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Risk factors for pulmonary complications after spine surgery

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Methods evaluation and class of evidence (CoE)

Methodological principle:	
Study design:	
Prospective cohort	
Retrospective cohort (registry)	•
Case control	
Case series	
Methods	
Patients at similar point in course of treatment	•
Follow-up ≥ 85%	•
Similarity of treatment protocols for patient groups	•
Patients followed for long enough for outcomes to occur	•
Control for extraneous risk factors	•
Evidence class:	**II**

The definiton of the different classes of evidence is available on page 73.

ABSTRACT

Study design: Registry study with prospectively collected data

Objective: To determine risk factors for pulmonary complications in spine surgery.

Methods: The Spine End Results Registry 2003–2004 is an exhaustive database of 1,592 patients who underwent spine surgery at the University of Washington Medical Center or Harborview Medical Center. Detailed information regarding patient demographic, medical comorbidity, and comorbidities, surgical invasiveness and adverse outcomes were prospectively recorded. The primary outcome measure was the occurrence of a pulmonary complication following surgery. Univariate relative risks and 95% confidence intervals for each of the risk factors were determined. Multivariate log binomial regression analysis was performed to investigate the association between each risk factor and a pulmonary complication, while controlling for other important risk factors.

Results: Altogether, there were 199 pulmonary complications after spine surgery. The cumulative incidence of a respiratory complication after spine surgery was 9% (144 patients). Multivariate analysis suggested gender, chronic obstructive pulmonary disease, congestive heart failure, diabetes, age, diagnosis, surgical invasiveness and surgery in the thoracic spine are significant risk factors for pulmonary complications after spinal surgery.

Conclusions: The results of the present study suggest numerous statistically significant risk factors for pulmonary complications after spine surgery. These results may aid the clinician with preoperative risk stratification and patient counseling.

UWMC IRB-approved.
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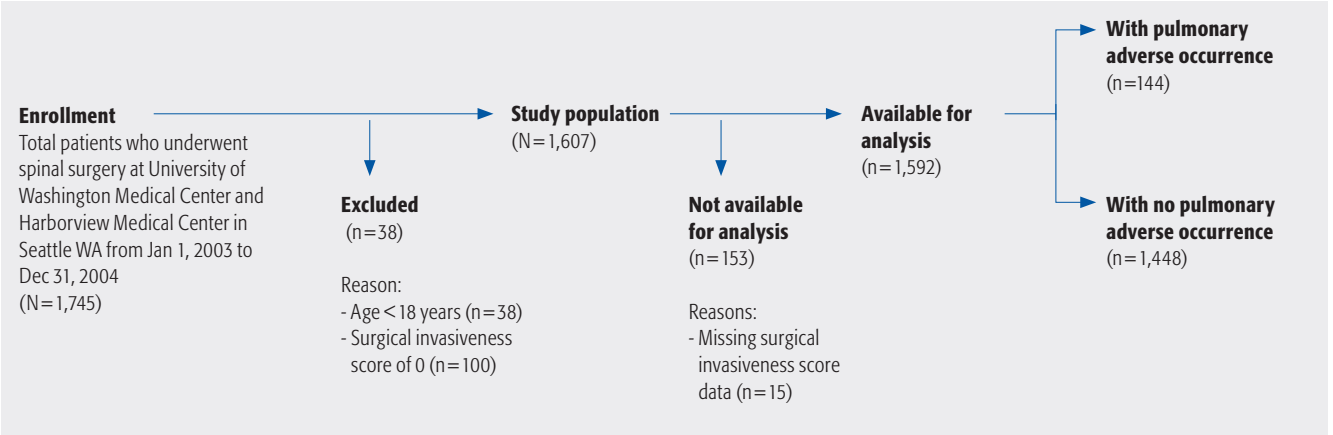
STUDY RATIONALE

While multiple studies have examined complication rates after spinal surgery, few studies have focused on risk factors for pulmonary complications after spine surgery. The rates of pulmonary complications after spine surgery has been reported to range from 0.9% to 5%, but methodology and definitions vary from study to study [1–4].

OBJECTIVE

The objective of this study is to identify risk factors for pulmonary complications after spine surgery.

Figure 1 **Patient selection and sampling**



METHODS

Study design: Registry study

Inclusion criteria: All patients who underwent spinal surgery from January 1, 2003 to December 31, 2004 at Harborview Medical Center and the University of Washington Medical Center.

Exclusion criteria:
- Patients younger than 18 years of age
- Patients with incompletely recorded surgical invasiveness scores.
- Patients with surgical invasiveness scores of 0, as these included patients who did not undergo spinal surgery (Risser casting or closed reduction under general anesthesia).

Patient population: The Spine End Results Registry at the University of Washington Medical Center is a prospectively recorded database of patients who underwent spinal surgery from January 1, 2003 to December 31, 2004 at Harborview Medical Center or the University of Washington Medical Center in Seattle WA. Detailed information with 2-year follow up regarding patient demographic, medical comorbidity, disease severity, surgical invasiveness and adverse outcomes were prospectively recorded as described by Mirza et al [5] **(Table 1)**. All patients were followed for at least 2 years prospectively for adverse occurrences.

Outcome: The primary outcome measure was the occurrence of a pulmonary complication in the 2-year period after spinal surgery. A detailed list of all pulmonary complications with definitions used is summarized in **Table 2**.

Analysis:
- Categorical data were presented as number of events and percentages.
- Continuous data were presented as mean ± standard deviation.
- Univariate analysis evaluating the association between each categorical variable and a pulmonary complication was performed using Pearson's Chi-square test or Fisher's exact tests (where cell counts were low).
- Univariate analysis evaluating the association between each continuous variable and a pulmonary complication was performed using unpaired t-tests.
- Multivariate log-binomial regression was used to determine the association between each risk factor and a pulmonary complication, while controlling for other predictive factors.
- Risk factors were included in the multivariate log-binomial regression model if they were deemed of clinical importance by the study investigators or if their univariate association had a P-value $< .10$.
- We examined congestive heart failure, asthma, chronic obstructive pulmonary disease, and diabetes as individual risk factors and subsequently examined and adjusted the Charlson comorbidity score minus these two components to avoid conflagration of our risk calculation [7].

Table 1 **Cohort characteristics**

	N=1,592
Age, years (mean ± SD)	49.6 ± 16.0
Male, n (%)	914 (57%)
Currently smoke, n (%)	488 (32%)
Illicit drug use, n (%)	167 (12%)
Alcohol use, n (%)	668 (46%)
Diabetes, n (%)	179 (11%)
Previous cardiac incident, n (%), includes angina, myocardial infarction, cardiovascular vascular disease, congestive heart failure	200 (13%)
Degenerative, n (%)	992 (62%)
Trauma, n (%)	372 (23%)
Neoplasm, n (%)	117 (7%)
Other diagnosis, n (%)	111 (7%)
Revision surgery, n (%)	286 (18%)
Anterior surgical approach, n (%)	292 (18%)
Posterior surgical approach, n (%)	934 (59%)
Combined surgical approach, n (%)	366 (23%)

RESULTS

- Of the 1,745 patients, 38 were excluded because they were younger than 18 years of age and 100 were excluded for surgical invasiveness scores of 0 (Risser casting or closed reduction under general anesthesia). Fifteen had missing invasiveness scores, leaving 1,592 patients for analyses **(Figure 1)**.
- The mean age of the study population was 49.6 years. Thirty two percent smoked, 12% were illicit drug users and 11% had diabetes and 13% had a defined past cardiac health history. We found degenerative cases to comprise 62% of our study cohort, with 23% to be traumatic. Posterior only surgery was performed in 59% of patients, anterior only in 18% of patients and revision surgery constituted 18% of our patients **(Table 1)**.
- The cumulative incidence of pulmonary complication after spine surgery was 9%. The incidence rate of pulmonary complications was 3.28 per 100 persons per year. There were 199 pulmonary complications after spine surgery **(Table 2)**.
- The mortality rate from pulmonary complications was 3.61 per 1,000 persons per year.
- In the univariate analysis, age older than 65, presence of smoking, diabetes, COPD, CHF, elevated Charlson comorbidity score, indication for surgery of nondegenerative nature (ie, trauma, tumors), cervical and thoracic level surgery compared to lumbar surgery, and increased surgical invasiveness were all statistically significant risk factors for pulmonary complication after spine surgery **(Table 3)**.
- In the multivariate analysis, male gender, COPD, CHF, Diabetes mellitus, age greater than 65 years, diagnosis (nondegenerative), thoracic level surgery and surgical invasiveness were statistically significant risk factors for pulmonary complication **(Table 4)**.

Table 2 **Pulmonary adverse occurrence (AO)**

Pulmonary complications	Prevalence
ARDS (FiO2 >50/vent >48h + mc04/mro5/BxAu) Acute hypoxemic respiratory failure due to pulmonary edema caused by increased permeability of the alveolar capillary barrier. Criteria: (1) FiO2 >50%; (2) Ventilator support for >48h; (3) PaO2/FiO2 <= 300 mm Hg; and (4) bilateral lung infiltrates on CXR	20 (1.3%)
Empyema Purulent fluid collection in the pleural space confirmed by imaging studies and aspiration or by surgery	1 (0.06%)
Hemothorax Blood in the pleural space confirmed by imaging studies and aspiration or surgery	2 (0.13%)
Pleural effusion Pleural effusion is excess fluid in the pleural space	20 (1.3%)
Postop hypoxia(FiO2 > 50 × 48h or suppl O2 × 7d) Requirement for supllemental oxygen post-operatively, with FiO2 >50% for 48h or supplemental oxygen by nasal cannula for 7 days.	24 (1.5%)
Pneumonia(>38.0 + Cx/CXR and Tx) Infection of the lung parenchyma confirmed by fever, sputum or brochial cultures, CXR, and requiring treatment	72 (4.5%)
Pneumothorax Accumulation of gas in the pleural space resulting in symptoms (tachycardia, hypotension), requiring extra surveillance (eg, repeat CXRs or pulse oximetry) or treatment (chest tube placement)	9 (0.6%)
Pulmonary embolus(CTA/VQ/Angio + Tx) Sudden onset of shortness of breath, tachypnea, cyanosis, tachycardia, hypotension, or chest pain confirmed to be a imaging studies to be a pulmonary thrombus and requiring treatment; or diagnosis made at autopsy	23 (1.4%)
Respiratory arrest Sudden cessation of voluntary breathing, requiring CPR or mechanical ventilation	10 (0.63%)
Other pulmonary Other respiratory problem	18 (1.1%)
Total pulmonary adverse occurrence events	199 (13%)

Table 3 **Univariate analysis of relative risk for pulmonary adverse occurrence (AO) following spine surgery**

Risk factors	Pulmonary AO 144 (9%)	No pulmonary AO 1,448 (91%)	Relative risk pulmonary AO	95% CI	*P*-value
Age (years), mean (sd)					
18–39	29 (7%)	402 (93%)	1.00	-	<.001
40–64	65 (8%)	794 (92%)	1.12	0.74–1.72	
≥ 65	50 (17%)	252 (83%)	2.46	1.60–3.79	
Gender					
male	90 (10%)	824 (90%)	1.00	-	.20
female	54 (8%)	624 (92%)	0.81	0.59–1.12	
Smoking					
no	93 (8%)	1,011 (92%)	1.00	-	.19
yes	51 (10%)	437 (90%)	1.24	0.90–1.72	
Alcohol					
no	84 (9%)	840 (91%)	1.00	-	.94
yes	60 (9%)	608 (91%)	0.99	0.72–1.36	
Drug use					
no	124 (9%)	1,301 (91%)	1.00	-	.16
yes	20 (12%)	147 (88%)	1.38	0.88–2.15	
Diabetes					
no	113 (8%)	1,300 (92%)	1.00	-	<.001
yes	31 (17%)	148 (83%)	2.17	1.50–3.12	
Chronic obstructive pulmonary disease					
no	123 (8%)	1,359 (92%)	1.00	-	<.001
yes	21 (19%)	89 (81%)	2.30	1.51–3.50	
Asthma					
no	123 (9%)	1,247 (91%)	1.00	-	.82
yes	21 (9%)	201 (91%)	1.05	0.68–1.64	
Congestive heart failure					
no	126 (8%)	1,404 (92%)	1.00	-	<.001
yes	18 (29%)	44 (71%)	3.53	2.31–5.38	
BMI	27.6 (6.6)	27.7 (6.5)			.85
underweight (<18.5)	18 (13%)	122 (87%)	1.00	-	.36
normal (18.5 – <25)	48 (9%)	462 (91%)			
overweight (25 – <30)	42 (8%)	461 (92%)	0.82	0.57 – 1.19	
obese (30 – <35)	19 (7%)	250 (93%)	0.70	0.43 – 1.14	
≥ 35	17 (10%)	153 (90%)			
Charlson comorbidity adjusted for diabetes and pulmonary disease, mean (sd)	1.17 (1.44)	0.97 (1.46)			.11
0	73 (8%)	803 (92%)	1.00	-	.23
1	20 (7%)	279 (93%)	0.80	0.50–1.29	
2	20 (12%)	146 (88%)	1.45	0.91–2.30	
3	20 (14%)	124 (86%)	1.67	1.05–2.65	
≥ 4	11 (10%)	96 (90%)	1.23	0.68–2.25	
Diagnosis group					
degenerative	41 (4%)	33 (89%)	1.00	-	<.001
trauma	74 (20%)	298 (80%)	4.81	3.35–6.91	
neoplasm	16 (14%)	101 (86%)	3.31	1.92–5.71	
other	13 (12%)	98 (88%)	2.83	1.57–5.12	
Diagnosis level					
lumbar	36 (5%)	718 (95%)	1.00	-	<.001
cervical	57 (10%)	525 (90%)	2.05	1.37–3.07	
thoracic	50 (21%)	191 (79%)	4.35	2.90–6.50	
sacral	1 (8%)	12 (92%)	1.61	0.24–10.9	
Revision					
no	117 (9%)	1,189 (91%)	1.00	-	.80
yes	27 (9%)	259 (91%)	1.05	0.71–1.57	
Surgical approach					
posterior	76 (8%)	858 (92%)	1.00	-	.22
anterior	27 (9%)	265 (91%)	1.14	0.75–1.73	
combined	41 (11%)	325 (89%)	1.38	0.96–1.97	
Invasiveness index, mean (SD)	8.3 (7.4)	11.1 (8.7)			<.001
1–5	45 (6%)	688 (94%)	1.00	-	.005
6–10	43 (10%)	367 (90%)	1.71	1.15–2.55	
11–15	26 (11%)	214 (89%)	1.76	1.11–2.80	
16–20	13 (14%)	79 (86%)	2.30	1.29–4.10	
21–25	6 (13%)	41 (87%)	2.08	0.94–4.62	
>25	11 (16%)	59 (84%)	2.56	1.39–4.72	

RR=relative risk, CI=confidence intervals
All factors listed in the table were included in the final model.

Table 4 **Multivariate analysis of relative risk for pulmonary adverse occurrence**

Risk factors	RR	95% CI	*P*-value
Gender (female)	0.69	0.50–0.97	.04*
Diabetes (yes)	1.28	0.76–1.90	.23
Smoking (yes)	0.97	0.68–1.38	.85
Drug use (yes)	1.55	0.95–2.41	.07
Hx of COPD (yes)	2.05	1.27–2.54	.003*
Hx of CHF (yes)	1.79	1.03–2.91	.03*
Hx of asthma (yes)	1.06	0.68–1.56	.79
Age (years)			
18–39	1.00	-	-
40–64	1.31	0.86–2.05	.22
≥ 65	1.90	1.15–3.19	.01*
Charlson comorbidity adjusted			
0	1.00	-	-
≥ 1	0.97	0.71–1.40	.85
Diagnosis group			
degenerative	1.00	-	-
trauma	4.46	2.88–7.00	<.001*
neoplasm	2.37	1.22–4.32	.01*
other	2.04	1.05–3.65	.02*
Diagnosis level			
lumbar	1.00	-	-
cervical	1.27	0.83–1.96	.27
thoracic	1.61	1.02–2.58	.04*
Invasiveness index			
1–5	1.00	-	-
6–10	1.15	0.74–1.81	.53
11–15	1.22	0.72–1.44	.44
≥ 16	2.28	1.43–3.14	<.001*

*Significant, RR=odds ratio, CI=confidence intervals

DISCUSSION

- We observed a cumulative incidence of pulmonary complications after spine surgery to be 9%. Reported incidences after spine surgery range from 0.9% to 5%, but definitions of pulmonary complications and study populations vary from study to study [1–4]. Our reported rate of pulmonary complications is nearly triple that of the highest previously reported incidence. A number of factors may contribute to this. Firstly, we recorded all pulmonary complications that occurred within two years after spine surgery. This inclusive approach likely contributes to the elevated rate of pulmonary complications that may not necessarily be related to the index spine procedure. The large patient population in our study reflects a very diverse patient population, including individuals with serious spinal disorders and major comorbidities who typically seek care in a tertiary care center like ours. This creates a negative selection bias from which tertiary care institutions like ours frequently experience when compared to institutions with very selective care approaches. In addition, the closer one looks at complications the more they appear to occur. As in any such study, identification of the amount of pulmonary complications led to the creation of care teams including perioperative medicine consult services and spine surgery anesthesia care teams to standardize care protocols and improve consistency of implementation of medical treatment recommendations.
- While many of these risk factors are intuitive, these data allow for quantification of these risks and may aid the clinician in decision making and counseling of patients.
- Strengths: Our large sample size and the quality of our data on several possible predictive variables for a pulmonary complication make this a very exhaustive analysis. Our analysis methods using multivariate regression allowed us estimate the effect of several risk factors on the probability of a pulmonary complication, while controlling for other possible predictive factors.

- Limitations: When groups are not randomized, selection bias comparing groups or risk factors may lead to a distortion of the findings based on confounding. Our data were collected prospectively using an ongoing spine registry created for enhanced quality assurance with monitoring and recording of all surgical activity, recording of preoperative baseline data and postoperative follow-up visits at defined intervals. We also identified several potential risk factors that may influence pulmonary complications and carefully controlled for them in a regression analysis. We feel this limits concerns regarding potential confounding.
- Future research should involve building prediction models whereby the probability of a complication can be predicted for each patient who undergoes spine surgery based on their composite of risk factors. This prediction model would need to be externally validated in another population of spine surgery patients.

SUMMARY AND CONCLUSIONS

- In this study, the cumulative incidence of pulmonary complication after spine surgery was 9%.
- Risk factors for pulmonary complications after spine surgery include age greater than 65 years, diabetes, previous cardiac history, revision surgery, elevated Charlson morbidity score, greater surgical invasiveness.

REFERENCES

1. **Carreon LY, Puno RM, Dimar JR 2nd, et al** (2003) Perioperative complications of posterior lumbar decompression and arthrodesis in older adults. *J Bone Joint Surg Am*; 85-A(11):2089–2092.
2. **Deyo RA, Cherkin DC, Loeser JD, et al** (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.
3. **Kalanithi PS, Patil CG, Boakye M** (2009) National complication rates and disposition after posterior lumbar fusion for acquired spondylolisthesis. *Spine;* 34(18):1963–1969.
4. **Vaidya R, Carp J, Bartol S, et al** (2009) Lumbar spine fusion in obese and morbidly obese patients. *Spine*; 34(5):495–500.
5. **Mirza SK, Deyo RA, Heagerty PJ, et al** (2006) Towards standardized measurement of adverse events in spine surgery: conceptual model and pilot evaluation. *BMC Musculoskelet Disord*; 7:53.
6. **Mirza SK, Deyo RA, Heagerty PJ, et al** (2008) Development of an index to characterize the "invasiveness" of spine surgery: validation by comparison to blood loss and operative time. *Spine;* 33(24):2651–2661; discussion 2662.
7. **Charlson ME, Pompei P, Ales KL, et al** (1987) A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis;* 40(5):373–383.

EDITORIAL STAFF PERSPECTIVE

This is an excellent study regarding complications in spine surgery. We are unaware of a similar undertaking. Of course an interesting follow-up study would be to see if any specific care measures that have been changed by the investigators have reduced the incidence of pulmonary complications. This would require a prospective follow-up study.

The other point not directly addressed in this study is the influence of antibiotics, application of a standardized postoperative respiratory care protocol for known at-risk patients, and intraoperative anesthesiologic management of patients. For instance, presence of intraoperative hypotension, requiring resuscitation, the number of blood transfusions, fresh frozen plasma or colloids as well as type and duration of intravenous antibiotic prophylaxis may be variables to consider. These are variables which usually can not readily be gathered from a retrospective study.

The value of a study like this, is that a potentially underestimated clinical problem can now be studied prospectively in a more detailed fashion. No doubt this study advances our awareness of pulmonary problems and more invasive spine surgery in an ill population.