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ORIGINAL ARTICLE - SPINE DEGENERATIVE

# Morbidity and mortality following degenerative spine surgery in a prospective cohort of 1687 consecutive surgical procedures

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## Abstract

**Study design** Prospective, observational cohort study.

**Objective** To determine the true incidence of adverse events (AEs) in European adults undergoing surgery for degenerative spine diseases.

**Summary of background data** The majority of surgeries performed for degenerative spinal diseases are elective, and the need for adequate estimation of risk-benefit of the intended surgery is imperative. A cumbersome obstacle for adequate estimation of surgery-related risks is that the true incidence of complications or adverse events (AEs) remains unclear.

**Methods** All adult patients (≥ 18 years) undergoing spine surgery at a single center from February 1, 2016, to January 31, 2017, were prospectively and consecutively included. Morbidity and mortality were determined using the Spine AdVerse Events Severity (SAVES) system. Additionally, the correlation between the AEs and length of stay (LOS) and mortality was assessed.

**Results** A total of 1687 procedures were performed in the study period, and all were included for analysis. Of these, 1399 (83%) were lumbar procedures and 288 (17%) were cervical. The overall incidence of AEs was 47.4%, with a minor AE incidence of 43.2% and a major of 14.5%. Female sex (OR 1.5 [95% CI 1.2–1.9), $p < 0.001$) and age > 65 years (OR 1.5 [95% CI 1.1–1.7], $p = 0.012$) were significantly associated with increased odds of having an AE.

**Conclusion** Based on prospectively registered AEs in this single-center study, we validated the use of the SAVES system in a European population undergoing spine surgery due to degenerative spine disease. We found a higher incidence of AEs than previously reported in retrospective studies. The major AEs registered occurred significantly more often perioperatively and in patients > 65 years.

**Keywords** Degenerative spine surgery · Complications · Adverse events · Prospective

This article is part of the Topical Collection on *Spine degenerative*

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## Abbreviations

| | |
|---|---|
| AEs | Adverse events |
| ASA | American Society of Anaesthesiologists |
| CI | Confidence interval |
| LOS | Length of stay |
| OR | Odds ratio |
| SAVES | Spine AdVerse Events Severity system |
| SD | Standard deviation |

## Introduction

Degenerative spine disease has been the leading cause of loss of functional health (years lived with disability) during the last three decades [25]. The majority of surgical procedures for degenerative disease is elective, and the need for adequate estimation of risk-benefit of the intended surgery is imperative both in patient counseling and when deciding to perform surgery. However, the true incidence of complications or adverse events (AEs) following spine surgery remains unclear. This is in large part due to inconsistencies in defining surgery-related complications [10, 14, 15, 24]. Furthermore, the majority of previous studies are retrospective and based on hospital registries or large national databases. The completeness and accuracy of these registries and databases have not been established [28]. In addition, retrospective studies are susceptible to underestimation of the incidence of complications [15]. Definitions for major complications often vary between studies and are often limited to describing risks of specific procedures or etiologies, resulting in limited general applicability. Rampersaud et al. addressed this issue by presenting a comprehensive, clinically relevant, and simple classification system for evaluating AEs related to spine surgery—the Spine Adverse Events Severity system (SAVES) [16–18]. Their intent was to propose a system for quantitative comparison across centers and procedures. Street et al. used this system to report the incidence of AEs in 942 consecutive adult patients undergoing spine surgery, both emergency and elective, at an academic quaternary referral center [10]. Karstensen et al. validated the SAVES system in a European population undergoing more complex spine surgeries (including surgery for deformity, major revisions, trauma, metastatic medullary cord compression, and infectious conditions) by comparing their results with that of Street et al. [5].

The primary purpose of this study was to use the SAVES system to determine the true incidence of adverse events (AEs) in European adults undergoing spine surgery for purely degenerative spine diseases both acute and elective, in efforts to further validate the SAVES system. The secondary purpose was to assess the correlation between the AEs and length of stay (LOS) and mortality.

## Materials and methods

This study was performed at an academic tertiary referral center serving a population of approximately 2.5 million people.

All adult patients (≥ 18 years) undergoing spine surgery from February 1, 2016, to January 31, 2017, were prospectively included. The SAVES system V2 was used to record all intra- and perioperative AEs. This version contains 14 predefined intraoperative AEs, 29 predefined perioperative AEs, and categories for "other" (miscellaneous) intra- or perioperative AEs [10, 16, 20]. All AEs were categorized as major AE if the AE leads to intensive care, prolonged hospital stay, prolonged poor outcome (> 6 months), or death. AE grading was adopted from the original article by Rampersaud et al. [16], according to a previously published article by Bari et al. [1]. Individual SAVES forms were filled out prospectively for each included patient by a research coordinator. Written informed consent was obtained from all individual participants included in the study. The research coordinator was not involved in the treatment of the patients. Once a week, all admitted patients were reviewed for additional AEs by the surgical staff, and questions raised by the research coordinator were clarified. All forms were concluded on the day of discharge. Extended LOS was defined as LOS exceeding the mean with one standard deviation (SD) and obesity as having a BMI > 30 kg/m$^2$.

### Data

Patient characteristics, type of admission, and surgical data were registered for all. LOS and in-hospital, 30-day, and 90-day mortality was also recorded. Procedures were classified as lumbar (foraminotomy or laminotomy and discectomy, laminectomy, anterior stand-alone fusion, percutaneous minimal invasive posterior instrumentation, non-instrumented fusion, posterior lumbar interbody fusion (PLIF) or transforaminal lumbar interbody fusion (TLIF) with pedicle screw instrumentation) or cervical (anterior cervical discectomy and fusion (ACDF) with or without anterior plating, posterior decompression with or without fusion and instrumentation, corpectomy).

### Statistical analysis

Data analysis was performed using SPSS version 27 (SPSS Inc., IBM Corp., Armonk, NY, USA). Normality was determined using histograms, qq plots, and Kolmogorov-Smirnov tests. Incidences were compared using Fischer's exact test. Continuous, normally distributed data were compared using the Student *t* test. The Mann-Whitney *U* test was applied when assumptions of normality were not met. Logistic regression was performed to assess the correlation of the registered AEs to LOS and mortality while adjusting for clinically relevant confounders such as sex, age, and surgical subgroup. $p < 0.05$ was considered statistically significant. Results were reported with 95% confidence intervals (95% CI) and standard deviations (SD).

## Results

A total of 1687 procedures were included in the study period representing 100% of eligible patients. Mean (±SD) age was 60.4 ± 14.9, and 55.1% ($n = 930$) of patients were female. The majority of procedures were lumbar 1399 (82.9%), and the most common surgical spine procedure was lumbar foraminotomy or laminotomy and discectomy ($n$ = 545, 32.3%), followed by lumbar laminectomy ($n$ = 389, 23.1%) and posterior fusion (PLIF or TLIF) with pedicle screw instrumentation ($n$ = 325, 19.3%). There was a total of 288 cervical procedures of which ACDF with or without anterior plating was the most common procedure ($n$ = 246, 14.6%). Table 1 shows patient characteristics.

The overall incidence of AEs was 47.4%. Minor AEs were recorded in 43.2% of cases and major AEs in 14.5%. During the prospective study period, there were 1144 perioperative AEs and 144 intraoperative AEs resulting in an overall rate of 67.8% and 8.5%, respectively. Perioperative AEs were more common in older patients (> 65 years) compared with younger patients (mean AEs per patient 0.86 ± 1.09 vs 0.54 ± 0.79, $p$ < 0.001). There was no significant difference comparing intraoperative AEs (mean AEs per patient 0.08 ± 0.30 vs 0.09 ± 0.29, $p$ = 0.474). When examining major AEs only, these were more common perioperatively than intraoperatively (11.9% vs 4.1%, $p$ < 0.001).

Stratified by surgical procedure, we saw the highest mean AE per patient among patients undergoing non-instrumented posterior lumbar fusion (1.4, SD ± 1.2) and PLIF or TLIF with pedicle screw instrumentation (1.4, SD ± 1.3). The mean AE per patient in patients undergoing lumbar laminotomy due to disc herniation or foraminotomy due to lateral spinal stenosis was significantly lower (0.4, SD ± 0.6, $p$ < 0.001) (Table 2).

Patient characteristics were assessed for correlation to the occurrence of any AE (Table 3). Univariable analysis showed several parameters with significantly increased odds (OR [95% CI]) of an AE (Table 3). In the multivariable model, female sex (1.5 [1.2–1.8], $p$ < 0.001) and age > 65 years (1.4 [1.1–1.7], $p$ = 0.012) remained significant.

**Table 1** Patient characteristics

| | Cohort ($n$ = 1687) |
|---|---|
| Demographics | |
| Female | 937 (55.1%) |
| Male | 757 (44.9%) |
| Age (years) | 60.4 (± 14.9) |
| Range (years) | 19-92 |
| Length of stay (days) | 3.0 (± 3.3) |
| Type of admission | |
| Elective ($n$) | 1570 (93.1%) |
| Acute ($n$) | 117 (6.9%) |
| Comorbidity | |
| CCI (mean) | 2.9 (± 1.6) |
| ASA score (mean) | 1.9 (± 0.7) |
| BMI (kg/m$^2$) | 27.1 (± 5.0) |

Data is presented as numbers (proportions) or means (± standard deviation)

*CCMI* Charlson Comorbidity Index, *ASA* American Society of Anaesthesiologists, *BMI* body mass index

## Length of stay

The overall mean ± SD LOS was 3.0 ± 3.3 days (range 1–67 days). Patients ≥ 65 years had significantly longer LOS compared with younger patients (3.6 ± 3.5 vs 2.5 ± 3.1 days, $p$ < 0.001).

Univariable logistic regression showed that age > 65 years, American Society of Anaesthesiologists' (ASA) score, and surgical procedure were significantly associated with increased odds of extended LOS (Table 4). These parameters, in addition to sex and emergency surgery, were then included in a multivariable model. We found that emergency surgery (4.0 [2.1–7.7], $p$ < 0.001) and ASA score (1.9 [1.4–2.5], $p$ < 0.001) remained significantly associated with increased odds of extended LOS.

Looking at specific types of intraoperative AEs, dural tear (1.6 [1.2–2.3], $p$ = 0.004) and implant malposition requiring revision (7.1 [1.1–44.0], $p$ = 0.036) were significantly associated with increased odds of extended LOS. Regarding perioperative AEs, anemia (OR 3.2 [1.5–6.9], $p$ = 0.003). Fever of unknown origin (OR 3.4 [2.5–4.5], $p$ < 0.001), hematoma (OR 3.2 [ 2.0–5.3], $p$ < 0.001), electrolyte imbalance (OR 1.8 [1.2–2.7], $p$ = 0.004), urinary tract infection (OR 3.0 [2.0–4.5], $p$ < 0.001), and nausea/vomiting (OR 1.6 [1.1–2.2], $p$ = 0.019) were significantly associated with increased odds of extended LOS in our multivariable model (Table 4).

## Mortality

The in-hospital mortality rate was 0.1% ($n$ = 2). The causes of death were sepsis with subsequent multiorgan failure and a central nervous system (CNS) infection. The patients were 68 and 80 years old, and both were electively admitted. Both patients had one minor perioperative AE and no intraoperative AE. The 80-year-old patient with the CNS infection also had one major perioperative AE (urinary tract infection).

# Discussion

In the present study, we prospectively examined AEs in a consecutive cohort of patients undergoing spine surgery for lumbar or cervical degenerative diseases. In 1687 procedures, we found an overall AE rate of 47.4%. A previous review of retrospective studies reported complication rate between 5.0 to 19.3% in 7 cervical and 3.7 to 12.8% in 11 lumbar spine studies [6]. Nasser et al.'s review (80% were retrospective) found an overall complication rate of 16.4% in 105 studies, varying between 19.9% in the prospective and 16.1% in the retrospective studies [15]. In the studies included in both reviews, there was no consensus or consistent definition of AEs

**Table 2** Incidence of any adverse event per surgical procedure

| | Number of patients | Number of patients with any adverse event |
|---|---|---|
| Cervical procedures | | |
| Anterior discectomy and fusion (ACDF) with or without anterior plating | 246 | 92 (37.4%) |
| Corpectomy | 11 | 6 (54.5%) |
| Posterior decompression with or without fusion and instrumentation | 31 | 12 (38.7%) |
| Lumbar procedures | | |
| Foraminotomy or laminotomy and discectomy | 545 | 172 (31.6%) |
| Laminectomy | 389 | 191 (23.9%) |
| Anterior discectomy and fusion (ALIF) | 20 | 8 (40.0%) |
| Percutaneous minimal invasive instrumentation | 18 | 12 (66.7%) |
| Posterior fusion (TLIF and PLIF) with pedicle screw instrumentation | 325 | 229 (70.5%) |
| Non-instrumented posterior fusion | 102 | 78 (76.5%) |
| Total | 1687 | 800 (47.4%) |

Data is presented as numbers (incidence)

*AEs* adverse events, *ACDF* anterior cervical discectomy and fusion, *ALIF* anterior lumbar interbody fusion, *TLIF* transforaminal lumbar interbody fusion, *PLIF* posterior lumbar interbody fusion

or complications. The majority of the studies were retrospective which, as indicated in the study by Nasser et al., tended to underestimate the rate of complications.

In contrast, Street et al. reported the incidence of AEs in a prospective cohort of 942 patients using the SAVES system [20]. They found that AEs were more common, occurring at a mean rate of 0.1 intraoperative and 2.0 perioperative AEs per patient. In the present study, the mean rate per patient was similar for intraoperative AEs, although less frequent for perioperative AEs. However, the cohort presented by Street et al. consisted of patients undergoing more complex spine surgery, and procedures for degenerative diseases amounted to only 20% of procedures with a subsequent expected higher AE rate. Similarly, Karstensen et al. assessed AEs in a prospective cohort of 679 patients undergoing mainly complex spine procedures, using the same SAVES system [10]. Results were similar to the study by Street et al. (0.2 intraoperative and 2.1 perioperative AEs per patient) [20].

LOS was markedly shorter in the current study (3.0 days) compared with the studies by Street et al. [20] (13.7 days) and Karstensen et al. [10] (7.4 days), again presumably due to the difference in etiology and complexity of the surgery [8, 11, 19].

Female sex was significantly associated with having an AE. Previous studies have reported inconsistent results on being female and association with a higher occurrence of complications [5, 7, 9, 12, 22]. AEs were also more common in elderly patients (> 65 years). Age and the effect on AEs and complications have previously been inconsistently reported, and one should be careful of putting too much emphasis on age alone without any stratification in the risk-benefit estimation when contemplating spine surgery [2, 12, 13, 21].

## Length of stay

Reducing LOS is important in a patient perspective, in efforts to minimize risk of AEs (e.g., infections and deep vein thrombosis) and in reducing costs related to treatment [8, 23, 26]. Therefore, identifying potentially modifiable factors affecting LOS is crucial when developing preventative customized protocols as enhanced recovery after surgery (ERAS).

We found that emergency surgery co-morbidity (increasing ASA score), and surgical procedures were all associated with extended LOS. These are not modifiable factors but should be allocated added attention in efforts to reduce the risks related to extended LOS. Turning to potentially modifiable factors, electrolyte imbalance and nausea/vomiting were also associated with extended LOS. These are often regarded as minor AEs and not given much attention in previous studies related to complications despite being easily avoidable. The present results warrant future validation.

Length of stay can potentially be influenced by several different factors, and we therefore performed logistic regression analysis to adjust for clinically relevant patient characteristics and surgical variables when examining the effect of recorded AEs both intraoperatively and perioperatively on extended LOS. We recognize that there may be factors influencing LOS that were not included in our analysis. However, there is not a clear consensus in the literature regarding which factors that do significantly influence LOS [8, 19, 29]. We therefore hope our results can contribute to the body of knowledge.

**Table 3** Patient characteristics' effect on any adverse event. Univariable and multivariable logistic regression

| | Univariable model OR (95% CI) | *p* value | Multivariable model OR (95% CI) | *p* value |
|---|---|---|---|---|
| Age > 65 years | 1.6 (1.3–1.9) | < 0.001† | 1.4 (1.1–1.7) | 0.012† |
| Sex (female) | 1.7 (1.4–2.0) | < 0.001† | 1.5 (1.2–1.9) | < 0.001† |
| Emergency surgery | 0.6 (0.4–0.9) | 0.010† | 1.0 (0.6–1.5) | 0.979 |
| ASA-score | 1.3 (1.1–1.5) | 0.003† | 1.0 (0.9–1.2) | 0.846 |
| Obesity (BMI>30kg/m$^2$) | 1.4 (1.1–1.7) | 0.005† | 1.2 (1.0–1.6) | 0.074 |
| Surgical procedure | | | | |
| Lumbar foraminotomy or laminotomy and discectomy | Ref. | Ref. | Ref. | Ref. |
| Cervical procedure | | | | |
| Anterior discectomy and fusion (ACDF) with or without anterior plating | 1.3 (0.9–1.8) | 0.107 | 1.4 (1.0–1.9) | 0.068 |
| Corpectomy | 2.6 (0.8–8.6) | 0.118 | 2.6 (0.8–8.8) | 0.126 |
| Posterior decompression with or without fusion and instrumentation | 1.4 (0.7–2.9) | 0.408 | 1.2 (0.6–2.7) | 0.576 |
| Lumbar procedure | | | | |
| Laminectomy | 2.1 (1.6–2.7) | < 0.001† | 1.8 (1.3–2.4) | < 0.001† |
| Anterior discectomy and fusion (ALIF) | 1.4 (0.6–3.6) | 0.429 | 1.4 (0.5–3.5) | 0.500 |
| Percutaneous minimal invasive instrumentation | 4.3 (1.6–11.7) | 0.004† | 4.4 (1.6–12.1) | 0.004† |
| Posterior fusion (TLIF and PLIF) with pedicle screw instrumentation | 5.2 (3.8–7.0) | < 0.001† | 5.0 (3.7–6.8) | < 0.001† |
| Non-instrumented posterior fusion | 7.0 (4.3–11.5) | < 0.001† | 5.6 (3.3–9.4) | < 0.001† |

*OR* odds ratio, *CI* confidence interval, *ASA score* American Society of Anaesthesiologists, *BMI* body mass index, *ACDF* anterior cervical discectomy and fusion, *ALIF* anterior lumbar interbody fusion, *TLIF* transforaminal lumbar interbody fusion, *PLIF* posterior lumbar interbody fusion

†$p<0.05$

## Mortality

The mortality rate was low as expected since the majority of cases were elective and therefore underwent preoperative risk assessment. The number of deaths was too low for meaningful logistic regression analysis.

## Strength and limitations

The prospective and systematic registration of AEs more accurately describe the true incidence [10, 15, 20]. The 100% cohort completeness minimizes the risk of selection bias and adds to the external validity. This was a single-center study performed at a dedicated surgical department for degenerative spine disease which is the only public hospital serving 2.5 million. The patient population, therefore, represents an appropriate cross section of the total population. In addition, the short study period of 1 year reduces the risk of significant changes in treatment principles.

The types of AEs used in the SAVES system are often monitored and recorded in the clinical setting at our hospital, and implementation did therefore not cause added staff strain or require specific added instructions. AEs were registered prospectively and coordinated by a research administrator not involved in clinical treatment, which further minimizes the effect of recall bias as when reported by the surgeon [4]. The prospective nature and the use of predefined AEs in the SAVES system allowed for a more objective assessment and data aggregation in efforts to more thoroughly understand the complexity of factors associated with outcome. Both minor and major complications have previously been associated with increased costs of care in spine surgery [3, 10, 27].

However, despite exhaustive efforts to detect every predefined AE, all AEs may not have been captured. Although the SAVES system incorporates a category for miscellaneous AEs, there may be subtypes of relevance not included in the predefined categories. Furthermore, as the decision to operate was at the surgeon's discretion, although in accordance with relevant guidelines, an extent of selection bias may be present by excluding patients with severe comorbidities from surgery.

# Conclusion

Based on prospectively registered AEs in this single-center study, we validated the use of the SAVES system in a European population undergoing surgery due to degenerative spine disease. We found that AEs were more common than

**Table 4** Assessment of adverse events and the effect on extended length of stay. Univariable and multivariable logistic regression

| | Univariable model OR (95% CI) | *p* value | Multivariable model OR (95% CI) | *p* value |
|---|---|---|---|---|
| Age (> 65 years) | 2.4 (1.8–3.2) | < 0.001† | 1.3 (0.9–2.0) | 0.184 |
| Sex (female) | 1.0 (0.8–1.3) | 0.926 | 0.8 (0.6–1.2) | 0.352 |
| Emergency surgery | 1.3 (0.8–2.2) | 0.269 | 4.7 (2.4–9.5) | < 0.001† |
| ASA score | 2.2 (1.7–2.7) | < 0.001† | 2.0 (1.4–2.7) | < 0.001† |
| Obesity (BMI > 30 kg/m$^2$) | 1.5 (1.1–2.0) | 0.010† | 1.2 (0.8–1.8) | 0.368 |
| Surgical procedure | | | | |
| Lumbar foraminotomy or laminotomy and discectomy | Ref. | Ref. | Ref. | Ref. |
| Cervical procedure | | | | |
| Anterior discectomy and fusion (ACDF) with or without anterior plating | 2.3 (1.3–4.2) | 0.004† | 2.9 (1.4–6.1) | 0.004† |
| Corpectomy | 4.8 (1.0–23.6) | 0.052 | 2.8 (0.4–19.5) | 0.292 |
| Posterior decompression with or without fusion and instrumentation | 23.2 (10.3–52.3) | < 0.001† | 35.2 (13.8–89.9) | < 0.001† |
| Lumbar procedure | | | | |
| Laminectomy | 2.8 (1.7–4.7) | < 0.001† | 1.7 (0.9–3.2) | 0.112 |
| Anterior discectomy and fusion (ALIF) | 1.1 (0.1–8.9) | 0.899 | 1.1 (0.1–13.6) | 0.955 |
| Percutaneous minimal invasive instrumentation | 6.2 (1.9–4.7) | 0.003† | 4.7 (1.1–20.9) | 0.042† |
| Posterior fusion (TLIF and PLIF) with pedicle screw instrumentation | 7.7 (4.8–12.4) | < 0.001† | 3.8 (2.0–7.0) | < 0.001† |
| Non-instrumented posterior fusion | 9.0 (5.0–16.3) | < 0.001† | 4.0 (1.9–8.7) | < 0.001† |
| Intraoperative AE | | | | |
| Anesthesia related | 0.8 (0.1–5.1) | 0.839 | | |
| Dural tear | 2.0 (1.6–2.6) | < 0.001† | 1.8 (1.3–2.5) | < 0.001† |
| Implant malposition requiring revision | 10.0 (1.9–53.1) | 0.007† | 6.5 (1.0–43.1) | 0.055 |
| Major blood loss | 10.2 (1.3–80.1) | 0.027† | 0.7 (0.1–5.4) | 0.727 |
| Airway/ventilation | 3.2 (0.3–35.0) | 0.348 | | |
| Postoperative AE | | | | |
| Anemia | 10.7 (5.0–22.0) | < 0.001† | 4.6 (2.1–10.1) | < 0.001† |
| Cardiac arrhythmia/arrest | 3.6 (1.1–11.9) | 0.038† | 0.8 (0.1–5.5) | 0.856 |
| CSF leakage/meningocele | 1.8 (0.5–5.9) | 0.348 | | |
| Delirium | 6.1 (1.9–19.7) | 0.003† | 2.8 (0.8–10.3) | 0.122 |
| Dysphagia | 2.4 (1.3–4.4) | 0.005† | 2.2 (0.9–5.4) | 0.087 |
| Dysphonia | 1.2 (0.4–3.0) | 0.762 | | |
| Fever of unknown origin | 3.7 (2.9–4.8) | < 0.001† | 3.4 (2.5–4.5) | < 0.001† |
| Hematoma | 3.8 (2.6–5.6) | < 0.001† | 3.2 (2.0–5.3) | < 0.001† |
| Electrolyte imbalance | 5.8 (4.4–7.8) | < 0.001† | 1.8 (1.2–2.7) | 0.004† |
| Neurological deterioration (< 1 motor grade ASIA scale) | 2.0 (0.5–7.3) | 0.309 | | |
| Pneumonia | 3.4 (1.9–6.0) | < 0.001† | 1.4 (0.7–2.9) | 0.348 |
| Superficial wound infection | 10.2 (1.3–80.1) | 0.027† | 5.1 (0.5–49.7) | 0.158 |
| Urinary tract infection | 4.4 (3.2–6.1) | < 0.001† | 3.0(2.0–4.5) | < 0.001† |
| Wound dehiscence | 2.3 (0.5–10.2) | 0.260 | | |
| Nausea/vomiting | 1.8 (1.4–2.3) | < 0.001† | 1.6 (1.1–2.2) | 0.019† |
| Medication related | 2.4 (1.7–3.4) | < 0.001† | 1.6 (1.0–2.6) | 0.057 |

*OR* odds ratio, *CI* confidence interval, *ASA* American Society of Anaesthesiologists, *BMI* body mass index, *ACDF* anterior cervical discectomy and fusion, *ALIF* anterior lumbar interbody fusion, *TLIF* transforaminal lumbar interbody fusion, *PLIF* posterior lumbar interbody fusion

†$p < 0.05$

previously reported in retrospective studies. Major AEs occurred more frequently perioperatively than intraoperatively, and in patients > 65 years. We believe that this study adds significantly to our understanding of the AE burden in degenerative spine surgery and may prove important in both patient counseling and when deciding to perform surgery.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

## References


1. Bari TJ, Karstensen S, Sørensen MD, Gehrchen M, Street J, Dahl B (2020) Revision surgery and mortality following complex spine surgery: 2-year follow-up in a prospective cohort of 679 patients using the Spine AdVerse Event Severity (SAVES) system. Spine Deform 20(5):717–729
2. Boakye M, Patil CG, Santarelli J, Ho C, Tian W, Lad SP (2008) Cervical spondylotic myelopathy: complications and outcomes after spinal fusion. Neurosurgery 62(2):455–461
3. Calland JF, Guerlain S, Adams RB, Tribble CG, Foley E, Chekan EG (2002) A systems approach to surgical safety. Surg Endosc 16(6):1005–1014
4. Chen BP, Garland K, Roffey DM, Poitras S, Dervin G, Lapner P, Phan P, Wai EK, Kingwell SP, Beaulé PE (2017) Can surgeons adequately capture adverse events using the Spinal Adverse Events Severity System (SAVES) and OrthoSAVES? Clin Orthop Relat Res 475(1):253–260
5. Cloyd JM, Acosta FL, Cloyd C, Ames CP (2010) Effects of age on perioperative complications of extensive multilevel thoracolumbar spinal fusion surgery. J Neurosurg Spine 12(4):402–408
6. Dekutoski MB, Norvell DC, Dettori JR, Fehlings MG, Chapman JR (2010) Surgeon perceptions and reported complications in spine surgery. Spine (Phila Pa 1976) 35(Supplement):S9–S21
7. Deyo RA, Cherkin DC, Loeser JD, Bigos SJ, Ciol MA (1992) Morbidity and mortality in association with operations on the lumbar spine. The influence of age, diagnosis, and procedure. J Bone Joint Surg Am 74(4):536–543
8. Gruskay JA, Fu M, Bohl DD, Webb ML, Grauer JN (2015) Factors affecting length of stay after elective posterior lumbar spine surgery: a multivariate analysis. Spine J 15(6):1188–1195
9. Kalanithi PS, Patil CG, Boakye M (2009) National complication rates and disposition after posterior lumbar fusion for acquired spondylolisthesis. Spine (Phila Pa 1976) 34(18):1963–1969
10. Karstensen S, Bari T, Gehrchen M, Street J, Dahl B (2016) Morbidity and mortality of complex spine surgery: a prospective cohort study in 679 patients validating the Spine AdVerse Event Severity (SAVES) system in a European population. Spine J 16(2): 146–153
11. Lau D, Han SJ, Lee JG, Lu DC, Chou D (2011) Minimally invasive compared to open microdiscectomy for lumbar disc herniation. J Clin Neurosci 18(1):81–84
12. Lee MJ, Konodi MA, Cizik AM, Bransford RJ, Bellabarba C, Chapman JR (2012) Risk factors for medical complication after spine surgery: a multivariate analysis of 1,591 patients. Spine J 12(3):197–206
13. Li G, Patil CG, Lad SP, Ho C, Tian W, Boakye M (2008) Effects of age and comorbidities on complication rates and adverse outcomes after lumbar laminectomy in elderly patients. Spine (Phila Pa 1976) 33(11):1250–1255
14. Mirza SK, Deyo RA, Heagerty PJ, Turner JA, Lee LA, Goodkin R (2006) Towards standardized measurement of adverse events in spine surgery: conceptual model and pilot evaluation. BMC Musculoskelet Disord 7(1):53
15. Nasser R, Yadla S, Maltenfort MG et al (2010) Complications in spine surgery. J Neurosurg Spine 13(2):144–157
16. Rampersaud YR, Anderson PA, Dimar JR, Fisher CG, __ (2016) Spinal Adverse Events Severity System, version 2 (SAVES-V2): inter- and intraobserver reliability assessment. J Neurosurg Spine 25(2):256–263
17. Rampersaud YR, Moro ERP, Neary MA, White K, Lewis SJ, Massicotte EM, Fehlings MG (2006) Intraoperative adverse events and related postoperative complications in spine surgery: implications for enhancing patient safety founded on evidence-based protocols. Spine (Phila Pa 1976) 31(13):1503–1510
18. Rampersaud YR, Neary MA, White K (2010) Spine adverse events severity system: content validation and interobserver reliability assessment. Spine (Phila Pa 1976) 35(7):790–795
19. Siemionow K, Pelton MA, Hoskins JA, Singh K (2012) Predictive factors of hospital stay in patients undergoing minimally invasive transforaminal lumbar interbody fusion and instrumentation. Spine (Phila Pa 1976) 37(24):2046–2054
20. Street JT, Lenehan BJ, DiPaola CP, Boyd MD, Kwon BK, Paquette SJ, Dvorak MFS, Rampersaud YR, Fisher CG (2012) Morbidity and mortality of major adult spinal surgery. A prospective cohort analysis of 942 consecutive patients. Spine J 12(1):22–34
21. Tetreault L, Ibrahim A, Cote P, Singh A, Fehlings MG, Côté P, Singh A, Fehlings MG (2016) A systematic review of clinical and surgical predictors of complications following surgery for degenerative cervical myelopathy. J Neurosurg Spine 24(1):77–99
22. Tetreault L, Tan G, Kopjar B, Côté P, Arnold P, Nugaeva N, Barbagallo G, Fehlings MG (2016) Clinical and surgical predictors of complications following surgery for the treatment of cervical spondylotic myelopathy. Neurosurgery 79(1):33–44
23. Trouillet J-L, Chastre J, Vuagnat A, Joly-Guillou M-L, Combaux D, Dombret M-C, Gibert C (1998) Ventilator-associated pneumonia caused by potentially drug-resistant bacteria. Am J Respir Crit Care Med 157(2):531–539
24. Vincent C, Moorthy K, Sarker SK, Chang A, Darzi AW (2004) Systems approaches to surgical quality and safety. Ann Surg 239(4):475–482
25. Vos T, Flaxman AD, Naghavi M et al (2012) Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 380(9859):2163–2196
26. White RH, Zhou H, Romano PS (1998) Length of hospital stay for treatment of deep venous thrombosis and the incidence of recurrent thromboembolism. Arch Intern Med 158(9):1005
27. Whitmore RG, Stephen J, Stein SC, Campbell PG, Yadla S, Harrop JS, Sharan AD, Maltenfort MG, Ratliff JK (2012) Patient comorbidities and complications after spinal surgery: a societal-based cost analysis. Spine (Phila Pa 1976) 37(12):1065–1071
28. Yadla S, Malone J, Campbell PG, Maltenfort MG, Harrop JS, Sharan AD, Ratliff JK (2010) Early complications in spine surgery and relation to preoperative diagnosis: a single-center prospective study. J Neurosurg Spine 13(3):360–366
29. Zheng F, Cammisa FP, Sandhu H, Girardi FP, Khan SN (2002) Factors predicting hospital stay, operative time, blood loss, and transfusion in patients undergoing revision posterior lumbar spine decompression, fusion, and segmental instrumentation. Spine (Phila Pa 1976) 27(8):818–824


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