BMC Geriatrics

RESEARCH

Open Access

Mortality in patients older than 65 years undergoing surgery for degenerative lumbar spine disease: a comparison with the general population

Raquel Gutiérrez-González[1,2*], Marta Macarrón[2], Ana Royuela[3], Alberto Vallejo-Plaza[4] and Alvaro Zamarron[1]

Abstract

Background The increased life expectancy and prevalence of spondylarthrosis have led to a growing frequency of spinal surgery in older people. This study aims to assess whether there is an excess mortality concerning that expected in the general population associated with surgical procedures performed in patients over 65 years old for a degenerative disease of the lumbar spine.

Methods All patients aged 65 years or older undergoing surgery at a single center between 2009 and 2019 for lumbar spine degenerative disease were included. Standardized mortality ratios (SMRs) were estimated to compare the mortality risk with the expected in the Spanish population for the same age, gender, and calendar-period. Multivariable Cox analysis was employed to determine risk factors of mortality.

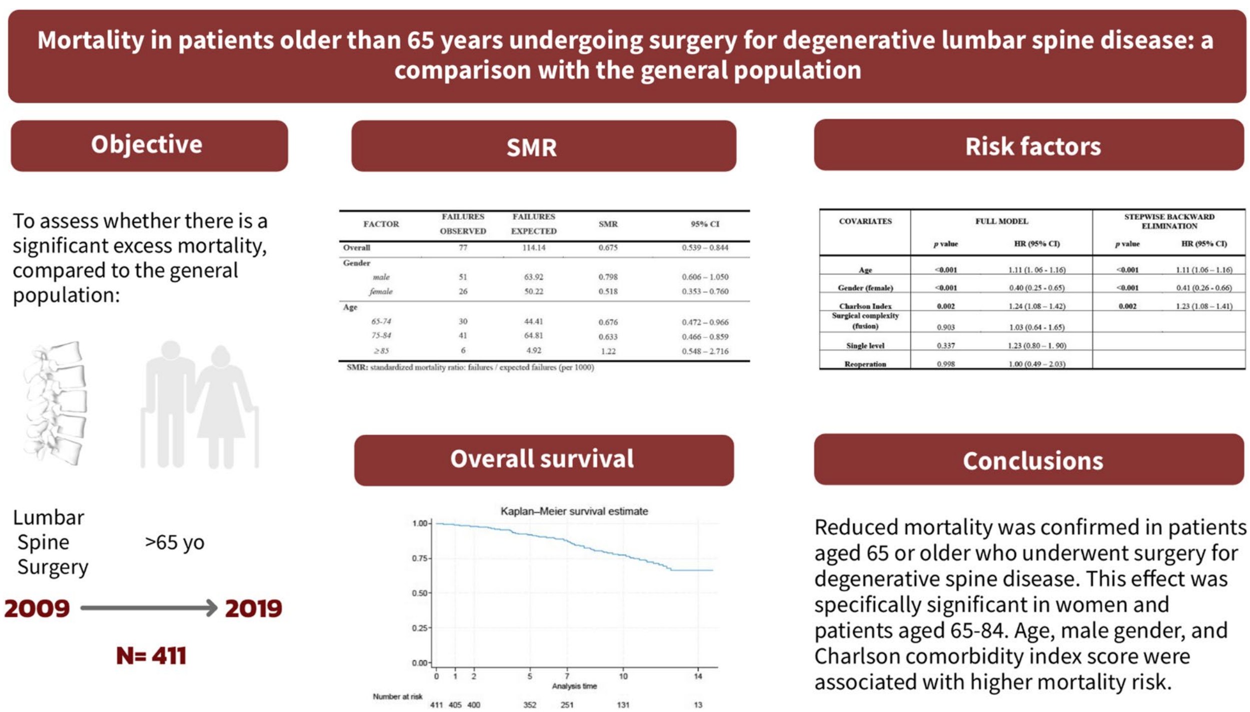
Results A total of 411 procedures were analyzed. The mean age was 72.6 years old. SMR was 0.67 (CI 95% 0.54–0.84). That benefit was significant in women after gender stratification. Patients operated on between 65–84 years old had a lower mortality rate than that expected for the general population. For patients aged 85 or older, the observed mortality was not different from that expected in the general population. Multivariable Cox analysis observed an association between higher mortality and the variables age, male, and Charlson comorbidity index score.

Conclusions Compared with the general population, patients over 65 years old who underwent spinal surgery for degenerative disease of the lumbar spine experienced a reduction in mortality. This effect was particularly significant in women and patients aged 65–84 years. Age, male gender, and Charlson comorbidity index score were associated with higher mortality risk.

Keywords Aged, Life expectancy, Mortality, Spine surgery

*Correspondence:
Raquel Gutiérrez-González
rgutierrezgonzalez@yahoo.es
Full list of author information is available at the end of the article

Graphical Abstract



Background

Life expectancy has increased progressively over the last few decades. According to data for 2021, people in Spain who will be 65 years old in that year can expect to live an average of 21.4 years longer (19.1 for men and 23.4 for women) [1]. In addition, according to the National Health System Report 2020/21, three out of every four people rate their health as "good" or "very good", with increasing quality of life achieved at these ages [2]. Degenerative spinal pain is already more prevalent than hypertension, hypercholesterolemia, or diabetes in our environment, especially in women [3], and is a leading cause of disability and loss of quality of life in older people [4, 5].

Increasing life expectancy and prevalence of spondylarthrosis have led to a growing number of spine surgeries in older people. Thus, the indication for posterior lumbar fusion in the United States is estimated to increase in the next 15 years, with the most significant demand in the 64–84 age group [6].

There is a wide range of options for the treatment of degenerative spinal disorders, given the wide range of diagnoses included in this very general entity (spinal stenosis, disc herniation, foraminal or lateral recess stenosis, among others). Two shorter and "less invasive" procedures (simple discectomy and laminectomy with their different variables -minimally invasive or open-) and a longer and more aggressive procedure, which also requires a more extended hospital stay and recovery time (vertebral fusion with its different variations -minimally invasive, open, interbody fusion, among others-), are the most frequently performed [7, 8]. The latter, a more complex technique, has been associated both with excess of hospital costs [7, 8], and greater use of primary care in the long-term when performed on older patients [9].

Despite the patients' older age, the clinical results are satisfactory [10]. However, a certain likelihood of complications has been reported, especially in patients over 80 [11–13]. Two recent studies evaluated the role of frailty in octogenarians undergoing lumbar spine surgery. They found a particular effect on short-term mortality (3 and 6 months) but no relevant differences in the long term [14, 15]. Regarding mortality, only two studies have compared the observed and expected mortality in older patients undergoing surgery for degenerative spine disease. The first analyzed 1-year mortality in a sample of 34418 patients older than 65 years and found a rate of 3.52% [16]. The relative risk of death during this follow-up period, compared with the general American population, adjusted for age and sex, was less than 1 in most of the subgroups analyzed. Furthermore, mortality was higher in men and in patients with an increasing number of comorbidities [16]. The other study mentioned above achieved a longer follow-up of 10 years in a sample of 1015 patients of all ages (538 were older than 60) in South Korea [17]. The 10-year mortality in this study was 6%, and the standardized mortality ratio (SMR) was less than 1 in all age groups older than 50 years (0.45 for ages 70 to 85). In both trials, therefore, the mortality or risk of mortality in older patients was lower than expected in the general population, adjusted for age and gender. However, neither study reported confidence intervals (CI) to determine whether these results were statistically significant.

Given the limited previous experience in this area, confirmation of these findings would consolidate surgical treatment in older patients whose quality of life is impaired by a prevalent pathology. The results of the study may be particularly useful for geriatricians, who have a general view of the patient, consider the impact of coexisting comorbidities, and often diagnose and refer (or not) the patient to the surgeon.

Methods

Aim, design, and setting of the study

The primary objective of this study is to assess whether there is significant excess mortality compared to the general population associated with surgery for degenerative disease of the lumbar spine in patients over 65 years of age. The secondary objectives of the study are to determine the expected survival after surgery and the association between various clinical (such as comorbidity or anesthetic risk) and therapeutic factors (such as complexity of surgery or number of spinal levels involved) and the risk of mortality, to select the best candidates for surgery.

A single-center retrospective study based on hospital medical records was designed to assess the SMR in patients over 65 undergoing surgery for degenerative lumbar spine disease. The study was approved by the local Ethics Committee (reference 37/23) and was conducted under the 1964 Helsinki Declaration and its later amendments or equivalent ethical standards.

Patients' selection

Patients were selected with the aid of the Admissions and Clinical Documentation Department. Inclusion criteria were all patients aged 65 years or older who underwent surgery for degenerative disease of the lumbar spine at a single center between 1 January 2009 and 31 December 2019. Patients who required more than one procedure were included only for the first procedure. Patients with incomplete follow-up were excluded.

Variables of the study

The date of death was confirmed using the information available from the public Healthcare System. In cases where follow-up was missed because the patient had moved to another region or country, the patient or their relatives were contacted by telephone. The end of follow-up was December 2023 for all surviving patients. Expected deaths were measured from annual data for the entire Spanish national population according to the National Institute of Statistics, adjusted for age and gender for each calendar period (yearly) [18]. The information is freely available [18]. Overall survival was calculated as the time from spinal surgery to death or the end of follow-up.

Epidemiological variables (age, gender), clinical variables (Charlson comorbidity index, ASA physical status classification, diagnosis, date of surgery, history of previous spinal surgery, need for subsequent reintervention), and therapeutic variables (complexity of the surgical procedure, intervention of one or more spinal levels, type of intervention according to whether it was emergency or scheduled, hospital stay) were collected from the patient's electronic health record. As degenerative spinal diseases often include a sum of radiological findings that can give rise to several compatible diagnoses (disc herniation, foraminal stenosis, central canal stenosis, etc.), the diagnosis was categorized according to the finding that contributed most to the symptoms and the indication for surgery, although in many cases it was not an isolated diagnosis. The complexity of the procedure was classified according to the EUROSPINE Surgical Spine Centre of Excellence (Table 1) [19]. "Small" surgery corresponded to discectomy, foraminotomy, or laminectomy, whereas "medium" surgery corresponded to vertebral fusion (less than 5 segments) with or without one of the above decompression procedures.

Statistical analysis

Dataset information was processed and analyzed using Statav 18 (*StataCorp. 2023. Stata Statistical Software: Release 18*. College Station, TX: StataCorp LLC). A descriptive analysis of the variables was performed, using frequency distributions and percentages for qualitative variables and central tendency and dispersion parameters for quantitative variables. If the normality assumption was accomplished for numerical variables, the mean and standard deviation are used; if not, the median and percentiles 25 and 75 are used. The SMR was employed to determine the excess mortality and was estimated as the ratio of the number of deaths observed in the sample over the given period to the number expected over the same period if the study population had the same age-specific

Table 1 Severity intervention according to the EUROSPINE Surgical Spine Centre of Excellence [19]

"SMALL" SPINE SURGERY	"MEDIUM" SPINE SURGERY	"LARGE" SPINE SURGERY
removal of implant	Surgery on cervical, thoracic, lumbar spine and sacrum which are not mentioned under small and large spine surgery	en-bloc spondylectomy with reconstruction and stabilization
sequestrectomy, discectomy (disc surgery, non-instrumented)		correction interventions due to deformity ≥ 6 segments
pain surgical intervention on spine with permanent implants (f. e. SCS-pump)		resection interventions due to intra medulla tumors
percutaneous cement augmentation of vertebrae		revision surgery with implant removal and complete re-instrumentation ≥ 6 segments
non-instrumented dorsal decompressions biopsy on spine		combined dorso ventral interventions due to spine injury over separate approaches with vertebral (partial) replacement
application of inter spinous implants		combined interventions with multiple change of approach (dorsal ventral dorsal or ventral dorsal ventral)

rates as the standard population. A value greater than 1.0 would point to an excess mortality in the sample studied concerning the general population. The 95% CI was also estimated.

Overall survival was estimated using the Kaplan–Meier method, and multivariable Cox regression was used to determine the association of covariates and time to death. The proportional hazards assumption was tested using the Schoenfeld residuals for each of the variables entered into the model. Every statistical hypothesis was two-tail tested. The null hypothesis was rejected in all hypothesis contrasts with type I error or α error less than 0.05.

This study was made following the recommendations of the STROBE statement [20].

Results

During the study period, 576 procedures were recorded in patients aged 65 years or older. Of these, 129 were excluded due to coding errors (other pathologies or procedures) and 36 were reoperations in patients already included. Thus, 411 patients were identified and finally analyzed [21], as there were no exclusions due to incomplete follow-up (Fig. 1).

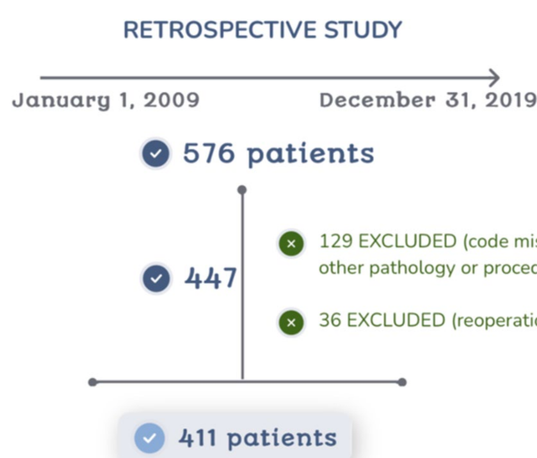


Fig. 1 Flow diagram representing patients' selection process

The mean age of the sample was 72.6 years (SD 5.60), with a slightly higher proportion of women (51.3%). Seventeen percent of the patients had a history of previous spinal surgery. The median score on the Charlson comorbidity index was 4 points (corresponding to an estimated 10-year survival of 53.4%). According to the ASA anesthetic risk classification, 65.2% of patients had a score of II, and 32.6% had a score of III. Most procedures were low complexity (62.5%), and almost half (42.8%) involved two or more spinal levels. Only 0.7% of operations were emergency procedures. The median length of stay after surgery was 5 days (3; 9), and 13.2% of the patients required subsequent spinal surgery. Table 2 summarizes the characteristics of the sample.

The median follow-up was 9.2 years (95% CI 8.8; 9.6). The overall SMR was 0.67 (95% CI 0.54–0.84), indicating a statistically significant reduction in mortality compared with the general population of the same age, gender, and calendar period. When stratified by gender, the benefit was significant only in women, with an SMR of 0.52 and maintained statistical significance (95%CI 0.35—0.76). However, the male mortality rate does not appear to be different from that expected for the general male population for the same age and calendar period. When stratified by age at surgery, patients who underwent surgery between the ages of 65 and 84 years were associated with a lower mortality rate than expected for the general population of the same age, gender, and calendar period. For patients aged 85 years or older, the observed mortality was not different from that expected in the general

Table 2 Demographic description

Factor	*N* patients	%
Age (yr)		
65–74	*265*	*64.5*
75–84	*134*	*32.6*
≥ 85	*12*	*2.9*
Gender		
Male	*200*	*48.7*
Female	*211*	*51.3*
Charlson Index		
2	*64*	*15.6*
3	*124*	*30.2*
4	*107*	*26*
5	*53*	*12.9*
6	*32*	*7.8*
7	*21*	*5.1*
8	*6*	*1.5*
9–10	*4*	*1*
Previous spine surgery	70	17.0
ASA		
I	*8*	*1.9*
II	*268*	*65.2*
III	*134*	*32.6*
IV	*1*	*0.2*
Main diagnosis		
Spinal stenosis	*270*	*65.7*
Disc herniation	*93*	*22.6*
Listhesis	*39*	*9.5*
Combined	*9*	*2.2*
Procedure complexity		
Simple (non-fusion)	*257*	*62.5*
Medium (fusion < 6 segments)	*154*	*37.5*
Large	*0*	*0*
Number of levels		
single	*235*	*57.2*
multiple	*176*	*42.8*
Type of surgery		
scheduled	*408*	*99.3*
emergency	*3*	*0.7*
Reoperation	54	13.2

N Number of patients, *yr* years, *ASA* American Society of Anesthesiologists' physical status classification

Table 3 Standardized mortality ratio in patients undergoing surgery due to spinal degenerative disease

Factor	Failures Observed	Failures Expected	SMR	95% CI
Overall	77	114.14	0.675	0.539 – 0.844
Gender				
male	51	63.92	0.798	0.606 – 1.050
female	26	50.22	0.518	0.353 – 0.760
Age				
65–74	30	44.41	0.676	0.472 – 0.966
75–84	41	64.81	0.633	0.466 – 0.859
≥ 85	6	4.92	1.22	0.548-2.716

SMR Standardized mortality ratio: failures / expected failures (per 1000)

population of the same age, gender, and calendar period (Table 3).

At the end of the study, 20.7% of the sample had died. The 1-year mortality was 1.2%. Figure 2 shows the estimate of overall survival, and Table 4 shows the survival function at 1, 2, 5, 7, 10, and 14 years.

Finally, multivariable Cox analysis revealed an association between higher all-cause mortality and the variables of age, male gender, and Charlson comorbidity index score (Table 5). Surgical complexity, the number of spinal levels operated on, or the need for subsequent reoperation did not show any impact on the risk of mortality. The proportional hazard assumption was accomplished by the Schoenfeld residuals.

Discussion

The study showed a reduced mortality rate in patients aged 65–84 who underwent surgery for degenerative lumbar spine disease. In patients over 84, there was no significant difference compared with the general population. The benefit was particularly significant in women. Age, male gender, and Charlson comorbidity index score were associated with a higher risk of death. These findings support the beneficial role of surgery for degenerative diseases in older patients. Therefore, despite the frequent additional comorbidity, invasive treatment should not be ruled out without an individualized analysis of the real risks against the potential benefits in these patients.

Several factors may explain the protective effect. The use of opioids, often used to treat chronic back pain, has been associated with further cognitive impairment, sedation, or respiratory depression, among other side effects [22, 23]. Pain relief after surgery and the subsequent reduction in opioid intake may be one of the protective elements mentioned above. It has been well described that back pain and gait changes secondary to degenerative lumbar spine disease are associated with reduced mobility in older people, which may increase the need for care [5, 24]. Thus, pain relief may also lead to increased physical activity, which has been associated with increased life expectancy, even in frail, older patients [25, 26]. A beneficial effect of physical activity on bone metabolism and bone turnover may also be suggested as

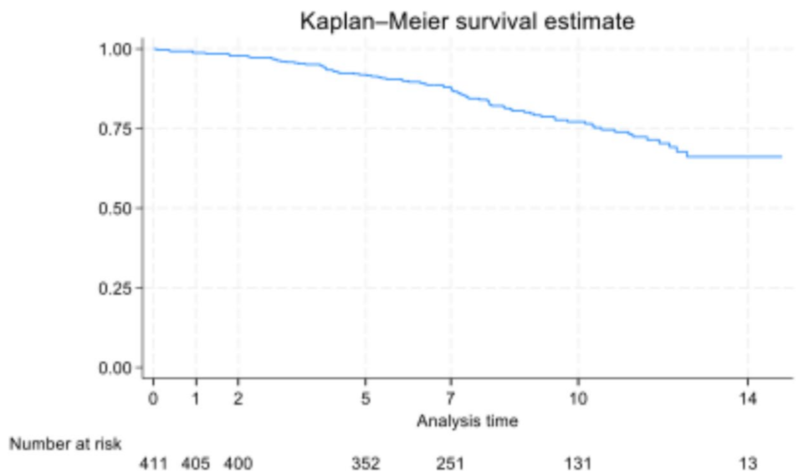


Fig. 2 Cumulative survival probability after surgical treatment of degenerative lumbar spine disease. X axis represents the time after surgery (in years) and Y axis represents the survival probability

Table 4 Kaplan–Meier survivor function at different time intervals after surgery

Time after surgery (years)	Subjects at risk	Survivor function	95% CI
1	405	0.988	0.97 – 0.99
2	400	0.978	0.96 – 0.99
5	352	0.919	0.89 – 0.94
7	251	0.880	0.84 – 0.91
10	131	0.771	0.72 – 0.82
14	13	0.661	0.58 – 0.73

CI Confidence interval

a mechanism, given the association of high bone turnover with all-cause mortality [27, 28].

Two independent studies from the USA and South Korea have also shown comparable results. However, neither reported CIs to ensure statistical significance [16, 17]. For example, a relative risk of 1-year mortality of less than 1 has previously been reported for most patients aged 65 years or older [16]. However, the reduction was more consistent in men than women according to age group and the surgical procedure, a different result from that described in the present study. All patients over 85 showed a reduced relative risk, regardless of the procedure. However, this specific age group was the only one that showed no benefit in our experience [16]. Another previous study analyzed a population of all ages and found an SMR of less than 1 in all age groups over 50 but did not distinguish between men and women [17]. The 1-year mortality was higher in the American population (3.52%) than in our study (1.2%), whereas another study in South Korea with an octogenarian population showed a 4.9% [14]. However, the 10-year mortality was significantly lower in the South Korean population (16.2% in patients over 70 years old, compared with the 22.9% observed in the present series, which included patients aged 65 years or older) [17]. These differences highlight the importance of comparing life expectancy within the general population to avoid bias.

Table 5 Multivariable Cox regression analysis of factors contributing to overall mortality of patients undergoing surgery due to spinal degenerative disease

Covariates	Full model		Stepwise backward Elimination	
	p value	HR (95% CI)	*p* value	HR (95% CI)
Age	**< 0.001**	1.11 (1. 06—1.16)	**< 0.001**	1.11 (1.06 – 1.16)
Gender (female)	**< 0.001**	0.40 (0.25—0.65)	**< 0.001**	0.41 (0.26—0.66)
Charlson Index	**0.002**	1.24 (1.08 – 1.42)	**0.002**	1.23 (1.08 – 1.41)
Surgical complexity (fusion)	0.903	1.03 (0.64—1.65)		
Single level	0.337	1.23 (0.80 – 1. 90)		
Reoperation	0.998	1.00 (0.49 – 2.03)		

The analysis of factors associated with increased survival showed similar results to previous evidence [17, 29]. Women and younger patients had better outcomes, as we also demonstrated [17, 29]. Physiological differences have been suggested for the gender differences, which have also been documented in other cardiothoracic surgical procedures [30]. A possible explanation may be based on a worse preoperative clinical situation (pain) in women and an equal or more remarkable interval change after surgery compared to men [31]. However, further research specifically designed to understand such gender differences is needed. In addition, we assessed the preoperative medical condition using the Charlson comorbidity index and the ASA physical status classification system. The strong correlation between both variables led us to discard the ASA classification. The Charlson comorbidity index score was strongly associated with poorer outcomes, a result comparable to that observed in a previous study that looked only at short-term mortality [16]. Therefore, patient selection seems essential to minimize complications and achieve clinical benefit. The complexity of the procedure and the number of levels treated are important issues, as they may increase hospital stay and recovery time. Other studies have reported conflicting results. For example, in some studies, non-fusion procedures were associated with worse outcomes [14, 16], whereas in another study fusion was associated with a higher likelihood of death in the first year [17]. No long-term effect was observed in our study, as reported by other authors [17]. A limited retrospective cohort of octogenarians showed a higher risk of major complications with an increasing number of levels operated, but no study analyzed the risk of mortality [32]. Further studies are needed to clarify these findings.

The main limitation to be considered is a potential selection bias of those patients who were operated on versus those who were not operated on due to age, medical condition, or patient choice. The effect on reduced mortality is unknown, but those patients who were not operated on would likely have worse outcomes than those who were operated on. Further studies are planned to compare SMR in operated and non-operated patients. Second, the study was conducted at a single institution, so the mortality findings may not apply to populations with greater demographic diversity. Multicenter or national studies are needed to validate the results. Finally, the small sample size may have prevented the observation of significant differences in men. However, the long-term follow-up and the addition of CIs make this study more relevant than previous publications.

Conclusions

Compared with the general population, patients aged 65–84 who underwent spinal surgery for degenerative disease of the lumbar spine experienced a reduction in mortality. The beneficial effect was particularly significant in women. Increased mortality was associated with age, male gender, and increasing Charlson comorbidity index score. The complexity of surgery, the number of spinal levels operated on, or the need for a subsequent revision surgery did not affect the risk of death.

Abbreviations

ASA	American society of anesthesiologists
CI	Confidence interval
SMR	Standardized mortality ratio

Acknowledgements

The authors thank Cristina Ruiz Quevedo for assistance in the translation of the manuscript.

Authors' contributions

RGG conceived the study, participated in its design, carried out data collection and drafted the manuscript; MM: participated in the design, carried out data collection and drafted the manuscript; AR: participated in the design of the study and performed statistical analysis; she also revised the manuscript for intellectual content; AVP: carried out data collection and critical review of the manuscript for intellectual content. AZ: carried out data collection and critical review of the manuscript for intellectual content.

All authors read and approved the final manuscript. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved..

Funding

No funding was received for conducting this study.

Data availability

The dataset generated and analyzed during the current study is available in Zenodo, https://doi.org/10.5281/zenodo.10519828, and from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. It was approved by the Ethics Committee of Puerta de Hierro University Hospital (reference 37/23). No informed consent to participate in the study was collected since the design was retrospective (the need for consent was waived by the Ethics Committee of Puerta de Hierro University Hospital).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Neurosurgery, Puerta de Hierro University Hospital, IDIPHISA, Manuel de Falla 1, Majadahonda-Madrid 28222, Spain. [2]Department of Surgery, Faculty of Medicine, Autonomous University of Madrid, Arzobispo Morcillo 4, Madrid 28029, Spain. [3]Biostatistics Unit Biomedical Research Institute - IDIPHISA, CIBERESP, Puerta de Hierro, University Hospital, Manuel de Falla 1, Majadahonda-Madrid 28222, Spain. [4]Department of Admission and Clinical Documentation, Puerta de Hierro University Hospital, Manuel de Falla 1, Majadahonda-Madrid 28222, Spain.

Received: 10 May 2024 Accepted: 1 November 2024
Published online: 15 November 2024

References

1. 2023 health statistics and information. Ministry of health. Available from: https://www.sanidad.gob.es/estadEstudios/estadisticas/inforRecopilaciones/ESPERANZAS_DE_VIDA_2021.pdf. Accessed 12 Jan 2024.
2. National health system annual report. Ministry of health. Available from: https://www.sanidad.gob.es/estadEstudios/estadisticas/sisInfSanSNS/tablasEstadisticas/InfAnualSNS2020_21/INFORME_ANUAL_2020_21.pdf. Accessed 12 Jan 2024.
3. National health survey 2017. Ministry of health, consumer affairs and social welfare. Available from: https://www.sanidad.gob.es/estadEstudios/estadisticas/encuestaNacional/encuestaNac2017/ENSE17_pres_web.pdf .(page 8). Accessed 12 Jan 2024.
4. GBD 2015 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016;388:1545–602. https://doi.org/10.1016/S0140-6736(16)31678-6.
5. Zhu K, Devine A, Dick IM, Prince RL. Association of back pain frequency with mortality, coronary heart events, mobility, and quality of life in elderly women. Spine (Phila Pa 1976) 2007;32:2012–8. https://doi.org/10.1097/BRS.0b013e318133fb82.
6. Neifert SN, Martini ML, Hanss K, Rothrock RJ, Gilligan J, Zimering J, Caridi JM, Oermann EK. Large rises in thoracolumbar fusions by 2040: a cause for concern with an increasingly elderly surgical population. World Neurosurg. 2020;144:e25–33. https://doi.org/10.1016/j.wneu.2020.06.241.
7. Deyo RA, Cherkin DC, Loeser JD, Bigos SJ, Ciol MA. Morbidity and mortality in association with operations on the lumbar spine. The influence of age, diagnosis, and procedure. J Bone Joint Surg Am 1992;74:536–43.
8. Ji H, Shin S, Kim Y, Ha IH, Kim D, Lee YJ. Trends of surgical service utilization for lumbar spinal stenosis in South Korea: s 10-year (2010–2019) cross-sectional analysis of the health insurance review and sssessment service-national patient sample data. Medicina (Kaunas). 2023;59:1582. https://doi.org/10.3390/medicina59091582.
9. Andersen T, Bünger C, Søgaard R. Long-term health care utilisation and costs after spinal fusion in elderly patients. Eur Spine J. 2013;22:977–84. https://doi.org/10.1007/s00586-012-2479-5.
10. Rihn JA, Hilibrand AS, Zhao W, Lurie JD, Vaccaro AR, Albert TJ, Weinstein J. Effectiveness of surgery for lumbar stenosis and degenerative spondylolisthesis in the octogenarian population: analysis of the Spine Patient Outcomes Research Trial (SPORT) data. J Bone Joint Surg Am. 2015;97:177–85. https://doi.org/10.2106/JBJS.N.00313.
11. Lee JY, Moon SH, Suh BK, Yang MH, Park MS. Outcome and complications in surgical treatment of lumbar stenosis or spondylolisthesis in geriatric patients. Yonsei Med J. 2015;56:1199–205. https://doi.org/10.3349/ymj.2015.56.5.1199.
12. Puvanesarajah V, Jain A, Shimer AL, Li X, Singla A, Shen F, Hassanzadeh H. Complications and mortality following 1 to 2 level lumbar fusion surgery in patients above 80 years of age. Spine (Phila Pa 1976) 2017;42:437–41. https://doi.org/10.1097/BRS.0000000000001759.
13. Kuo CC, Royse KE, Prentice HA, Harris JE, Guppy KH. Are octogenarians at higher risk of complications after elective lumbar spinal fusion surgery? analysis of a cohort of 7880 patients from the Kaiser Permanente Spine Registry. Spine (Phila Pa 1976) 2022;47:1719–27. https://doi.org/10.1097/BRS.0000000000004451.
14. Jang HJ, Chin DK, Park JY, Kuh SU, Kim KS, Cho YE, Kim KH. Influence of frailty on life expectancy in octogenarians after lumbar spine surgery. Neurospine. 2021;18:303–10. https://doi.org/10.14245/ns.2040688.344.
15. Kweh B, Lee H, Tan T, O'Donohoe T, Mathew J, Fitzgerald M, Gantner D, Kambourakis T, Tew K, Hunn M, Rosenfeld J, Tee J. Spinal surgery in patients aged 80 years and older: risk stratification using the modified frailty index. Global Spine J. 2021;11:525–32. https://doi.org/10.1177/2192568220914877.
16. Oldridge NB, Yuan Z, Stoll JE, Rimm AR. Lumbar spine surgery and mortality among Medicare beneficiaries, 1986. Am J Public Health. 1994;84:1292–8. https://doi.org/10.2105/ajph.84.8.1292.
17. Kim HJ, Lee HM, Kim HS, Moon ES, Park JO, Lee KJ, Moon SH. Life expectancy after lumbar spine surgery: one- to eleven-year follow-up of 1015 patients. Spine (Phila Pa 1976) 2008;33:2116–21. https://doi.org/10.1097/BRS.0b013e31817e1022.
18. National Statistics Institute. Available from: https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736177004&menu=ultiDatos&idp=1254735573002. Accessed 12 Jan 2024.
19. EUROSPINE task force surgical spine centre of excellence (SSCoE). Guidelines. Available from: https://www.eurospine.org/fileadmin/Quality_Assurance/SSCoE/20220426_Guidelines_SSCoE.pdf. (page 11). Accessed 14 Ja 2024.
20. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet 2007;370:1453–7. https://doi.org/10.1016/S0140-6736(07)61602-X.
21. Gutierrez-Gonzalez R. Reduced mortality in patients over 65 years old that undergo surgery for degenerative spine disease. 2024. Zenodo. https://doi.org/10.5281/zenodo.10519827.
22. Benyamin R, Trescot A, Datta S, Buenaventura R, Adlaka R, Sehgal N, Glaser SE, Vallejo R. Opioid complications and side effects. Pain Physician. 2008;11(2 Suppl):S105–20.
23. Schiltenwolf M, Akbar M, Hug A, Pfüller U, Gantz S, Neubauer E, Flor H, Wang H. Evidence of specific cognitive deficits in patients with chronic low back pain under long-term substitution treatment of opioids. Pain Physician. 2014;17:9–20.
24. Natarajan P, Fonseka RD, Kim S, Betteridge C, Maharaj M, Mobbs RJ. Analysing gait patterns in degenerative lumbar spine diseases: a literature review. J Spine Surg. 2022;8:139–48. https://doi.org/10.21037/jss-21-91.
25. Landi F, Cesari M, Onder G, Lattanzio F, Gravina EM, Bernabei R. Physical activity and mortality in frail, community-living elderly patients. J Gerontol A Biol Sci Med Sci. 2004;59:833–7. https://doi.org/10.1093/gerona/59.8.m833.
26. Li CL, Chiu YC, Shyu YL, Stanaway FF, Chang HY, Bai YB. Does physical activity protect older persons with frailty and cognitive impairment from excess all-cause mortality? Arch Gerontol Geriatr. 2021;97:104500. https://doi.org/10.1016/j.archger.2021.104500.
27. Sambrook PN, Chen CJ, March L, Cameron ID, Cumming RG, Lord SR, Simpson JM, Seibel MJ. High bone turnover is an independent predictor of mortality in the frail elderly. J Bone Miner Res. 2006;21:549–55. https://doi.org/10.1359/jbmr.060104.
28. Mussolino ME, Gillum RF. Low bone mineral density and mortality in men and women: the Third National Health and Nutrition Examination Survey linked mortality file. Ann Epidemiol. 2008;18:847–50. https://doi.org/10.1016/j.annepidem.2008.07.003.
29. Poorman GW, Moon JY, Wang C, Horn SR, Beaubrun BM, Bono OJ, Francis AM, Jalai CM, Passias PG. Rates of mortality in lumbar spine surgery and factors associated with its occurrence over a 10-year period: a study of 803,949 patients in the nationwide inpatient sample. Int J Spine Surg. 2018;12:617–23. https://doi.org/10.14444/5076.
30. Schoenfeld AJ, Reamer EN, Wynkoop EI, Choi H, Bono CM. Does patient sex affect the rate of mortality and complications after spine surgery? A systematic review. Clin Orthop Relat Res. 2015;473:2479–86. https://doi.org/10.1007/s11999-014-4102-z.
31. MacLean MA, Touchette CJ, Han JH, Christie SD, Pickett GE. Gender differences in the surgical management of lumbar degenerative disease: a scoping review. J Neurosurg Spine. 2020;32:799–816. https://doi.org/10.3171/2019.11.SPINE19896.
32. Mihailidis HG, Manners S, Churilov L, Quan GMY. Is spinal surgery safe in octogenarians? ANZ J Surg. 2017;87:605–9. https://doi.org/10.1111/ans.13885.

Publisher's Note