ORIGINAL ARTICLE

Surgical management of lumbar spinal stenosis in patients over 80: is there an increased risk?

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Abstract

Management of lumbar spinal stenosis (LSS) represents the first cause of spinal surgery for the elderly and will increase with the aging population. Although the surgery improves quality of life, the procedure involves anaesthetic and operative risks. The aim of this study was to assess whether the postoperative complication rate was higher for elderly patients and to find confounding factors. We conducted a retrospective study including all LSS surgeries between 2012 and 2020 at the University Hospital of Caen. We compared two populations opposing patients aged over 80 with others. The primary endpoint was the occurrence of a severe complication (SC). Minor complications were the secondary endpoint. Comorbidities, history of lumbar spine surgery and surgical characteristics were recorded. Nine hundred ninety-six patients undergoing surgery for degenerative LSS were identified. Patients over 80 were significantly affected by additional comorbidities: hypertension, heart diseases, higher age-adjusted comorbidity Charlson score, ASA score and use of anticoagulants. Knee-chest position was preferred for younger patients. Older patients underwent a more extensive decompression and had more incidental durotomies. Of the patients, 5.2% presented SC. Age over 80 did not appear to be a significant risk factor for SC, but minor complications increased. Multivariate analysis showed that heart diseases, history of laminectomy, AA-CCI and accidental durotomies were independent risk factors for SC. Surgical management for lumbar spinal stenosis is not associated to a higher rate of severe complications for patients over 80 years of age. However, preoperative risk factors should be investigated to warn the elderly patients that the complication risk is increased although an optimal preparation is the way to avoid them.

Keywords Lumbar spinal stenosis · Complication · The elderly · Comorbidities

Introduction

Neurosurgical practice will naturally evolve with the demographic changes. Indeed, an aging population has been observed for several years in France. In 2020, the National Institute of Statistics and Economic Studies (INSEE) reported an increasing number of people aged over 65 years old: 15% in 2000 compared to 20% in 2020 [1]. This social trend is more pronounced in Normandy, a northwest region of France, where an increasing number of retirees live. By 2050, the INSEE forecasts an inflation for the seniors of 37% and of 127% for the over 80 s in Normandy [60], while the number of dependent persons will increase by 50% [61]. Consequently, geriatric pathologies will represent most of the neurosurgical activity.

Lumbar spinal stenosis (LSS) is defined by the North American Spine Society (NASS) as "the narrowing of the vacant space for the roots of the equina cauda and their vessels in the lumbar spine due to degenerative processes" [28]. Neurologic claudication in the legs exacerbated when walking and decreased when sitting is a typical symptom of LSS. This condition affects 8–23% of patients suffering from low back pain [21] and is the number one spinal surgery in the US for seniors [10]. In France, LSS accounted for 24,737 hospitalisations in 2019 and is a frequent cause of consultation [62]. The LSS remains a classic geriatric condition leading to dependency and weakness in the elderly [5, 35, 36].

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The surgery offers an advantage over nonsurgical management for selected individuals suffering from LSS and disabling symptoms [53]. The surgical technique is based on posterior decompression of the lumbar canal with a laminectomy and a bilateral foraminotomy with or without fusion.

However, the patient's age and comorbidities may impact the invasiveness of the surgery and affect the risk-benefice balance. Many studies have attempted to assess the potential increased risk for older patients, but their results were different [17, 33]. The aim of our study was to find out whether patients over 80 years have an increased risk of developing postoperative complications and to identify risk factors.

Material and methods

Inclusion and exclusion criteria

We conducted a single-centre retrospective study at the University Hospital of Caen in the neurosurgical unit.

All patients admitted for a planned surgery of LSS were included between 2012, when the computerisation of records started in our institution, and 2020. We used the surgical planning software to include patients according to precise surgical criteria.

Four surgical procedures were used:

– Open lumbar laminectomy with foraminotomy: the patient is placed in a knee-chest or prone position and the support points are checked. After a median incision, the posterior arch of the lumbar vertebrae is exposed by reclining the paravertebral muscles. We then performed central decompression by removing the spinous process and the laminae bilaterally to expose the spinal canal. Then, we perform root decompression on both sides by removing the medial part of the articular process and the isthmus. The root is exposed and then followed in its canal. It is checked that all roots are decompressed. Careful haemostasis and thorough washing of the operative cavity are then performed. A suction drain is used most of the time and closure is done plane by plane.
– Segmental arthrodesis not exceeding one level: the patient is often positioned prone to maintain the lordosis. Using the same approach as the laminectomy, pedicle screws are typically placed in open technique without neuronavigation and controlled by intraoperative radiography.
– Minimally invasive decompression and interspinous device: the patient is usually in a knee-chest position to decrease the lordosis. We remove only the interspinous ligament and perform a foraminotomy under the microscope. We then place an interspinous device fixed to

adjacent spinous processes to decrease the lordosis and perform an indirect decompression.
– Unilateral foraminotomy: with a midline incision, we expose the posterior arch on one side. We resect the upper part of the inferior lamina and the flavum ligament under the microscope and then follow the root into its canal to decompress it. Closure is classically done without drain placement.

It was decided to exclude from this analysis other surgical procedures such as scoliosis correction, interbody fusion and posterolateral arthrodesis affected at least two-level. The study obtained the consent of the ethics committee of the French College of Neurosurgery (showed in Appendix).

Two groups were formed: the over 80 s versus the under 80 s. Eighty was the chosen limit, that of the 4th age [1] where the risk of postoperative complications is theoretically higher.

Outcomes

The primary outcome was the occurrence of severe complications within the 30 days following the surgery.

A severe complication was defined as death, intensive care unit hospitalisation, reoperation and severe organ failure. The secondary outcome was the occurrence of minor complications, including sepsis, thrombosis without pulmonary emboly (PE), transfusions, urinary retention, or abdominal occlusion and rehospitalisations within the 30 days after discharge.

Variables

We retrospectively recorded patient characteristics from the medical records. We reported:

– Demographic data: age, sex
– Body mass index (BMI)
– Comorbidities described during the pre-anaesthetic consultation: diabetes mellitus, high blood pressure, heart diseases (valvulopathy, arrhythmia, myocardial infarction or angina pectoris, hypertrophic heart disease, heart transplantation and congestive heart failure), breathing disorders (chronic obstructive pulmonary disease, severe asthma, severe sleep apnea) and chronic kidney disease
– Medication: anticoagulants and platelet antiaggregants
– ASA score and age-adjusted Charlson Comorbidity Index (CCI) [7]. The CCI is widely used in the spine literature to evaluate postoperative risk in relation to comorbidities [47].
– Medical history of lumbar spinal surgery
– Presence of scoliosis or degenerative spondylolisthesis (DS)

– Surgical procedures: position, length of the surgery, number of decompressed levels, technique, use of a drain in the surgical site and incidental durotomy.

Statistical analysis

The baseline characteristics were described by the mean (std) or the median (IQR) for quantitative variables according to their distribution and by the number (frequency) for qualitative variables. The two groups were independent. The comparisons of these variables between the age groups were performed using the Student's *t*-test or the Mann–Whitney test for quantitative variables giving to their normal distribution or not. We performed the chi^2 test or the Fisher exact test for qualitative variables. To identify potential risk factors of severe complications up to 30 days, univariate analyses were performed using logistic regression. All significant variables associated with serious complications on univariate analysis ($p < 0.05$) were considered for inclusion in the multivariate logistic regression analysis. We explored collinearity among these potential risk factors by calculating the variance inflation factor (VIF), with a value above 5 indicating collinearity. We followed a backward procedure among qualified variables for selecting independent risk factors associated with severe complications, with the threshold of $p < 0.10$ to stay in the model. Only our variable of interest, the age group, was included in every model. The minor complications and the length of hospitalisation were compared between the age groups using the chi^2 test and the Mann–Whitney test, respectively.

A sensitivity analysis was performed using the propensity score matching method to take into account the potential channelling bias on the endpoints after the inclusion. We modelled the probability of being ≥ 80 years old implementing a nonparsimonious logistic regression including the following variables: sex, BMI, diabetes, high blood pressure, heart diseases, anticoagulants, platelet antiaggregants, breathing disorders, chronic kidney diseases, Charlson Comorbidity Index, ASA score, history of lumbar surgery, herniated disc, spondylolisthesis, scoliosis, operative position, time, number of operating levels, L4L5, L3L4, L2L3, L1L2, laminectomy, foraminotomy, arthrodesis, interspinous spacer, durotomies, sutured, patch of fat to overcome the gap, organic glue, setting up a drain in suction (odds ratios with 95% Wald confidence limits). We performed a one-to-one procedure (macro ONETOMANY) to match age groups based on their propensity score. Next, we analysed this paired population adopting the generalized linear model with the binomial distribution. Baseline characteristics were compared between groups before and after the matching procedure exploiting the standardized average differences.

All analyses were conducted in the thorough case analysis. A *p*-value less than 0.05 was considered significant; all *p* values were two-tailed. Statistical analysis was performed with SAS software V9.4 (SAS Institute, NC, Cary) and R software, version 4.0.5 (the R Foundation for Statistical Computing).

Results

Cohort

From 2012 to 2020, we included 1409 surgical procedures for lumbar spine stenosis in the neurosurgical unit of the University Hospital of Caen and 413 patients were excluded (Fig. 1). The mean age for the whole cohort was 71.2 years (± 9.9). The over 80 s represented 20.4% of patients. The youngest patient was 38 years old and the oldest was 99. Considering the sex ratio, 53.2% of the patients were women. The oldest age group contained significantly more women (61% vs 51% *p* = 0.019, Table 1).

Comorbidities (Table 1)

The mean BMI was 28.4 kg/m^2 (± 5.12) and the elderly had on average a significantly lower BMI (27.2 kg/m^2 vs 28.7 kg/m^2, *p* < 0.001). High blood pressure was the main comorbidity for 60% of the patients and the elderly were more affected. Patients over 80 years of age presented significantly more heart diseases and use of anticoagulants. Age-adjusted CCI and ASA score were higher for these patients. The rate of diabetes was 17.8% and this disease mainly affected the youngest patients, but no statistical difference was found as for breathing disorders and CKD.

Surgical characteristics (Table 2)

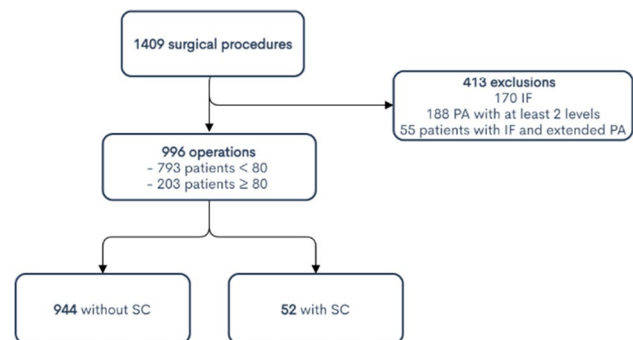A history of lumbar spinal surgery was present in 13.8% of cases with no difference between the two classes

Fig. 1 Flowchart. IF, interbody fusion; PA, posterolateral arthrodesis

Table 1 Comorbidities

Comorbidities	< 80 (n = 793)	≥ 80 (n = 203)	p
BMI (kg/m^2), mean ± SD	28.7 ± 5.1	27.2 ± 5.0	**< 0.001**
Female, n (%)	407 (51)	123 (61)	**0.019**
Diabetes, n (%)	146 (18)	31 (15)	0.310
High blood pressure, n (%)	446 (56)	141 (69)	**< 0.001**
Heart disease, n (%)	179 (23)	78 (39)	**< 0.001**
Anticoagulant, n (%)	50 (6)	33 (16)	**< 0.001**
Platelet Antiaggregant, n (%)	227 (29)	68 (34)	0.169
Breathing disorder, n (%)	104 (13)	19 (9)	0.147
CKD, n (%)	29 (4)	10 (5)	0.408
Age-adjusted Charlson Comorbidity Index, median (IQR)	3 (2–4)	4 (4–5)	**< 0.001**
ASA score, median (IQR)	2 (2–3)	3 (2–3)	**< 0.001**

BMI body mass index; *CKD* chronic kidney disease; *IQR* interquartile range; *SD* standard deviation

p-value obtained by chi^2 or Fischer's exact test for qualitative variables, and by Student's *t* test or Mann-Withney test if the distribution does not follow a normal distribution, for quantitative variables, *p-value* is significant in boldface

studied. Regarding the morphology of the lumbar spine, 23.2% of the patients were affected by a degenerative spondylolisthesis DS and 9.7% by a degenerative scoliosis in the entire cohort. The rate of scoliosis was higher in the elderly whereas the rate of DS was equivalent.

In most cases (72%), patients were positioned in knee-chest. This position was more used in younger patients and the prone position was predominant in the elderly (43% vs 24%, *p* < 0.001). Of the patients, 63.5% underwent laminectomy with bilateral foraminotomy without fusion as a decompression technique. This technique was more commonly realized in older patients (81% vs 59%, *p* < 0.001). The most decompressed level was L4L5. The number of decompressed levels was higher in the elderly group (*p* < 0.001). We found a statistical difference for the levels L4L5, L3L4, L2L3 and L1L2, which were more decompressed in the elderly group. Posterolateral arthrodesis was performed in 22.2% of cases, mainly in young subjects (24% vs 16%, *p* = 0.02) as the use of interspinous devices (11% vs 1%, *p* < 0.001). Regarding the duration of surgery, it was similar between the two groups. The rate of durotomies was higher in the elderly group. We found a rate of 17.3% in the entire cohort. Durotomies were treated with sutures in 53.2% of leakages, 60.7% with fat graft and 70.5% with biologic glue. In most cases, surgeons used drains (93.8%). Finally, the average LOS was 5.8 days, and the elderly patients had a longer LOS showed by the median LOS (6 days vs 5 days, *p* < 0.001; Table 3).

Table 2 Comparison of surgical characteristics

Surgical characteristics	< 80 (n = 793)	≥ 80 (n = 203)	p
History of lumbar spinal surgery	114 (14)	23 (11)	0.256
Disc herniation, n (%)	61 (8)	9 (4)	0.106
Laminectomy, n (%)	34 (4)	8 (4)	0.827
Interepinous spacer, n (%)	10 (1)	0 (0)	0.228
Arthrodesis, n (%)	21 (3)	7 (3)	0.524
Foraminotomy, n (%)	2 (0.3)	0 (0.0)	1.000
Radiological characteristics			
Spondyloisthesis, n (%)	178 (22)	53 (26)	0.270
Scoliosis, n (%)	70 (9)	27 (13)	0.056
Position, n (%)			
Ventral (0)	188 (24)	86 (43)	**< 0.001**
Knee-chest (1)	601 (76)	116 (57)	
Length (min), median (IQR)	82 (63–107)	84 (70–113)	0.071
Level			
Number, median (IQR)	1 (1–2)	2 (1–2)	**< 0.001**
L5S1, n (%)	40 (5)	11 (5)	0.832
L4L5, n (%)	615 (78)	174 (86)	**0.011**
L3L4, n (%)	424 (53)	135 (67)	**< 0.001**
L2L3, n (%)	115 (15)	41 (20)	**0.048**
L1L2, n (%)	8 (1)	7 (3)	**0.020**
Procedure			
Laminectomy, n (%)	467 (59)	165 (81)	**< 0.001**
Discectomy, n (%)	22 (3)	4 (2)	0.630
Foraminotomy, n (%)	32 (4)	4 (2)	0.207
Arthrodesis, n (%)	189 (24)	33 (16)	**0.020**
Interspinous spacer, n (%)	91 (11)	2 (1)	**< 0.001**
Durotomy	125 (16)	48 (24)	**0.008**
Sutured, n (%)	67 (8)	25 (13)	0.079
Fat graft, n (%)	79 (10)	26 (13)	0.223
Biologic glue, n (%)	91 (12)	31 (15)	0.131
Use of drain	737 (94)	192 (96)	0.207
Drain in suction, n (%)	631 (80)	152 (76)	0.156

p-value obtained by chi^2 or Fischer's exact test for qualitative variables and by Student's *t* test, or Mann-Withney test if the distribution does not follow a normal distribution, for quantitative variables

Complications between the two groups (Table 3)

In our study, 52 severe complications were reported representing 5.2% of cases. Two patients aged 77 and 79 years old died within 30 days after surgery. Three cases were admitted to ICU. Regarding the surgical procedure, 3.6% of patients underwent revision, and the main cause was a postoperative epidural hematoma. Among the 222 patients who had a segmental fusion, 3.6% had revisions for symptomatic pedicle screw malposition. Removal of drains was impossible for the nurses and required revision for two patients.

Table 3 Comparison of complications

Outcomes	All (n = 996)	< 80ans (n = 793)	≥ 80 ans (n = 203)	p
Severe complications, n (%)	52 (5.2)	38 (4.8)	14 (6.9)	0.229
Death	2 (0.2)	2 (0.3)	0 (0.0)	
ICU admission	3 (0.3)	2 (0.3)	1 (0.5)	
Revision surgery	36 (3.6)	29 (3.7)	7 (3.5)	
Malposition of screws	8 (0.8)	7 (0.9)	1 (0.5)	
Wound infection	10 (1.0)	9 (1.1)	1 (0.5)	
Epidural hematoma	17 (1.7)	12 (1.5)	5 (2.5)	
Trapped drain	2 (0.2)	0 (0)	2(0.1)	
CSF leakage (sutured, fat graft, biologic glue)	6 (0.6)	6 (0.8)	0 (0.0)	
Severe medical complications	14 (1.4)	7 (0.9)	7 (3.5)	
Minor complications, n (%)	80 (8.0)	51 (6.4)	29 (14.3)	**< 0.001**
Phlebitis	3 (0.3)	0 (0.0)	3 (1.5)	
Sepsis	30 (3.0)	23 (2.9)	7 (3.5)	
Abdominal occlusion and urine retention	25 (2.5)	13 (1.6)	12 (5.9)	
Transfusion	9 (0.9)	4 (0.5)	5 (2.5)	
CSF leakage without surgery	3 (0.3)	3 (0.4)	0 (0.0)	
Fracture	2 (0.2)	2 (0.3)	0 (0.0)	
Confusion	2 (0.2)	1 (0.1)	1 (0.5)	
Readmission	26 (2.6)	22 (2.8)	4 (2.0)	
Length of stay (days), median (IQR)	5 (4–7)	5 (4–6)	6 (4–9)	**< 0.001**

ICU intensive care unit; *CSF* cerebrospinal fluid

p-value obtained by chi^2 or Fischer's exact test for qualitative variables and by Student's *t* test, or Mann-Withney test if the distribution does not follow a normal distribution, for quantitative variables, *p-value* is significant in boldface

Regarding the medical management, 14 patients suffered from severe medical complications. We described two anaphylactic shocks, one severe pneumopathy with death, three hypovolemic shocks, two myocardial infarctions, one pulmonary embolism, one congestive heart failure, one acute respiratory failure due to COVID infection, one acute ischemic stroke with aphasia, one acute tubular necrosis and one cerebellar haemorrhage. Regarding minor events, 8% of patients had minor complications after surgery: sepsis was the main complication for 3% of cases. Of the patients, 0.9% had a transfusion in postoperative period. 2.6% of patients were readmitted within 30 days of surgery.

Risk factors of complications

Among the 996 selected patients, 135 patients (Table 4) from each group were matched to assess the impact of age without confounding factors. An age over 80 did not appear to be a risk factor for SC because the difference between the two classes was not significant in the multivariate analysis and with propensity score matching (Table 5). However, age was identified as a risk factor in the univariate analysis (Table 6). In addition, the rate of minor complications increased for the elderly: we noted more phlebitis, sepsis, abdominal obstructions and urinary retentions and transfusions.

The length of stay was extended for the elderly, but the rate of readmissions was relatively similar between the two groups.

Regarding gender differences, we described that women had more complications, but we did not find any statistical difference. Concerning the comorbidities, the presence of heart disease, breathing disorders and platelet antiaggregants increased the risk of developing a SC. Anticoagulants and CKD did not appear to be risk factors. A higher ASA score and an age-adjusted CCI were strongly associated with the development of SC. Even though these scores were higher in older patients, the age-adjusted CCI was an independent risk factor of the postoperative complication with a *p*-value significant in the multivariate analysis.

Scoliosis and a history of laminectomy were associated with increased postoperative complications.

For the surgical features, the knee-chest position and a quick procedure seemed to decrease the risk of SC. We did not find any difference in SC related to the surgical procedure. The intraoperative durotomy was a high-risk factor for SC with a *p*-value of 0.002. At the opposite, the use of drains in suction prevented the occurrence of severe complications.

Table 4 Matching with propensity score

Baseline characteristics	Unmatched			Matched		
	< 80 (*n* = 793)	≥ 80 (*n* = 203)	SMD	< 80 (*n* = 135)	≥ 80 (*n* = 135)	SMD
Female, *n* (%)	407 (51)	123 (61)	**0.19**	86 (64)	82 (61)	0.06
BMI (kg/m²), moy ± ET	28.7 ± 5.1	27.2 ± 5.0	**0.31**	27.3 ± 4.4	27.7 ± 5.3	0.08
Comorbidity						
Diabetes, *n* (%)	146 (18)	31 (15)	0.08	23 (17)	23 (17)	0.00
High blood pressure, *n* (%)	446 (56)	141 (69)	**0.27**	98 (73)	94 (70)	0.07
Heart diseases, *n* (%)	179 (23)	78 (39)	**0.35**	44 (33)	50 (37)	0.09
Anticoagulants, *n* (%)	50 (6)	33 (16)	**0.32**	16 (12)	19 (14)	0.07
Platelet antiaggregant, *n* (%)	227 (29)	68 (34)	**0.11**	46 (34)	45 (33)	0.02
Breathing disorders, *n* (%)	104 (13)	19 (9)	**0.12**	9 (7)	11 (8)	0.06
Chronic kidney disease, *n* (%)	29 (4)	10 (5)	0.06	7 (5)	8 (6)	0.03
Age-adjusted Charlson score, median (IQR)	3 (2–4)	4 (4–5)	**1.12**	4 (3–5)	4 (4–5)	0.09
ASA score, median (IQR)	2 (2–3)	3 (2–3)	**0.42**	3 (2–3)	3 (2–3)	0.04
History of lumbar spine surgery	114 (14)	23 (11)	0.09	15 (11)	15 (11)	0.00
Disc herniation, *n* (%)	61 (8)	9 (4)	**0.14**	5 (4)	7 (5)	0.07
Morphology of the spine						
Spondyloisthesis, *n* (%)	178 (22)	53 (26)	0.09	30 (22)	36 (27)	**0.10**
Scoliosis, *n* (%)	70 (9)	27 (13)	**0.14**	19 (14)	18 (13)	0.02
Surgery						
Position, *n* (%)						
Prone (0)	188 (24)	86 (43)	**0.41**	49 (36)	47 (35)	0.03
Genu pectoral (1)	601 (76)	116 (57)		86 (64)	77 (65)	
Time (minutes), median (IQR)	82 (63–107)	84 (70–113)	**0.14**	87 (72–106)	84 (70–113)	0.08
Levels						
Number, median (IQR)	1 (1–2)	2 (1–2)	**0.40**	2 (1–2)	2 (1–2)	0.04
L4L5, *n* (%)	615 (78)	174 (86)	**0.21**	114 (84)	114 (84)	0.00
L3L4, *n* (%)	424 (53)	135 (67)	**0.28**	82 (61)	83 (61)	0.02
L2L3, *n* (%)	115 (15)	41 (20)	**0.15**	31 (23)	26 (19)	0.09
L1L2, *n* (%)	8 (1)	7 (3)	**0.17**	4 (3)	4 (3)	0.00
Procedure						
Laminectomy, *n* (%)	467 (59)	165 (81)	**0.50**	105 (78)	105 (78)	0.00
Foraminotomy, *n* (%)	32 (4)	4 (2)	**0.12**	3 (2)	3 (2)	0.00
Arthrodesis, *n* (%)	189 (24)	33 (16)	**0.19**	27 (20)	26 (19)	0.02
Interspinous device, *n* (%)	91 (11)	2 (1)	**0.45**	3 (2)	1 (1)	**0.12**
CSF leakage	125 (16)	48 (24)	**0.20**	27 (20)	30 (22)	0.05
Sutured, *n* (%)	67 (8)	25 (13)	**0.13**	16 (12)	16 (12)	0.00
Fat graft, *n* (%)	79 (10)	26 (13)	0.09	18 (13)	17 (13)	0.02
Biologic glue, *n* (%)	91 (12)	31 (15)	**0.12**	21 (16)	19 (14)	0.04
Drain	737 (94)	192 (96)	**0.11**	129 (96)	130 (97)	0.08
In aspiration, *n* (%)	631 (80)	152 (76)	**0.11**	105 (78)	106 (79)	0.02
Propensity score, mean ± SD	0.12 ± 0.17	0.49 ± 0.26	**1.67**	0.39 ± 0.22	0.39 ± 0.22	0.02

[*]*p*-value obtained by chi² or Fischer's exact test for qualitative variables and by Student's *t* test, or Mann-Withney test if the distribution does not follow a normal distribution, for quantitative variables, *p-value* is significant in boldface

Table 5 Relationship between two groups and severe complications

Risk factor for major complications	Univariate model			Multivariate model (n = 978)			Propensity score matching (n = 270)		
	OR	**95% IC**	***p*** *	**OR**	**95% IC**	***p*** **	**OR**	**95% IC**	***p*** ***
Age class									
< 80	1			1			1		
≥ 80	1.47	[0.78–2.77]	0.232	0.82	[0.40–1.66]	0.573	1.15	[0.39–3.37]	0.797

* *p*-value obtained by univariate logistic regression

** *p*-value obtained by multivariate logistic regression with stepwise downward selection and holding condition in the model fixed at 0.10 except for the variable of interest (age class) which was fixed in the model

*** *p*-value obtained by generalized linear model with a binomial distribution and taking into account the matching

Discussion

Main results

In this study, we demonstrated that patients over 80 years of age were not at greater risk of developing a severe postoperative complication after surgery of lumbar spinal stenosis. Older patients had more comorbidities and the surgical procedure was different for this category. These parameters influenced the occurrence of a severe postoperative complication.

Complications in elderly patients

We found a 6.9% risk of SC within 30 days following LSS surgery for patients over 80 years of age. For patients over 80 s who undergone LSS surgery, the complication rate is variable in the literature, according to the definition of a SC. Saleh et al. [44] did a retrospective study in the USA based on national data with 2320 patients over 80 years of age. They found a lower risk of severe complications of 3.23%. However, they did not include revisions as severe complications. Their SC corresponded to our severe medical complications with a similar rate: 3.5%. Contrary to this study, we believe that a surgery revision should be considered as a severe complication. Another French study by Balabaud et al. [2] showed a 13% rate of SC: they counted a higher epidural hematomas and wound infections rate of 3.3% and 4% (against 2.5% and 0.5% respectively for us). Their definition of severe medical complications was larger including new-onset cardiac arrhythmia and SIADH. Wang et al. [52] made a similar study with 26 patients over 85 years. Their complication rate was higher: 7.6% of SC. These observations continue to raise the question of the relationship between age and complications.

In our study, we showed that the risk of SC was not increased after surgical management of LSS in patients older than 80. To compare, Giannadakis et al. [17] using the same design showed that the age over 80 was not associated with increased complications. Murphy et al. [33] made the same observation in a US national cohort of 8744 patients divided into four classes: < 65, 65–75, 75–85, > 85YO. They showed an increased complication rate for patients over 65 years of age. Dividing the cohort into several classes was interesting; nevertheless, 58% of patients were under 65 years while the LSS mainly involved older people. Thus, our main question was to know whether in a group of seniors, the oldest patients were more likely to have complications. We also included patients under 65, but they represented only 25%. Li et al. [30] published in 2008 the largest study on this topic with 471,215 patients. They found a direct association between the occurrence of complications and an age above 65. More interestingly, they showed an excess risk for people over 85 to develop a complication after a decompression of the lumbar spine.

Regarding complications in our cohort, the death rate was 0.2%, but no patient died in the older group. Studies with young patients like the studies of Li et al. [30] and Murphy [33] found a similar death rate. Studies including only elderly patients found a higher number: Gerhardt et al. [14] reached a death rate of 0.8% while Saleh [44] found a rate of 0.4%. Concerning admission to ICU, Kay et al. [23] reported a 5.1% rate after lumbar spinal surgery, more than ours: 0.3%. However, they included more extensive procedures: the rates of fusions and length of surgery were higher. In their study, female gender, ASA grade, cardiac comorbidities, age, length of surgery and blood loss were identified as risk factors for ICU admissions.

For unplanned readmissions, 2.6% of patients returned to the neurosurgical unit in our cohort. This rate is low compared to the literature: 6.39% for Saleh et al. [44] with patients over 80 and 4.4% found in the Kim et al. study [63]. This last study showed that a high ASA score, venous thromboembolic events, re-operations in the first stay and postoperative complications were risk factors. In our cohort, the rate of readmissions was similar between the older and younger groups. Murphy et al. [33] found a higher readmission rate in older people compared to those under 65, but they did not show evidence of an increased risk after 85 years old.

Table 6 Risk factor of severe complications

Baseline characteristics	n	Severe complication within 30 days	No complications within 30 days	Univariate analysis			Multivariate analysis		
				OR	95% IC	p*	OR	95% IC	p**
Age, mean ± SD	996	73.9 ± 7.1	71.0 ± 10.0	1.03	[1.00–1.07]	**0.043**			
Age class, n (%)									
< 80	996	38 (73)	752 (80)	1			1		
≥ 80		14 (27)	189 (20)	1.47	[0.78–2.77]	0.232	0.82	[0.40–1.66]	0.573
Female, n (%)	996	30 (58)	500 (53)	1.21	[0.69–2.13]	0.507			
BMI (kg/m²), mean ± SD	957	28.9 ± 4.7	28.4 ± 5.1	1.02	[0.96–1.08]	0.487			
Comorbidities									
Diabetes, n (%)	995	12 (23)	165 (18)	1.41	[0.73–2.76]	0.308			
High blood pressure, n (%)	993	36 (69)	550 (58)	1.60	[0.87–2.92]	0.127			
Heart diseases, n (%)	995	24 (46)	233 (25)	2.61	[1.48–4.60]	**< 0.001**	2.02	1.07–3.81]	**0.031**
Anticoagulant, n (%)	994	5 (10)	78 (8)	1.18	[0.46–3.05]	0.735			
Platelet antiaggregant, n (%)	993	24 (46)	271 (29)	2.12	[1.21–3.72]	**0.009**	-	-	-
Breathing disorder, n (%)	996	11 (21)	112 (12)	1.99	[1.00–3.99]	0.052	-	-	-
Chronic kidney disease, n (%)	995	1 (2)	38 (4)	0.47	[0.06–3.47]	0.457			
Age-adjusted Charlson Comorbidity Index, median (IQR)	996	4 (3–5)	3 (2–4)	1.31	[1.12–1.53]	**< 0.001**	1.23	[1.02–1.49]	[1.02–1.49]
Score ASA, median (IQR)	974	3 (2–3)	2 (2–3)	1.96	[1.21–3.15]	**0.006**			
History of lumbar spinal surgery	994	11 (21)	126 (13)	1.74	[0.87–3.47]	0.118			
Disc herniation, n (%)	996	5 (10)	65 (7)	1.44	[0.55–3.74]	0.456			
Laminectomy, n (%)	996	6 (12)	36 (4)	3.29	[1.32–8.20]	**0.011**	2.62	[1.00–6.86]	**0.050**
Interspinous device, n (%)	996	0 (0)	10 (1)	*Not applicable*					
Arthrodesis, n (%)	994	2 (4)	26 (3)	1.41	[0.33–6.11]	0.647			
Foraminotomy, n (%)	996	0 (0)	2 (< 1)	*Not applicable*					
Morphology of the spine									
Spondylolisthesis, n (%)	996	12 (23)	219 (23)	0.99	[0.51–1.93]	0.984			
Scoliosis, n (%)	996	9 (17)	88 (9)	2.04	[0.96–4.32]	0.064			
Surgery									
Position opératoire, n(%)									
Prone (0)	995	20 (39)	254 (27)	1					
Knee-chest (1)		31 (61)	686 (73)	0.57	[0.32–1.03]	0.061			
Duration (minutes), mean ± SD		96.0 ± 39.3	88.6 ± 35.3	1.01	[1.00–1.01]	0.159			
Level									
Number, median (IQR)	994	1 (1–2)	1 (1–2)	1.12	[0.75–1.66]	0.591			
L5S1, n (%)	995	0 (0)	51 (5)	*Not applicable*					
L4L5, n (%)	996	38 (73)	751 (80)	0.70	0.37–1.31]	0.265			
L3L4, n (%)	995	30 (58)	529 (56)	1.07	0.61–1.88]	0.822			
L2L3, n (%)	995	16 (31)	140 (15)	2.55	1.38–4.72]	**0.003**	2.31	[1.22–4.39]	**0.011**
L1L2, n (%)	995	3 (6)	12 (1)	4.75	1.30–17.38]	**0.019**	-	-	-
Procedure									
Laminectomy, n (%)	991	35 (69)	597 (64)	1.26	[0.69–2.30]	0.460			
Discectomy, n (%)	994	2 (4)	24 (3)	1.53	[0.35–6.66]	0.571			
Foraminotomy, n (%)	995	0 (0)	36 (4)	*Not applicable*					
Arthrodesis, n (%)	994	14 (27)	208 (22)	1.30	[0.69–2.45]	0.416			
Interspinous device, n (%)	994	2 (4)	91 (10)	0.38	[0.09–1.60]	0.188			
Durotomy	989	18 (35)	155 (17)	2.67	[1.47–4.85]	**0.002**	2.81	[1.51–5.23]	**0.002**
Sutured, n (%)	987	9 (17)	83 (9)	2.15	[1.01–4.56]	**0.047**			
Fat graft, n (%)	988	15 (29)	90 (10)	3.81	[2.01–7.21]	**< 0.001**			
Biologic glue, n (%)	987	12 (23)	110 (12)	2.25	[1.15–4.42]	**0.019**			
Drains	987	48 (92)	881 (94)	0.73	[0.26–2.11]	0.568			
In aspiration, n (%)	988	31 (60)	752 (80)	0.36	[0.20–0.64]	**< 0.001**			

BMI body mass index; *CCI* Charlson Comorbidity Index, *p-value obtained by univariate logistic regression, **p-value obtained by multivariate logistic regression with stepwise downward selection and holding condition in the model fixed at 0.10 except for the variable of interest (age class) which was fixed in the model, *p-value* is significant in boldface

Concerning the LOS, older patients stayed longer in the hospital as reported in the literature [17, 33]. Our median length of stay (5 days for the youngest and 6 days for the oldest) could be improved with the introduction of the enhanced recovery after surgery: currently, 4 days in the hospital for the surgical management of LSS is our daily goal regardless of the age class.

Management of comorbidities

Beyond age, it seems that the postoperative outcome is related to several other factors. To start with the patient's comorbidities: we noticed that patients over 80 had higher CCI and ASA score meaning more comorbidities. To compare with the literature, the studies of Giannadakis [17] and Nanjo [34] found almost the same result (p-value at 0.09 and 0.07 respectively). In the study of Murphy et al. [33], they showed an association between the increasing comorbidities and the aging expected for high blood pressure. In our cohort, the elderly were significantly more affected by hypertension, the most frequent affection with 69% of cases. In France, hypertension is the leading cardiovascular risk factor. It increases with age and affects more than two-thirds of the population aged 65 to 75 years of age [64], consistent with our observations.

In our study, the risk of postoperative SC was independently related to heart diseases and to the use of antiaggregants. The management of anticoagulants and platelet antiaggregants must be a compromise between the risk of intraoperative blood loss or epidural hematoma and the risk of arterial thrombosis. Soleman et al. [48] compared the impact of aspirin in 102 patients on the postoperative complications after LSS or herniated disc surgery. They showed no significant difference between the groups. However, they found higher blood loss, lower postoperative haemoglobin and more transfusions in the aspirin group. Compared with other studies, the rate of epidural hematoma varies between 0 and 1% [18]. Park et al. [38] made a large retrospective study of 17,549 patients who had undergone spinal decompression. They found a 1.15% rate of postoperative epidural hematoma. Risk factors were a high blood loss greater than 500 ml, a surgical duration greater than 2 h and hypertension. The use of anticoagulants increases the risk, but the result was near significant. Anticoagulants were not considered as a risk factor of SC in our study. Our rate of thromboembolic events was similar to the literature: 0.2% for Giannadakis [17], 0.5% for Murphy [33], 0.4% for Li [30]. In our study, the four patients concerned belonged to the elderly group. We did not perform a subgroup analysis for this risk factor although it appears that age may be a risk factor of thromboembolic events. This observation can be supported by Yoshioka's prospective study about thromboembolic

events after degenerative spine surgery, which showed that advanced age was a risk factor [55].

Other comorbidities did not play a major role in the occurrence of SC. Regarding diabetes, this condition was slightly increased in patients with SC. A large study based on data from the Korean National Health Insurance Service showed that after surgery for LSS, the mortality rate was multiplied by 1.35 for diabetes patients [29]. The criteria of inclusion in the Korean study are less restricted than ours: no exclusion for extensive surgical procedures. Furthermore, the result was significant in univariate analysis, but diabetic patients had more heart disease and chronic kidney disease which could impact the rate of severe complications. CKD did not appear as a risk factor for severe complications. To talk to diabetes again, its management must involve the anaesthesiologist. The SFAR recommends looking for its complications, evaluating its control and following the prescription of antidiabetic drugs [58]. The major risk of unbalanced diabetes is the surgical site infection [54].

Concerning the BMI for the elderly, the standards are different from those for the youth. We talk about undernutrition for patients whose BMI is under 21 and obesity when BMI is over 30. Undernutrition is a known risk for spinal infections and can multiplicate the risk by 2.3 [51]. Like in the study of Giannadakis et al. [17], the BMI was significantly lower for the elderly in our cohort, but no link with SC was noticed. A recent Chinese study made by Kong et al. [27] evaluated the impact of BMI on lumbar arthrodesis for elderly patients: they found that low BMI under 24 kg/m^2 increased the complication rates. The preoperative nutritional evaluation is a way to minimize these risks. This topic is included in our current protocol "enhanced recovery after surgery" and was described in the literature [9]. Patients are assessed by dieticians and receive nutrition therapy if necessary. The rate of serum albumin level was described in the literature to detect undernutrition: low albumin is associated with an increased risk of readmissions, mortality, length of stay and mortality [11, 65]. This data was not available. As the undernutrition, obesity also presented risks. Giannadakis et al. [16] found that obesity increases the duration of the surgery. In addition to being a risk factor for LSS [26], it rises postoperative complications in spine surgery [4] especially for spinal infections. Besides obesity, other risk factors for wound infections have been described in the literature: blood loss, reoperation, diabetes, duration of the surgery and length of stay at hospital [57]. Age over 80 was not found to be a risk factor of wound infection in our study.

Regarding breathing disorders, no difference was observed between the two groups. These diseases appeared as a risk factor for complications with a p-value close to 0.05. Our broad definition of breathing disorders would allow us to detect a possible risk factor that was not described in the literature. To go on, this study did not evaluate the impact

of smoking on SC. Giannadakis et al. [17] found that the proportion of smokers was lower in the older group, but they did not find an increased risk of complications in LSS surgery. Smoking is known to be a risk factor for surgical site infections [20]. It is a target of our enhanced recovery after surgery program, as described in the literature [9].

Performing the least morbid surgery

We have shown in our study that surgical procedures have an impact on the risk of SC. This highlights the issue of the invasiveness of the surgery. We need to propose the least risky surgery with the best benefit-risk ratio. This starts with the selection of the best operative position. In our cohort, the knee-chest position was the most used position for the management of LSS. Some compression complications, unfound in our cohort, have been described in the literature, such as blindness due to eyeball support, limb paralysis and shoulder dislocation [46]. Elderly patients were less likely to be positioned in knee-chest for hemodynamic reasons. The knee-chest position decreases the cardiac ejection fraction due to lack of venous return. It theoretically affects the elderly, who are more likely to suffer from heart disease. This position can lead to hypotension during surgery, which can cause strokes and acute renal failures [6]. However, this position is interesting for the surgeon: this hypotension reduces epidural blood loss during laminectomy and facilitates decompression by reducing the lordosis [43] leading to faster surgical procedures. In our cohort, the knee-chest position seemed to have a protective effect on the occurrence of serious postoperative complications. This is the first study that shows the positive impact of knee-chest position concerning the risk of complications and no comparative data on this subject was available in the literature. This position should be included in our ERAS protocol to decrease the risk of postoperative complications. Of course, the chosen position may vary according to the surgery and the surgeon: the placement of an interspinous device is generally performed in the knee-chest position to decrease the lordosis, whereas arthrodesis is performed in the supine position to maintain this lordosis. These data must therefore be confirmed by other studies.

Secondly, regarding durotomy, its rate varies in the literature between 0.5 and 18% [25]. In our study, the occurrence of a durotomy represented a strong risk factor for severe complications. Its rate was high: 17.3%. The Swedish study of Strömqvist et al. [49] evaluated the risk factors for the occurrence of durotomy in 64,431 patients. They found that age and history of lumbar spinal surgery were risk factors. In our cohort, older patients had significantly more durotomies, as shown in the literature [17]. In addition, they have undergone a significantly more extensive decompression that increases the risk to make a durotomy. Anatomically, during LSS decompression, most durotomies occur in the medial part of the joint

[50], where the enlarged ligament sticks [49] especially for the elderly. Lateral durotomies can be delicate to suture; however, no patient over 80 underwent a revision for CSF leakage. Another study from the USA [24] with 766 patients showed a risk of durotomy of 19% in patients over 65 years old. In practice, durotomy will result in the confinement to the bed of the patient for 48 h. This bed rest can cause complications as confusion for the elderly patients. Concerning confusions, its rate was very low and we think that we had a bias of information due to a lack of data in medical records. The rate of confusion after lumbar spinal surgery is variable in the literature: 0.8–13% [2, 27, 34]. Increased age was found as a risk factor in a large study of 578,457 lumbar decompressions [12]. Pernik et al. [39] study the impact of geriatric optimization before spinal surgery on the postoperative delirium. Patients with geriatric assessment were older and had more comorbidities, but they had less delirium in postoperative time. Involving geriatricians in our care could therefore be a way to reduce minor complications for the oldest patients. Finally, Balabaud et al. [2] found an association between instrumentation and the occurrence of delirium.

The question of whether an additional arthrodesis in the elderly should be performed is still being debated. We included in our study only arthrodesis with one level. The WNFS recommends a decompression alone if the patient has a predominantly radicular pain without signs of instability or with stable spondylolisthesis [45]. In our cohort, the prevalence of spondylolisthesis was 23%. The prevalence of degenerative spondylolisthesis was determined in the Kalichman et al. [22] study using the Framingham cohort: 16% for patients over 70 and 16% for patients with low back pain. The use of fusion depends on the preoperative evaluation on the X-ray and on the search for instability [28]. Regarding grade 1 spondylolisthesis, Blumenthal et al. [3] described the criteria for instability: sagittal facet joints with an angle > 50°, a disc height greater than 6.5 mm and a mobile spondylolisthesis of more than 1.25 mm on dynamic X-ray. In addition, it is recognised that arthrectomy or isthmus resection creates postoperative instability [31]. In our study, these criteria were not available in all hospital records. Our philosophy on LSS and fusions is to follow guidelines while remaining as minimally invasive as possible. We have to keep in mind that fusion does not improve the functional status at 2 and 5 years and increases the blood loss and surgical costs [13]. In our study, fusions were not a risk factor to develop SC. We reported an occurrence of symptomatic screw malposition of 3% comparing with 10% in mean in the literature [15]. These results can be explained by the fact that we excluded patients with posterolateral arthrodesis more than one level. Saleh et al. [44], who did not apply these criteria, found a complication rate twice as high in patients with arthrodesis. The sparing use of fusion reduces the risk of postoperative complications.

Then, the number of decompressed levels was greater in elderly subjects. Contrary to Murphy et al. [33], we did not

detect the number of levels as a major complication factor. The length of the surgery was also reported as a risk factor in their study. For Saleh et al. [44], procedures lasting over 180 min presented an extra risk. In our cohort, only 1.8% of procedures lasted over 180 min. Kong et al. [27] reported decompression as a risk factor from three levels. In our study, only 46 patients had more than three levels of extension decompression, showing our desire to be less invasive. Moreover, we decided to exclude interbody fusions even though their use has also been reported in the literature for the elderly. Regarding the classical technique of posterior lumbar interbody fusion PLIF, Choi et al. [8] found an overall complication rate of 25% for patients over 75. This rate was higher than ours when adding up the severe complication rate (6.9%) to the minor complications (14.3%). In addition, it is interesting to note that their infection rate was 6% compared against 0.5% in our study. Concerning the minimal invasive techniques, Ould-Slimane et al. [37] made a study using the unilateral lumbar interbody fusion (UNILIF) in a minimal invasive technique. They included patients with lumbar spinal stenosis and degenerative spondylolisthesis over 80. Satisfactory functional results were obtained without any revision for infection or hematoma or screw malpostion. However, they only included only 42 patients and no control group was used. To continue with MIS-TLIF in the elderly, Goh et al. [19] observed the same rate of minor perioperative complications between younger and older patients in their study including 129 patients. Their rate of 10% was relatively like our minor complications. Continuing with the use of minimally invasive surgery, 9.3% of patients underwent the installation of interspinous device, allowing correction of the hyperlordosis responsible for radicular pain. Of the patients, 9.3% underwent this technique. However, the disadvantage of this technique is its efficiency. Indeed, the decompression may be insufficient with a reoperation rate of up to 27% [56].

Finally, a more aggressive procedure may be related to increased blood loss during the operation. The postoperative red blood cell transfusion rate was 0.9% in our study. Giannadakis et al. [17] found an almost similar rate of 1.2% in their cohort. Our transfusion rate was higher in the elderly, but no subgroup analysis was performed in this study. ASA grade, duration of surgery and multilevel fusion were known risk factors of blood transfusion in the study of Morcos et al. [32] while age did not appear as a risk factor. They did not study the potential association between the operative position of the patient and transfusion. In our study, among nine transfused patients, five were positioned in a prone position (55.6%). As we have seen previously, this position could potentially increase blood loss and postoperative transfusions. Only one study by Rigamonti et al. [41] was found in the literature. With only 30 patients undergoing microdiscectomy, they compared prone vs knee-chest positions and their impact on blood loss. They reported significantly increased blood loss with knee-chest position. However, when the knee-chest position

was contraindicated due to cardiac or renal or respiratory disorders, patients were excluded. Moreover, microdiscectomy frequently involved younger patients with a mean age around 50, not comparable with our cohort. To avoid postoperative transfusions in lumbar spinal surgery, some authors reported the use of tranexamic acid before the procedure. This drug should be used with caution in the elderly. CKD, epilepsy and venous and arterial thrombosis contraindicate its use [66]. In addition, minimally invasive techniques reduce intraoperative blood loss [40]. Finally, the search for preoperative anaemia may also have an impact on the transfusion rate. This is a target of our ERAS program: patients with anaemia receive an iron infusion or erythropoietin.

Limitations

We must point out some boundaries of our study. First, the retrospective design of the study may cause bias. Even though we are in a university hospital, we have to note that the anaesthesia team has performed a first screening of our patients. They rejected patients deemed unfit to receive general anaesthesia, which defines a selection bias in our population.

Secondly, the unequal sample size between the groups may induce a bias or a lack of power. However, our analyses were carried out considering this imbalance, we used the chi-square test or Fisher exact test according to the number in each class and the *p*-value of continuous variables was obtained considering the distribution of variables and the equal or unequal variance between groups. In other parts, we performed a sensitivity analysis using the matching propensity score to balance groups on potential cofounding variables and sample size in each group with a ratio of 1:1. It should be highlighted that the standardized mean differences (Table 5) were 0.12 for an interspinous device and must keep between − 0.10 and 0.10 to have a good comparison. 0.12 is very close to 0.10 and we considered with statisticians that the model can still be used.

In severe complications, we chose to include the occurrence of severe organ failure. The definition of organ failure can be confusing. These complications are life-threatening for the patient and therefore we have included them. All patients had a standard postoperative follow-up; however, only early complications were recorded, described as the aim of the study. Of course, it would be interesting to study the long-term quality of life distance from the operation, and to look at the rate of late revision surgery.

Thirdly, the age limit of 80 years is an arbitrary limit. Even though it is used frequently in the literature, we find that physiological age is more important than chronological age. For a future study, we could have separated into 2 groups the patients considered fragile versus the others by evaluating the frailty. This corresponds to the reduction of physiological reserves through a multiorgan system that

decreases resistance to stress [42]. We can measure this parameter with Fried's criteria. The review done by Simcox et al. [47] showed a link between frailty and postoperative mortality, postoperative complications and the risk of prolonged hospitalisation. Concerning the impact of heart diseases on postoperative prognosis and anaesthetic scores like MET or Lee was interesting to study this link.

Finally, it would be interesting to compare the complication rate per year. This would show the impact of new anaesthesia techniques such as locoregional anaesthesia and new surgical techniques such as the use of minimally invasive surgery.

seems essential to avoid the occurrence of postoperative complications.

Operating on increasingly fragile patients, the neurosurgeon must warn his patients of the potential risks associated with his comorbidities, previous surgeries and the procedure itself. Indeed, we have detected many risk factors in this study. Enhanced recovery after surgery is potentially a useful tool to prevent complications by correcting risk factors. It would be interesting to evaluate its usefulness in elderly patients.

In the future, some risk factors should be detailed to better target the conditions in preoperative care.

Conclusion

To conclude, the age over 80 does not lead to higher surgical morbidity. Multidisciplinary management with the anaesthetist, geriatricians and other specialities

Appendix

Consent of the ethics committee n° IRB00011687 College de neurochirurgie IRB #1: 2020/25.

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Bordeaux le jeudi 11 juin 2020

L'IRB de neurochirurgie a évalué le projet :

« Chirurgie du canal lombaire étroit du sujet âgé : Y a-t-il un risque opératoire augmenté? Etude cas – témoins au CHU de Caen.»

à la demande de Mme le Pr Eveline Emery

Service de Neurochirurgie – Hôpital de Caen

Et émet :
un Avis favorable le 11/06/2020
n° IRB00011687 College de neurochirurgie IRB #1 : 2020/25

Pr emmanuel CUNY

Author contribution Not applicable.

Data availability Data were available if necessary.

Declarations

Ethics approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional Ethics of French College of Neurosurgery (showed in Appendix) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent to participate Not applicable, for this type of study formal consent is not required.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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