

Association Between Prolonged Operative Time and Postoperative Adverse Events in Patients Undergoing Spine Surgery in Pakistan

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ABSTRACT

Background: Longer operative duration has been associated with complications following spinal procedures, but locally reported evidence from Pakistan remains limited. **Objective:** To examine the association between operative duration of at least 3 hours and adverse events among patients undergoing spine surgery. **Methods:** This prospective observational cohort study included 60 patients undergoing spine surgery at Johar Child Poly Clinic, Lahore, Pakistan. Age, sex, Charlson Comorbidity Index (CCI), operative duration, and adverse events classified using the Spinal Adverse Events Severity System, version 2 (SAVES-V2), were recorded. Operative time was categorized as <3 hours or ≥3 hours. The primary outcome was occurrence of at least one intraoperative or postoperative adverse event. Group comparisons and crude logistic regression were used. **Results:** Mean age was 55.8 ± 10.6 years, and 42 participants (70.0%) were male. Operations lasted <3 hours in 26 patients and ≥3 hours in 34. At least one adverse event occurred in 21 patients (35.0%): 5/26 (19.2%) in the shorter-duration group versus 16/34 (47.1%) in the longer-duration group (Fisher's exact $p = 0.031$). The crude odds ratio (OR) was 3.73 (95% confidence interval [CI] 1.14–12.21). The reported crude associations were OR 3.21 (95% CI 1.01–10.24) for early postoperative events and OR 2.68 (95% CI 0.72–9.93) for late postoperative events. **Conclusion:** Operative duration of at least 3 hours was associated with a greater occurrence of perioperative adverse events in this cohort. The association may partly reflect procedural complexity and other unmeasured factors. **Keywords:** Adverse events; operative duration; Pakistan; spine surgery; postoperative complications; SAVES-V2.

INTRODUCTION

Spinal surgery includes procedures for degenerative, traumatic, deformity-related, neoplastic, and other conditions. The extent of exposure, number of operated levels, surgical approach, and use of instrumentation can differ considerably between operations, contributing to variation in operative time and complication risk. Complications may extend hospital stay, increase resource utilization, necessitate additional intervention, and delay recovery. Across surgical specialties, longer operative duration has been associated with an increased occurrence of postoperative complications. In spine-specific cohorts, prolonged operations have likewise been associated with adverse outcomes after lumbar fusion and anterior cervical discectomy and fusion (1–4). More recent research investigating spinal procedures of differing complexity has continued to identify operative duration as a clinically relevant correlate of adverse events (5).

Several mechanisms could contribute to this association. A longer operation may entail prolonged anesthetic exposure, sustained tissue retraction, greater wound exposure, cumulative blood loss, fluid administration, and physiological stress. Surgical-site infection is particularly consequential after spinal procedures because of its potential effects on wound healing, antimicrobial treatment, implant management, and reoperation. Studies of adult spinal surgery have identified patient- and procedure-related factors associated with postoperative wound infection (6,7). Blood loss and transfusion requirements are also relevant to complex spinal fusion and may increase with the extent and complexity of surgery (8). These processes provide biological plausibility, although duration itself cannot be separated easily from the complexity of the procedure.

Comparison of complication rates across spinal surgery studies is complicated by variation in patient selection, procedure mix, definitions of adverse events, and duration of follow-up. A systematic review identified substantial heterogeneity in the reporting of complications after spinal surgery (9). The Spinal Adverse Events Severity System, version 2 (SAVES-V2), was developed to provide structured identification and grading of adverse events and has undergone reliability assessment (10). Studies using this system have demonstrated the clinical burden of intraoperative and postoperative adverse events and their association with length of stay (11).

Both patient-related factors and surgical characteristics may influence adverse-event risk. A prospective spine-surgery study identified comorbidity and other clinical variables as relevant correlates of perioperative complications,

reinforcing the need to account for case mix when interpreting associations with operative time (12). Nevertheless, evidence describing operative duration and systematically classified adverse events in Pakistani clinical settings remains limited. Local data may help characterize the pattern of recorded complications and inform the interpretation of operative time during perioperative risk assessment.

The present study aimed to examine the association between prolonged operative duration, defined analytically as 3 hours or longer, and adverse events among patients undergoing spine surgery at Johar Child Poly Clinic, Lahore, Pakistan. The primary comparison concerned the occurrence of any intraoperative or postoperative adverse event, with additional assessment of early and late postoperative outcomes. We hypothesized that longer operative duration would be associated with a greater frequency of adverse events.

MATERIALS AND METHODS

This prospective observational cohort study was conducted among 60 consenting patients undergoing spine surgery at Johar Child Poly Clinic, Lahore, Pakistan. Operative characteristics were recorded prospectively, and adverse events were subsequently assessed using a standardized classification framework. The design and reporting were organized with reference to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations. The study population comprised patients undergoing spinal surgical procedures who provided informed consent for participation.

Demographic and clinical information was recorded using a standardized data-collection approach. Variables included age, sex, relevant comorbidities, operative duration, and recorded adverse events. Comorbidity burden was summarized using the Charlson Comorbidity Index (CCI), a commonly used index in spine-surgery risk assessment (13). Operative duration was recorded in minutes. For the principal analysis, patients were stratified into procedures lasting less than 3 hours and those lasting 3 hours or longer. The 180-minute cut point provided a practical group comparison and has been used in previous observational spine-surgery research (5); it was not treated as a validated biological threshold. Operative duration was also summarized as a continuous variable for descriptive analysis.

The primary outcome was a binary composite indicating whether a patient experienced at least one recorded intraoperative or postoperative adverse event. The presence of an event was determined using SAVES-V2, which provides structured categories for recording and grading complications associated with spine surgery (10). The adverse-event inventory included dural tears, pedicle-related events, cardiac events, hemorrhage, new neurological deficits, urinary tract infection, atelectasis, cerebrospinal fluid (CSF) leakage, hematoma, construct failure, deep wound infection, and systemic infection. Individual event categories were not assumed to be mutually exclusive: one patient could experience more than one type of event. For the temporal analysis, intraoperative events were distinguished from postoperative events, and postoperative events were classified as early when occurring within 14 days after surgery or late when occurring more than 14 days after surgery. These subgroups were analysed separately from the primary composite outcome.

Quantitative characteristics were summarized using means and standard deviations, and categorical variables using frequencies and percentages. The distribution of continuous variables was assessed with the Shapiro-Wilk test. Age and CCI were compared between operative-duration groups using bivariate analyses. The observed difference in the proportion of patients experiencing any adverse event was assessed using a two-sided Fisher exact test because of the modest cell counts. The primary crude odds ratio and its 95% confidence interval were calculated from the four observed patient counts; a two-sided Wald test was used for this odds-ratio estimate. Early and late postoperative adverse events were assessed using univariate logistic regression. Statistical significance was assessed at a two-sided level of 0.05. Statistical analyses were performed using IBM SPSS Statistics version 21.0.

Informed consent was obtained from participating patients. Standardized event definitions were used to promote consistent outcome classification. The analysis reports crude associations; because operative duration may be associated with surgical complexity and other clinical factors, the results were not interpreted as demonstrating an independent causal effect.

RESULTS

Sixty patients undergoing spinal surgery were included in the analysis. Their mean age was 55.8 ± 10.6 years; 42 (70.0%) were male and 18 (30.0%) were female. The mean CCI was 2.7 ± 1.8 , and mean operative duration was 176.5 ± 47.2 minutes.

Twenty-six procedures (43.3%) lasted less than 3 hours, and 34 (56.7%) lasted 3 hours or longer. Overall, 21 patients (35.0%) experienced at least one recorded intraoperative or postoperative adverse event (Table 1).

Table 1. Demographic, clinical, and operative characteristics of the study population

Characteristic	Total (n = 60)
Age, years, mean $\pm$ SD	55.8 $\pm$ 10.6
Male, n (%)	42 (70.0)
Female, n (%)	18 (30.0)
Charlson Comorbidity Index, mean $\pm$ SD	2.7 $\pm$ 1.8
Operative time, minutes, mean $\pm$ SD	176.5 $\pm$ 47.2
Operative time <3 hours, n (%)	26 (43.3)
Operative time $\geq$ 3 hours, n (%)	34 (56.7)
Patients with $\geq$ 1 adverse event, n (%)	21 (35.0)

The recorded adverse-event types are presented in Table 2. Dural tears were reported in five patients (8.3%), neurological deficits in six (10.0%), and hemorrhage, CSF leakage, urinary tract infection, construct failure, and deep wound infection in four patients each (6.7%). Most recorded event categories occurred more frequently in the group with operative duration of at least 3 hours. In total, 43 occurrences were represented across the event-category rows, whereas 21 unique patients experienced at least one event; the category counts therefore should not be interpreted as numbers of different affected patients.

Table 2. Recorded adverse-event categories by operative duration

Adverse-event category	<3 hours (n = 26), n (%)	$\geq$ 3 hours (n = 34), n (%)	Total (n = 60), n (%)
Dural tear	1 (3.8)	4 (11.8)	5 (8.3)
Pedicle-related event	1 (3.8)	2 (5.9)	3 (5.0)
Cardiac event	0 (0.0)	2 (5.9)	2 (3.3)
Hemorrhage	1 (3.8)	3 (8.8)	4 (6.7)
Neurological deficit	1 (3.8)	5 (14.7)	6 (10.0)
Urinary tract infection	1 (3.8)	3 (8.8)	4 (6.7)
Atelectasis	0 (0.0)	2 (5.9)	2 (3.3)
CSF leak	1 (3.8)	3 (8.8)	4 (6.7)
Hematoma	1 (3.8)	2 (5.9)	3 (5.0)
Construct failure	1 (3.8)	3 (8.8)	4 (6.7)
Deep wound infection	1 (3.8)	3 (8.8)	4 (6.7)
Systemic infection	0 (0.0)	2 (5.9)	2 (3.3)

Event categories may overlap within individual patients; percentages use the number of patients in the relevant operative-duration group as the denominator. CSF, cerebrospinal fluid.

The two operative-duration groups did not differ significantly in mean age (57.9 $\pm$ 10.2 versus 54.2 $\pm$ 10.8 years; p = 0.183) or CCI (2.5 $\pm$ 1.7 versus 2.9 $\pm$ 1.9; p = 0.401). At least one adverse event occurred in 5 of 26 patients (19.2%) whose operations lasted less than 3 hours and 16 of 34 patients (47.1%) with operative time of at least 3 hours. The absolute difference in observed event proportions was 27.8 percentage points, and the two-sided Fisher exact p -value was 0.031 (Table 3).

Table 3. Patient characteristics and occurrence of any adverse event by operative-duration category

Variable	<3 hours (n = 26)	$\geq$ 3 hours (n = 34)	p-value
Age, years, mean $\pm$ SD	57.9 $\pm$ 10.2	54.2 $\pm$ 10.8	0.183
Charlson Comorbidity Index, mean $\pm$ SD	2.5 $\pm$ 1.7	2.9 $\pm$ 1.9	0.401
Patients with $\geq$ 1 adverse event, n (%)	5 (19.2)	16 (47.1)	0.031

The adverse-event comparison uses the two-sided Fisher exact test. For the primary composite outcome, the crude odds of experiencing any adverse event were 3.73 times greater among patients with operative durations of at least 3 hours compared with those undergoing shorter procedures (OR 3.73, 95% CI 1.14–12.21; Wald $p = 0.029$). Univariate logistic regression also indicated an association between prolonged operative duration and early postoperative events (OR 3.21, 95% CI 1.01–10.24; $p = 0.048$). The corresponding association for late postoperative events was less precise and did not meet the prespecified significance threshold (OR 2.68, 95% CI 0.72–9.93; $p = 0.141$) (Table 4). All estimates are unadjusted associations.

Table 4. Crude associations between operative duration ≥ 3 hours and adverse events

Outcome	Crude OR	95% CI	p-value
Any intraoperative or postoperative adverse event	3.73	1.14–12.21	0.029
Early postoperative adverse event	3.21	1.01–10.24	0.048
Late postoperative adverse event	2.68	0.72–9.93	0.141

Reference category: operative duration < 3 hours. The primary composite confidence interval and p-value use the log-odds Wald method; early and late postoperative estimates derive from univariate logistic regression. CI, confidence interval; OR, odds ratio.

DISCUSSION

This prospective observational cohort study found that patients whose spinal operations lasted at least 3 hours had a higher recorded frequency of intraoperative or postoperative adverse events than patients undergoing shorter procedures. The difference was evident in the principal patient-level composite outcome, while the univariate analyses suggested a similar pattern for early postoperative events. The estimate for late postoperative events was imprecise and did not reach statistical significance. These findings identify operative duration as a potential marker of perioperative risk, but they do not establish that additional time in the operating room causes complications.

The direction of the association is consistent with evidence across surgical specialties. Cheng et al. observed a relationship between increased operative duration and postoperative complications in a systematic review and meta-analysis (1). In a large analysis of single-level lumbar fusion, Kim et al. reported operative duration as a risk factor for postoperative complications, while Hersey et al. described a comparable association among older patients undergoing posterior lumbar fusion (2,3). Ondeck et al. reported a graded association with adverse events after anterior cervical discectomy and fusion when operative time was examined in 15-minute intervals (4). These studies span different procedural types and therefore support the broad relevance of operative time without establishing one universal operative-time threshold.

A more directly comparable study by Monetta et al. assessed operative time and adverse events in a spinal-surgery cohort using SAVES-V2 and also stratified patients around 3 hours (5). Their work underscores that adverse-event occurrence varies with the underlying diagnostic and procedural profile. Falzetti et al. similarly demonstrated the clinical importance of structured complication recording in a cohort of 336 patients undergoing spinal surgery and identified associations between adverse events and length of stay (11). In the current cohort, the observed difference between operative-duration groups was substantial in absolute terms, although the sample of 60 patients and the broad confidence interval indicate that the magnitude of the association remains uncertain.

Several plausible processes may contribute to the observed pattern. Longer operations may involve additional tissue manipulation and retraction, exposure of the surgical field, anesthetic time, and cumulative blood loss. Prior spine-surgery studies have described risk factors for wound infection, while evidence on major spinal procedures highlights the importance of blood loss and perioperative hemorrhage management (6–8). These considerations provide plausible explanations for wound, neurological, and systemic adverse events occurring during or after complex procedures. Nevertheless, the present data do not separate these mechanisms from the underlying complexity that may lengthen an operation; the event-category frequencies are descriptive and do not demonstrate a duration-specific mechanism.

Structured event surveillance is another important consideration. As shown by Camino-Willhuber et al., the definitions and completeness of complication reporting differ across spine-surgery studies (9). SAVES-V2 offers a standardized framework with demonstrated observer reliability, while its use in other cohorts has facilitated identification of a broad range of complications (10,11). In the present study, multiple adverse-event types were recorded among some patients,

which distinguishes the 43 event-category occurrences from the 21 patients affected by one or more events. Maintaining this distinction is necessary to avoid overstating complication incidence.

The association with early postoperative adverse events is clinically plausible because tissue injury, hemodynamic changes, pulmonary events, urinary complications, and cerebrospinal fluid leakage may become apparent soon after surgery. The absence of statistical significance for late events should be interpreted cautiously: the corresponding odds ratio exceeded 1, but its confidence interval included both little or no association and a potentially large association. Late complications may also depend on wound healing, infection susceptibility, implant-related factors, and postoperative management beyond the duration of the index procedure. Differences in postoperative surveillance and follow-up windows across studies further constrain direct comparison (9,11).

Age and the CCI were similar on average between the two operative-duration groups, but this observation does not eliminate confounding. The study did not present an adjusted multivariable model. Surgical indication, operated levels, revision status, approach, instrumentation, surgeon experience, and operative-team organization may be associated with both procedure duration and adverse-event risk. Lange et al. identified several perioperative risk factors in a prospective spine-surgery cohort, while Whitmore et al. showed the clinical relevance of comorbidity assessment in spinal surgery (12,13). Studies of resident involvement and operating-room organization also illustrate that operative time can reflect service and team characteristics rather than exposure time alone (14–16). Consequently, the crude odds ratios reported here should not be interpreted as independent effects.

The 3-hour categorization made the results clinically interpretable, but it also reduced a continuous exposure to a binary comparison and may obscure a progressive or nonlinear relationship. Earlier cervical-spine research suggested that risk may change incrementally with operative duration (4), and a more recent thoracolumbar-spine analysis investigated thresholds associated with increased postoperative complications (17). These findings argue against assuming that all procedures below 180 minutes are low risk or that crossing 180 minutes itself produces an abrupt change in risk. Future studies with larger samples should evaluate operative time continuously and account for procedural factors.

The practical implication is not indiscriminate acceleration of surgery. Technical precision, hemostasis, adequate decompression, and patient safety remain paramount. Rather, operative planning, instrument availability, intraoperative communication, appropriate staffing, and reduction of avoidable delays may support more efficient care. Research on operating-room efficiency in orthopaedic settings has demonstrated that organization and specialist workflow can affect surgical time and resource use (16). Where prolonged surgery is anticipated, the duration may be considered alongside clinical and procedural factors when planning postoperative surveillance, without treating it as a stand-alone risk predictor.

The study has strengths in its prospective recording of operative characteristics, use of a structured adverse-event framework, and presentation of a patient-level composite outcome alongside a detailed event-category inventory. Several limitations constrain interpretation. It was conducted at a single center with 60 patients, limiting precision and external applicability. The 21 patients with the primary outcome provide a small number of events for explanatory modeling. Crude analyses did not account for surgical indication, operated levels, revision status, approach, or instrumentation, and the 3-hour threshold may conceal information present in continuous operative time. Individual event categories were uncommon, making comparisons of specific complications unstable. In addition, the available aggregate results do not describe the distribution of early and late postoperative event counts or the extent of late-event follow-up, limiting evaluation of the time-specific estimates. These constraints make the findings hypothesis-generating rather than definitive evidence of independent operative-time effects.

Overall, the results add a context-specific observation from Lahore to the wider literature linking operative duration with adverse events following spine surgery. The findings support attention to operative time as one component of perioperative risk assessment and underscore the importance of consistent complication reporting, while emphasizing the need for larger, procedurally stratified prospective cohorts with adequate follow-up and confounder adjustment.

CONCLUSION

Among 60 patients undergoing spine surgery at a single center in Lahore, an operative duration of at least 3 hours was associated with a greater occurrence of recorded intraoperative or postoperative adverse events than a duration of less than 3 hours. Early postoperative events showed a similar reported association, whereas the estimate for late

events was imprecise. Operative duration may therefore serve as a useful contextual marker during perioperative risk assessment, although the unadjusted observational findings cannot establish an independent causal effect.

DECLARATIONS

Authors' Contributions:	Concept: TA, SA; Design: SA, TA; Data Collection: TA; Analysis: SA; Drafting: SA.
Ethical Approval:	The institution responsible for ethical review was Johar Child Poly Clinic, Lahore, Pakistan
Informed Consent:	Written informed consent was obtained from all participants before enrolment.
Conflict of Interest:	The authors declare no conflict of interest.
Funding:	No external funding was received for this study.
Data Availability:	De-identified data may be available from the corresponding author on request, subject to participant consent and institutional confidentiality requirements.
Acknowledgments:	None.
AI Declaration:	Generative AI tools were used solely for language and grammatical refinement. The authors verified the final manuscript and remain fully responsible for its accuracy, integrity, and scientific content.

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