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# Risk factors for perioperative morbidity in spine surgeries of different complexities: a multivariate analysis of 1009 consecutive patients

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Abstract: BACKGROUND CONTEXT There is a broad spectrum of complications during or after surgical procedures, with differing incidences reported in the published literature. Heterogeneity can be explained by the lack of an established evidence-based classification system for documentation and classification of complications in a standardized manner. PURPOSE To identify predictive risk factors for peri- and early post-operative morbidities in spine surgeries of different complexities in a large cohort of consecutive patients. STUDY DESIGN Retrospective case series. OUTCOME MEASURES Occurrence of peri- and early post-operative morbidities. METHODS A classification of surgical complexity (grade I-III) was created and applied to 1009 patients who consecutively underwent spine surgery at a single university hospital. The incidence and type of peri- and early post-operative morbidities were documented. Multivariate binary logistic regression analyzed risk factors for (a) hospital stay 10 days, (b) intermediate care unit (IMC) stay 24 hours, (c) blood loss>500mL, and occurrence of a (d) surgical or (e) medical morbidity. RESULTS A deviation from the regular postoperative course (defined as "morbidity") included surgical reasons such as relapse of symptoms of any kind (3.3%), wound healing problems (2.4%), implant-associated complications (1.6%), post-operative neurological deficits (1.5%), infection (1.5%), fracture (0.8%), and dural tear in need of revision (0.6%). Medical reasons included anemia (1.8%), symptomatic electrolyte derailment (1.0%), and cardiac complications (0.7%), among others. An independent risk factor associated with a surgical reason for an irregular post-operative course was male gender. For a medical reason high creatinine levels preoperatively, higher blood loss, and systemic steroid use were identified as risk factors. Independent risk factors for a prolonged hospitalization were preoperatively high CRP, prolonged postoperative IMC stay, and revision surgery. Spinal stabilization/-fusion surgery, particularly if involving the lumbosacral spine, age, and length of surgery were associated with a blood loss>500mL. Higher surgical complexity, involvement of the pelvis in instrumentation, ASA class 3, and higher creatinine levels preoperatively were associated with a postoperative IMC stay>24 hours. CONCLUSION The present study confirms several modifiable and non-modifiable risk factors for peri- and early post-operative morbidities in spine surgery, among which surgical factors (complexity, revision surgery, instrumentation (including the pelvis etc.)) play a crucial role. A classification of surgical complexity is proposed and validated.

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# Risk Factors for Perioperative Morbidity in Spine Surgeries of Different Complexities: A Multivariate Analysis of 1009 Consecutive Patients

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Conflicts of Interest:
none

## ABSTRACT

*BACKGROUND CONTEXT:* There is a broad spectrum of complications during or after surgical procedures, with differing incidences reported in the published literature.

Heterogeneity can be explained by the lack of an established evidence-based classification system for documentation and classification of complications in a standardized manner.

*PURPOSE*: To identify predictive risk factors for peri- and early post-operative morbidities in spine surgeries of different complexities in a large cohort of consecutive patients.

*STUDY DESIGN:* Retrospective case series.

*OUTCOME MEASURES:* Occurrence of peri- and early post-operative morbidities.

*METHODS*: A classification of surgical complexity (grade I-III) was created and applied to 1009 patients who consecutively underwent spine surgery at a single university hospital. The incidence and type of peri- and early post-operative morbidities were documented. Multivariate binary logistic regression analyzed risk factors for (a) hospital stay≥10 days, (b) intermediate care unit (IMC) stay≥24 hours, (c) blood loss>500mL, and occurrence of a (d) surgical or (e) medical morbidity.

*RESULTS*: A deviation from the regular postoperative course (defined as "morbidity") included surgical reasons such as relapse of symptoms of any kind (3.3%), wound healing problems (2.4%), implant-associated complications (1.6%), post-operative neurological deficits (1.5%), infection (1.5%), fracture (0.8%), and dural tear in need of revision (0.6%). Medical reasons included anemia (1.8%), symptomatic electrolyte derailment (1.0%), and cardiac complications (0.7%), among others. An independent risk factor associated with a surgical reason for an irregular post-operative course was male gender. For a medical reason high creatinine levels preoperatively, higher blood loss, and systemic steroid use were identified as risk factors. Independent risk factors for a prolonged hospitalization were preoperatively high CRP, prolonged postoperative IMC stay, and revision surgery. Spinal stabilization/fusion surgery, particularly if involving the lumbosacral spine, age, and length of surgery were associated with a blood loss>500mL. Higher surgical complexity, involvement of the pelvis in instrumentation, ASA class≥3, and higher creatinine levels preoperatively were associated with a postoperative IMC stay>24 hours.

*CONCLUSION*: The present study confirms several modifiable and non-modifiable risk factors for peri- and early post-operative morbidities in spine surgery, among which surgical factors (complexity, revision surgery, instrumentation (including the pelvis etc.)) play a crucial role. A classification of surgical complexity is proposed and validated.

**Keywords:** complication, morbidity, spine surgery, revision, risk, blood loss, classification, hospital stay

## INTRODUCTION

Over the last decade, a steady increase in the number of spinal fusion surgeries was noted, with a reported increase of more than 55% from 2001 to 2010. Interestingly, besides increasing average costs, trend analyses showed a steady increase of average patient age at surgery[1], thereby creating a potentially changing spectrum of patient-associated risk factors. While the mortality rate was reported to be steady over time, increasing trends for perioperative complications were postulated.[1] There is a broad spectrum of complications during or after surgical procedures, with differing incidences reported in the published literature. Heterogeneity can be explained by the lack of an established evidence-based classification system for documentation and classification of complications in a standardized manner. Among the most commonly reported postoperative morbidities and/or complications are wound-related, pain-related, thromboembolic, or complications due to an infection. Factors such as surgical invasiveness, advanced patient age, higher ASA class, prolonged length of surgery, and a prolonged hospital length of stay, among others, have previously been reported as independent risk factors for an unplanned readmission after prior surgery, perioperative morbidity and/or complications.[2–5] While the majority of available data is collected in the setting of the United States healthcare system, little information exists for European countries. Furthermore, the majority of prior studies is based on multicenter databases with a large number of included institutions with an uncontrollable amount of biases produced both by different treatment regimens and methodologies of documentation and reporting. As previously suggested by different authors, despite several strengths of large-scale national databases, limitations associated with their use in the setting of surgical research need to be considered when interpreting such study results.[6,7] The aim of the present study therefore was to analyze potential risk factors for different morbidities and irregular courses in the peri- and early post-operative period after spine surgery in a large cohort of patients consecutively operated in a single-center, academic tertiary Swiss setting.

# MATERIALS & METHODS

## *Study Population*

After approval of the local ethical committee, patients who consecutively underwent spine surgery between 05/2014 and 12/2015 at a single Swiss university clinic were included in the present study if the following criteria were met: available data set, age at surgery > 18 years, and absence of a refusal to participate in scientific research studies. During the outpatient doctor's consultation, the indication for surgical intervention was assessed by a single attending spine surgeon. If surgery was necessary, a surgical date was defined based on medical priority. According to an institutional guideline, a departmental meeting is held 1-2 weeks prior to each surgery in order to discuss the indication for surgery, review all available imaging studies, and to define the level of surgery, as well as the needed surgical technique.

Since the majority of scoliosis patients were excluded due to an age of less than 18 years, other patients who underwent scoliosis surgery at a more advanced age were also excluded to reduce the risk of bias. All patients were postoperatively followed at least until the first postoperative outpatient consultation, which was usually conducted within the first 4-6 weeks after surgery. Any deviation from the regular postoperative course was defined as either a medical or surgical morbidity. Loss of follow up after the first postoperative visit after 4-6 weeks was not an exclusion criterion since the herein posed research question is specifically focused on peri-, and early postoperative morbidity. The term "complication" was not used in the present analysis on purpose, since a definition of complications during spine surgery is still missing.

Data were collected on age, gender, body mass index (BMI), medication, smoking status, preoperative American Society of Anesthesiologists (ASA) classification[8,9], laboratory values as well as surgical details such as clinical/radiographic surgical indication, blood loss, length of surgery, revision surgery, and type of surgery. Furthermore, postoperative length of intermediate care unit (IMC) and hospital stay were documented.

***Surgical Complexity Classification***

A consensus statement was defined to categorize procedures to quantify the complexity of surgical procedures (Table 1). Standard elective spine surgical interventions performed at a university hospital with tertiary care duties were classified into 3 different categories, based on the rating of the individual surgeons of the spine division (chief surgeon, 3 attending surgeons).

Complexity category I was defined as a standard spine surgical intervention an orthopedic surgeon should be able to perform under supervision after completion of residency. Complexity category II was defined as a spine surgical intervention a spine surgeon should be able to perform after completion of advanced surgical training (e.g. fellowship). Complexity category III was defined as a spine surgical intervention that should only be performed by a spine surgeon with a high level of expertise and perennial work experience.



***Statistical Analysis***

Continuous variables are reported as mean±standard deviation (SD), whereas categorical variables are reported as frequencies and proportions. The Kolmogorov Smirnov test was used to test for a normal distribution of data. Due to a non-normal distribution of data, the Mann-Whitney U test was used for the comparison of continuous variables. The Pearson's chi squared test was used for the comparison of proportions between groups. Univariate comparison of continuous variables between the different groups of surgical complexity (categories I-III) was performed via analysis of variance (ANOVA) in the setting of a normal distribution of data, or via the Kruskal-Wallis test in the setting of a non-normal distribution.

In order to control for potential confounding factors, binary logistic regression was performed to assess risk factors for (a) hospital stay ≥10 days, (b) post-operative IMC stay ≥24 hours, (c) blood loss >500mL, and occurrence of (d) a surgical or (e) medical morbidity in the early postoperative period. Risk factors identified in the univariate analysis with a p-value < 0.05 were analyzed via binary logistic regression models as follows: statistically significant risk factors identified via forward and/or backward stepwise logistic regression were then entered in the final multivariate binary logistic regression analysis models. The extent of surgical intervention is reflected by the length of surgery, and as such, included as a variable in the binary logistic regression models. The results of binary logistic regression are listed as adjusted odds ratios (aOR) with the 95% confidence intervals (CI). Goodness of fit of the binary logistic regression models was assessed via the Hosmer-Lemeshow test. Statistical significance was defined as a p-value < 0.05. Data analysis was performed using IBM SPSS Statistics, Version 24.0 (IBM Corp., Armonk, NY).

# RESULTS

## *Study Population*

In the previously defined observation period, a total of 1067 patients consecutively underwent spine surgery at a single center, out of whom 1009 (F: 481, M: 528) met the defined criteria to be included in the present study (94.6%). The average age at surgery was 60.9±15.7 (range: 18.3-93.7) years, and the average BMI 27.3±5.1 (range: 12.5-55.8) kg/$m^2$. Overall, active smoking status was reported in 35.9% of patients (n=362). Preoperative assessment revealed an ASA class I in 19.5%, class II in 55.7%, class III in 23.3%, and class IV in 1.5%. None of the patients was classified as ASA class V. Systemic steroid use, a previously identified risk factor for complications[5], was documented in 45 cases (4.5%).

## *Surgical Details*

Surgeries were performed at the cervical (n=88; 8.7%), cervicothoracic (n=12; 1.2%), thoracic (n=33; 3.3%), thoracolumbar (n=38; 3.8%), lumbar (n=528; 52.3%), and lumbosacral (n=321; 31.9%) spine. In 0.9% of cases (n=9), the pelvis was included in the surgical approach. Of all procedures, 32.1% were a revision surgery. The main clinical indications for surgical intervention are listed in table 2.

The most commonly performed type of surgical intervention was decompression surgery (54.7%). The average length of surgery was 145.5±69.9 (range: 10.0-405.0) minutes, with an average length of anesthesia of 192.0±70.9 (range: 50.0-480.0) minutes. Blood loss was estimated at 288.3±298.1 (range: 0-2800.0) milliliters on average. Patients stayed at the IMC for an average of 7.8±13.4 (range: 0-182.0) hours, and the average length of hospital stay was 6.1±3.6 (range: 0-48.0) days, on average.

***Surgical Complexity (Categories I-III)***

Results of the univariate sub-group analysis comparing patients assigned to the different categories of surgical complexity are shown in table 3. With an increasing degree of surgical complexity, there was a significantly increased length of surgery ($p<0.001$), amount of bloodloss ($p<0.001$), length of IMC stay ($p<0.001$), and length of hospital stay ($p<0.001$). Furthermore, there was a significantly different distribution of ASA classes ($p=0.019$), as shown in table 3. There was an increasing rate of surgical morbidities with higher complexity grades, which however did not reach level of statistical significance. There was a significantly different rate of medical morbidities with higher complexity grades ($p=0.015$). In order to control for potential confounding factors, multiple binary logistic regression analyses were performed as listed below.

***Spectrum of Morbidities***

A morbidity was defined by any kind of irregular peri- and/or early post-operative course for the purpose of the present study. A deviation from the regular postoperative course included surgery-associated reasons such as relapse of symptoms of any kind (3.3%), followed by wound healing problems (2.4%), implant-associated morbidities (1.6%), post-operative neurological deficits (1.5%), infection (1.5%), a fracture (0.8%), and a dural tear in need of revision surgery (0.6%), among others. Medical reasons included postoperative symptomatic anemia (1.8%), symptomatic electrolyte derangement (1.0%), cardiac morbidities (0.7%), pulmonary morbidities (0.5%), and renal morbidities (0.4%), among others (1.6%).

***Influence of an Irregular Peri-/Post-operative Course on IMC/hospital stay***

Based on univariate comparison of length of IMC stay between patients with versus without a surgical cause for an irregular peri-/post-operative course, there was no statistically significant difference (7.6±9.7 versus 7.8±13.8 days; $p=0.369$). There was a significantly longer hospital stay in patients with a surgical cause for an irregular peri-/post-operative course (7.3±5.5 days) versus patients without (5.9±3.2), with a p-value of 0.022.

Based on univariate comparison of length of IMC stay between patients with versus without a medical cause for an irregular peri-/post-operative course, there was a statistically significant difference for both the length of IMC stay and overall hospital stay. In fact, the average length of IMC stay was 20.7±25.2 versus 7.2±12.2 hours ($p<0.001$) in patients with versus without a medical cause for an irregular peri-/post-operative course. There also was a significantly longer hospital stay in patients with a medical cause for an irregular peri-/post-operative course (8.0±5.4 versus 6.0±3.4 days, $p<0.001$).

***Length of Hospital Stay***

Multivariate analysis identified preoperative CRP (aOR: 1.935; 95%CI: 1.314-2.849; p=0.001), length of IMC stay (aOR: 1.876; 95%CI: 1.092-3.222; p=0.023), and revision surgery (aOR: 1.716; 95%CI: 1.022-2.882; p=0.041) as factors significantly associated with a hospital stay of ≥10 days. Increased preoperative hemoglobin was associated with a decreased risk for a hospital stay ≥ 10 days (aOR: 0.976; 95%CI: 0.960-0.992; p=0.004). The Hosmer-Lemeshow test confirmed goodness of fit of the model (p=0.972).

***Length of IMC Stay***

Multivariate analysis identified preoperative creatinine (aOR: 16.197; 95%CI: 1.703-154.085; p=0.015), surgery involving the pelvis (aOR: 7.538; 95%CI: 1.347-42.181; p=0.021), surgical complexity category III (aOR: 5.351; 95%CI: 1.536-18.638; p=0.008), surgical complexity category II (aOR: 3.480; 95%CI: 1.798-6.733; $p<0.001$), and ASA class ≥ 3 (aOR: 3.119; 95%CI: 1.157-8.412; p=0.025) as significantly associated with a IMC stay of ≥24 hours. The Hosmer-Lemeshow test confirmed goodness of fit of the model (p=0.435).

***Blood Loss***

Multivariate analysis identified spinal stabilization/fusion surgery (aOR: 3.198; 95%CI: 1.731-5.906; p<0.001), surgery involving the lumbosacral spine (aOR: 2.845; 95%CI: 1.428-5.666; p=0.003), age (aOR: 1.025; 95%CI: 1.007-1.044; p=0.007), and length of surgery (aOR: 1.018; 95%CI: 1.014-1.022; p<0.001) as factors significantly associated with a blood loss of > 500 milliliters. The Hosmer-Lemeshow test confirmed goodness of fit of the model (p=0.606).

***Surgical Causes for an Irregular Peri-/Post-operative Course***

Multivariate analysis identified male gender (aOR: 1.679; 95%CI: 1.112-2.536; p=0.014) as being significantly associated with the occurrence of a surgical morbidity in the peri- or early post-operative period. Increased age was slightly associated with a decreased risk of a surgical morbidity in the peri- or early post-operative period (aOR: 0.982; 95%CI: 0.969-0.994; p=0.004). Surgical morbidities on the other hand were associated with the length of hospital stay (aOR: 1.096; 95%CI: 1.047-1.147; p<0.001). The Hosmer-Lemeshow test confirmed goodness of fit of the model (p=0.422).

***Medical Causes for an Irregular Peri-/Post-operative Course***

Multivariate analysis identified preoperatively high creatinine levels (aOR: 27.657; 95%CI: 1.769-432.456; p=0.018), blood loos (aOR: 17.954; 95%CI: 5.412-59.563; p<0.001), and systemic steroid use (aOR: 4.970; 95%CI: 1.523-16.216; p=0.008) as factors significantly associated with the occurrence of a medical morbidity in the peri- or early post-operative period. The Hosmer-Lemeshow test confirmed goodness of fit of the model (p=0.786).

## DISCUSSION

There is a plethora of potential risk factors associated with a peri- and early post-operative deviation of regular post-operative cause, morbidities and complications.[2–5] However, the complexity of a surgical procedure per se has not been considered sufficiently up to date. Large studies with single center data on consecutive patients with sufficient documentation are scarce at best and not present for the Swiss setting, to the best of the authors' knowledge. As a result, heterogeneity remains and comparison of the results of studies in different healthcare settings is challenging. The aim of the present study therefore was to assess potential risk factors for morbidities (defined by any deviation of a regular post-operative course for the purpose of the present study) in the peri- and early postoperative period in a large cohort of patients consecutively operated in a single-center, academic tertiary Swiss setting. Several factors, as described above, were considered and their associations with intra- and early postoperative morbidities were successfully quantified.

In the present study, we describe overall rates of 11.3% and 4.5% deviations from a regular peri-operative course caused by surgical and medical factors, respectively, which can be explained by the tertiary care setting with a high proportion of morbid patients, in addition to a high proportion of revision surgeries (approximately one third of cases) and complex procedures. However, these rates lie below or within the rates reported in the literature, to the best of the authors' knowledge[5,10–16]. In fact, as reported by Nasser et al.[16] in a systematic review including 105 articles, an overall complication incidence of 16.4% per patient was identified, which lies above the herein reported complication rate. However, due to a lack of an internationally established definition of a "complication" in spine surgery, comparability of different studies remains limited.

One quarter of patients were classified as ASA grade ≥ 3 by the anesthesiologists. The American Society of Anesthesiologists (ASA) Physical Status Classification System is used to preoperatively assess and categorize the medical health and associated risk of patients undergoing surgery.[8,9] As previously reported by Whitmore et al., an increasing ASA grade was a significant risk factor for a major complication, as assessed in a prospective study of 226 patients undergoing spine surgery at a single academic tertiary center. Interestingly, the authors also found a significant association with increasing direct costs.[17] This concurs with the results of a retrospective analysis of the Scoliosis Research Society Morbidity and Mortality database including 22857 patients who had undergone spine surgery, with a reported overall complication rate of 8.4%. While the rate of complications was 5.4% in ASA class I patients, this rate increased to 20.3% and 50.0% in ASA class IV and V patients, respectively.[18] In the present study, a similar increase in morbidity rate was observed in the different ASA classes. While the rate of surgical morbidities was 11.7% in ASA class I patients, this rate increased to 20.0% in ASA class IV patients. An even steeper increase was noted for the rates of medical morbidities. While in none of the patients within the ASA class I a medical morbidity was documented, 12.3% and 40.0% of patients in ASA classes III and IV developed a medical morbidity, respectively. With regard to the results of binary logistic regression analysis, ASA class $\geq 3$ was associated with an IMC stay of >24 hours, thereby also increasing the risk for a prolonged hospital stay.

We further created and validated a classification for complexity of surgical procedures (table 1), as the complexity of a surgical procedure was plausibly associated with longer IMC and thereby length of hospitalization. Further, univariate analysis revealed a significantly increased length of surgery, amount of blood-loss, length of IMC stay, and length of hospital stay in the setting of an increasing degree of surgical complexity. Multivariate analysis confirmed this finding for an increased length of IMC stay. In fact, with complexity class I as the reference, complexity classes II and III showed a 3.5-fold and 5.4-fold increase in risk for an IMC stay longer than 24 hours, which was further identified as an independent risk factor for an increased length of hospital stay via multivariate analysis. However, apart from many factors that were associated with an irregular postoperative course (including elevated CRP, revision surgery, high ASA scores, duration and complexity of surgery, among others), some factors such as BMI were surprisingly not associated with an increased blood loss, length of IMC or hospital stay, or incidence of complications in the herein performed analysis.

In a trend analysis analyzing spine fusion surgeries from 2001 to 2010, a relatively stable mortality rate at around 1 percent was reported, however the authors noted a steadily increasing age at surgery, as well as an increasing morbidity.[1] In another study, an age at surgery exceeding 80 years was associated with the highest mortality risk. Furthermore, advanced age was found to be significantly associated with the postoperative occurrence of a complication as well as with an increased risk of an infection.[3] Nevertheless, despite the reported higher risk of morbidity and occurrence of complications, patients older than 80 years who underwent lumbar decompression surgery for degenerative lumbar spinal stenosis had a significant improvement in Spinal Stenosis Measure scores, the Feeling Thermometer, the Numeric Rating Scale, and the Roland and Morris Disability Questionnaire, as reported by Ulrich et al.[19] With regard to the results of the present study, advanced patient age was significantly associated with all of the above mentioned primary outcomes in univariate analysis, however, binary logistic regression analysis only confirmed this observation for a blood loss of more than 500ml.

Patients with adiposity who undergo decompressive surgery in the setting of degenerative lumbar spinal stenosis have been reported to benefit from surgery, however, the proportion of patients with meaningful improvement was reported to be lower compared to patients with a BMI lower than 30kg/m$^2$.[20] Furthermore, a higher BMI has been identified as a potential risk factor for a broad spectrum of complications in patients undergoing spine surgery. As reported by Schoenfeld et al. in a retrospective analysis of the National Surgical Quality Improvement Program (NSQIP) database including 5887 patients, increased BMI was reported to be significantly associated with the postoperative occurrence of a complication as well as with the risk of an infection.[3] This concurs with the results reported by Olsen et al, who reported a 2.2-fold higher risk for obese patients to develop a surgical site infection.[21] While in the present study univariate analysis showed a significantly higher BMI in patients with a prolonged hospital length of stay, increased blood loss, and higher rate of medical morbidities, binary logistic regression analysis did not demonstrate a significant association of adiposity with any of the above mentioned outcomes. This discordance with regard to BMI as potentially being associated with a higher risk for an irregular intra- and early postoperative course could be caused by the study's limitations.

Despite the study's strengths, including the large sample size enabling the conductance of multiple binary logistic regression analyses for different outcomes, and the fact of a single-center analysis thereby reducing heterogeneity of data, there are indeed important limitations that need to be considered when interpreting the listed findings. A retrospective data analysis was performed, with a potential for introducing bias. Furthermore, the sub-analysis of binary logistic regression on identifying risk factors for a medical morbidity needs to be interpreted with caution due to the small number of patients with a medical morbidity. Moreover, the herein suggested classification of surgical complexity needs to be refined, re-validated and confirmed in prospective studies.

Furthermore, surgeon experience was not evaluated as a separate variable. Due to the fact that a large proportion of surgical cases were performed by a team of attending spine surgeons as opposed to a single attending spine surgeon who gets assistance by a resident, comparability of such cases is not granted. Future studies with a prospective design are being planned to include additional variables, which could not be analyzed in the present retrospective analysis. However, previous large-scale studies confirmed an association between an increasing complication rate and a decreasing surgeon/hospital volume of spine surgical cases. [22,23]

Nevertheless, our reported findings add to the current body of knowledge on risk factors for peri- and early-postoperative morbidities after spine surgery. While we agree that there are certain parameters that are associated with an increased risk but cannot be completely eliminated, such as age, gender, level of surgery, revision surgery, and surgical complexity, among others, we identified factors that can potentially be optimized before undergoing elective spine surgery. Based on the results of our findings, we believe that preoperative laboratory values such as elevated CRP and creatinine, as well as low hemoglobin levels (all potentially reflecting underlying pathologies) should be brought within the physiologic range, and corticosteroids should be discontinued if possible, particularly in the setting of complex revision surgery involving the lumbosacral spine or the pelvis with an anticipated high blood loss and duration of surgery. Further, the surgeon needs to consider the surgical complexity and enlighten the patient that the complexity of a surgical procedure is predictive for an irregular perioperative course.

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***Table 1***. Consensus of the categorization of surgical interventions based on their technical complexity. In addition to surgical complexity (categories I-III), revision surgery was included as a separate variable in the binary logistic regression models, which was identified as a risk factor for a hospital stay ≥ 10 days (aOR: 1.716; 95%CI: 1.022-2.882; p=0.041).

| | |
|---|---|
| ***Category I*** | Lumbar microdiscectomy<br>Lumbar posterior decompression<br>Lumbar posterior instrumentation (pedicle screws)<br>Lumbar kyphoplasty<br>Lumbar vertebroplasty |
| ***Category II*** | Cervical posterior decompression<br>Cervical posterior instrumentation<br>Cervical posterior foraminotomy (Frykholm)<br>Anterior cervical discectomy and fusion (ACDF)<br>Cervical disc prosthesis<br>Thoracic posterior decompression<br>Thoracic posterior instrumentation (pedicle screws)<br>Thoracic kyphoplasty<br>Thoracic vertebroplasty<br>Posterior/transforaminal lumbar interbody fusion (PLIF/TLIF)<br>Sacral-pelvic instrumentation |
| ***Category III*** | Occipitocervical instrumentation<br>Atlantoaxial instrumentation<br>Transthoracic decompression/instrumentation<br>Lateral lumbar interbody fusion (LLIF)<br>Anterior lumbar interbody fusion (ALIF)<br>Lumbar disc prosthesis<br>Hemi-/corpectomy |

***Table 2***. Summary of the most common main clinical indications for surgical intervention.

| ***Main clinical indication for surgery*** | ***%*** |
|---|---|
| Lumbar radiculopathy | 46.9 |
| Spinal claudication | 22.5 |
| Lumbar back pain | 15.1 |
| Lumbar back pain & radiculopathy | 8.2 |
| Cervical radiculopathy | 5.3 |
| Vertebral fracture | 3.6 |
| Cervical spondylotic myelopathy | 2.9 |
| Infection | 2.1 |
| Spinal tumor | 1.1 |
| Thoracic back pain | 1.0 |
| Cervical neck pain & radiculopathy | 0.9 |
| Cervical neck pain | 0.4 |

***Table 3***. Sub-group analysis comparing surgical complexity. Statistically significant p-values are listed in bold.

| | **SURGICAL COMPLEXITY** | | | |
|---|---|---|---|---|
| | **Category I** *(n=599)* | **Category II** *(n=358)* | **Category III** *(n=32)* | **p-Value** |
| Age [years] | 60.4±16.6 | 62.0±13.7 | 62.9±18.1 | 0.330 |
| Male gender | 56.8% | 45.0% | 46.9% | **0.002** |
| Length of surgery [min] | 119.5±53.2 | 181.7±65.9 | 267.2±80.3 | **<0.001** |
| Bloodloss [mL] | 209.4±226.1 | 402.6±344.2 | 612.0±395.9 | **<0.001** |
| IMC stay [hours] | 5.5±11.6 | 11.1±15.5 | 15.4±13.2 | **<0.001** |
| Hospital stay [days] | 5.6±3.1 | 6.6±3.9 | 9.8±4.5 | **<0.001** |
| ASA category | | | | **0.019** |
| ASA I | 21.9% | 14.8% | 9.4% | |
| ASA II | 54.5% | 58.3% | 56.3% | |
| ASA III | 22.6% | 25.2% | 28.1% | |
| ASA IV | 1.0% | 1.7% | 6.3% | |
| Morbidities | | | | |
| Surgical | 10.5% | 10.9% | 15.6% | 0.662 |
| Medical | 3.0% | 7.0% | 6.3% | **0.015** |