and a greater use of resources, especially when performing arthrodesis, than was surgery for herniated disc [16]. They noted a complication rate of 18% in patients who were older than 75

Table 4

Distribution of postoperative sequelae. Patients not affected and portions showing 0% are not listed. Patients were divided into one-level (1) and multi-level (2+) fusion groups.

Sequelae	No. of Patients	Fusion Group	Age Group	%
Anemia	2	1	66-74	9.52
	2	2+	66-74	8.33
	2	2+	74-85	7.14
Atrial Fibrillation	1	1	33-56	3.12
	1	1	74-85	4.35
	2	2+	74-85	7.14
Attack of Gout	1	1	56-66	5
Cardiac Ischemia	2	2+	74-85	7.14
Enteritis	1	2+	66-74	4.17
Ileus/Preileus	1	1	74-85	4.35
Myocardial Infarction	1	1	56-66	5
	1	2+	74-85	3.57
Neurological Deficit	4	1	33-56	12.5
	3	1	56-66	15
	2	1	66-74	9.52
	4	1	74-85	17.39
	3	2+	56-66	12
	8	2+	66-74	33.33
	6	2+	74-85	21.43
Pneumonia	1	2+	56-66	4
	1	2+	74-85	3.57
Pulmonary Embolism	1	2+	74-85	3.57
Reflux Oesophagitis	1	2+	66-74	4.17
Subfebrile Temperature	5	1	33-56	15.62
	4	1	56-66	20
	2	1	66-74	9.52
	6	1	74-85	26.09
	3	2+	33-56	23.08
	10	2+	56-66	40
	9	2+	66-74	37.5
	6	2+	74-85	21.43
Fever	3	1	33-56	9.38
	3	1	66-74	14.29
	3	1	74-85	13.04
	2	2+	33-56	15.38
	2	2+	56-66	8
	3	2+	66-74	12.5
	2	2+	74-85	7.14
Transient Ischemic Attack	1	2+	74-85	3.57
Urinary Retention	1	1	74-85	4.35
Urinary Tract Infection	1	1	33-56	3.12
	2	1	56-66	10
	1	1	74-85	4.35
	2	2+	66-74	8.33
	1	2+	74-85	3.57

years. It is well-known that comorbidity is associated with higher complication rates during spinal surgery [17]. Comorbidity occurrence rates increase with age. Bydon et al. believe that age is not an independent risk factor which leads to complications [18]. In a sample of 1395 patients, patients younger than 65 years had a complication rate of 9.04%. The highest rates of comorbidity were found in the ≥ 65 to < 75 and ≥ 75 to < 85 age groups, which displayed complication rates of 13.46% and 16.17% respectively. Patients older than 85 years were found to have the lowest comorbidity and complication rates (4%). Bydon attributes this phenomenon to a healthier lifestyle and a lower burden of comorbidity in this age group. We did not find a difference in complication rates between the four age groups in our cohort. An additional factor to take note of when assessing what affects complications is the surgical approach to the spine. Spinal surgery from a posterior approach is associated with a higher risk of surgical site infection [19]. MIS procedures are believed to be less traumatic because they make use of a smaller corridor to the spine. Consequently, MIS procedures are associated with reduced blood loss, faster recovery and less perioperative morbidity, while still yielding similar results to those of open procedures [3,4]. Stevens showed that the intramuscular pressure, as well as the muscle edemas generated by minimally invasive

fusion techniques, were significantly lower than in standard open procedures [20]. The enzyme count, which is indicative of muscle damage, and the amount of inflammatory cytokines, are lower in patients who undergo mini-open fusion than in patients who undergo open procedures [21]. We observed no severe wound healing disorders and seven superficial wound healing disorders. One patient needed a secondary suture. There were no statistically significant differences between the groups. There were no statistically significant differences in the complication rate proportions for any of these perioperative incidents. Fourteen patients (7.89%) suffered from surgery-related complications in our cohort. Of these, eight (4.29%) had to be revised. We did not detect significant differences in surgery-related complication rates between the four age groups. The most frequent surgery-related complication was an incidental durotomy, which occurred in 22 patients (11.76%). When dealing with surgery of the degenerative spine, a link between ossified yellow ligaments and intraoperative dural tears is often witnessed [22]. The frequency of incidental durotomies in our cohort is consistent with the numbers described in the literature [23], and had no relationship with increasing age. In addition, there was no relationship between older age and the overall occurrence of perioperative complications. Nevertheless, a tendency of older patients to experience higher perioperative complication rates was noted in the multi-level ('two plus') fusion group. We split the 16 possible postoperative sequelae into major and minor complications according to Carreon's classification [9]. Carreon noticed at least one major complication in 21 out of 98 patients (21%) after posterior lumbar decompression and arthrodesis in older adults. In Wong's series of 513 patients, 1.4% of patients reported a thromboembolic event, 1.4% urinary retention, and 1.8% an ileus after minimally invasive transforaminal lumbar interbody fusion [24]. We observed 12 major complications (6.45%). Again, we saw no difference between the age groups. In our cohort, 30 patients (16.04%) reported neurological sensations, which is higher than in the literature (0.7%–9%). Nevertheless, only one patient (0.53%) presented a persisting neurological deficit, which is in line with the literature [24]. Furthermore, we saw no statistically significant difference between the four age groups, regardless of whether the patients were part of the single-level fusion or 'two plus' level fusion groups. Wang studied complication rates in a sample of 26 elderly patients 85 years and older who underwent surgery for degenerative lumbar spine [25]. His examination of complication-predicting factors showed that patient age, blood loss, Charlson Comorbidity Index, ASA class, the number of levels treated, and fusion surgery generally, were not statistically associated with the occurrence of complications. However, a surgery time of more than 180 min was associated with the occurrence of complications. In his cohort, the average length of surgery for patients who experienced a complication was 196.8 min versus 176.9 min in those who did not experience complications. The mean operation time in our patients was 149.66 min (range: 28–340 minutes), which is comparable to those reported in the literature [26,27]. In our group of patients who had one vertebral segment fused, age did not have an effect on the duration of surgery, whereas in the group of patients with two or more fused levels, the duration of surgery tended to increase slightly with age. Despite these observations, we were not able to see a statistically significant difference between the four age groups, in either the one-level or the 'two plus' level groups ($p = .32$ and $p = .55$). Phan et al. [15] showed that patients aged 70 years or older stayed in hospital for longer than younger age groups after undergoing adult deformity surgery. Lee et al. investigated peri- and postoperative complications in MIS single-level fusion in elderly adults [28]. Patients aged 65 years or older experienced longer stays in hospital and were more likely to be discharged to subacute nursing facilities or acute inpatient rehabilitation centers. This agrees with findings of a study by Murphy which investigated 8744 patients after lumbar decompression without fusion in a multicenter analysis [29]. He showed that a significantly higher percentage of patients older than 65 years experienced minor postoperative

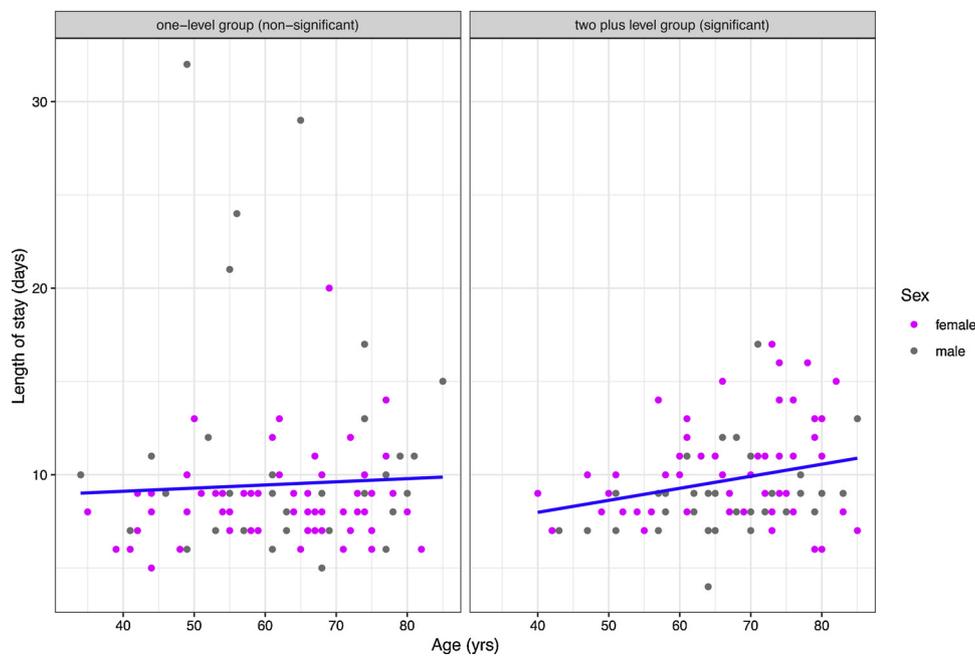


Fig. 3. There is a significant correlation between age and length of stay only in the multi-level ('two plus') group.

complications, required readmission within 30 days of surgery, had prolonged admissions and were discharged to a further facility, rather than sent home. In our study, a tendency towards longer hospital stays with increasing age was observed. Notably, the length of stay in hospital was significantly longer in the 'two plus' level group than in the one-level group.

Limitations: The present study – to our knowledge comprising one of the largest patient cohorts at a single center – has some limitations. The sample size for each of the four age groups was rather small (45 and 51 patients). Furthermore, the average age of patients who had one level fused was 61.76 years, whereas the average age of patients who had at least two levels fused was 66.79 years. The age distributions differed between the one-level fusion and 'two plus' fusion groups ($p = .01$). Therefore, we encourage more extensive studies. Parallel investigations which include other types of fusion surgery should be performed in the future.

5. Conclusion

The purpose of this study was to compare the early peri- and post-operative course in elderly patients undergoing MIS with that in younger patients. There is plenty of literature showing that clinical outcomes, as well as fusion rates, are similar in open fusion surgery and minimally invasive surgery [4,30]. Our results confirm that elderly patients may safely undergo MIS procedures of the spine, with little risk of developing major perioperative complications.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee – Ethikkommission Land Niederösterreich- and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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Conflict of interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Conflict of interest and source of funding

The authors report no conflicts of interest concerning the materials or methods used in this study or the findings specified in this paper.

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