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Perioperative Shift in Respiratory Bacterial Colonization and Post-operative Pneumonia in Spine Surgery Patients Requiring Intensive Care: A Prospective Cohort Study

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A B S T R A C T

Spine surgery frequently requires post-operative intensive care and endotracheal intubation, both of which predispose to nosocomial respiratory infection, yet the perioperative dynamics of airway bacterial colonization in spine surgery patients and their relationship to pneumonia are poorly characterised, particularly in Indonesian practice. We conducted a prospective cohort study of 34 patients undergoing elective spine surgery with post-operative care in the ICU/PICU of Dr. Moewardi Regional General Hospital, Surakarta. Paired pharyngeal swab cultures were obtained at induction and during intubated intensive care, with disk-diffusion susceptibility testing. Post-operative pneumonia was defined by chest-radiographic infiltrate plus leukocytosis or leukopenia. Associations were assessed using Fisher exact tests, Haldane-Anscombe corrected odds ratios, rank correlation, and Cohen's h, with 95% confidence intervals. Most patients underwent decompressive laminectomy with posterior spinal fusion (76.5%). Pre-operative pathogenic colonization was present in 21/34 patients (61.8%; 95% CI 45.0-76.1). The flora shifted toward pathogens post-operatively, with Staphylococcus aureus rising from 6 to 9 isolates (+50%), Acinetobacter baumannii from 2 to 4, and new Serratia marcescens and Proteus mirabilis; ciprofloxacin resistance predominated and increased. Post-operative pneumonia occurred in 1/34 patients (2.94%; 95% CI 0.52-14.92). Pre-operative colonization was not associated with pneumonia (Fisher p=1.000; OR 1.98, 95% CI 0.07-52.17). ICU stay >48 h and endotracheal-tube duration >24 h were each strongly rank-correlated with pneumonia (rho=0.696), although, given a single event, the exact test was not significant (p=0.059). Intensive-care exposure rather than pre-operative colonization characterised pneumonia risk, while resistant Gram-negative organisms emerged perioperatively. Duration-focused prevention and antimicrobial stewardship are warranted in orthopedic critical care.

1. Introduction

Spine surgery encompasses a broad range of procedures performed on the vertebral column and surrounding tissues to decompress neural elements, correct deformity, stabilise the spine, or resect disease, and is indicated across degenerative disorders, deformity, trauma, infection, and neoplasia.[1,2] The global volume of spinal procedures has risen steadily,

and complications remain more frequent than for general orthopedic surgery, spanning wound and surgical-site infection, cerebrospinal-fluid leakage, mechanical and neurological events, and systemic and procedure-related morbidity, including respiratory complications arising during the perioperative period.[2,3] Pulmonary complications are a clinically important component of this burden: post-operative pneumonia after spinal procedures is reported in roughly 1-6% of cases and is associated with prolonged operative duration, older age, male sex, comorbidity, and pre-operative myelopathy.[4-6]

Because spinal surgery often involves extensive dissection, bony decortication, and prolonged operative times, it is associated with substantial blood loss and a frequent need for post-operative critical care and endotracheal intubation, particularly when prone positioning or multilevel fusion is required.[3,4] Endotracheal intubation, while life-sustaining, bypasses the natural defences of the upper airway, impairs mucociliary clearance and effective cough, and provides an abiotic surface on which microbial biofilm can form, predisposing to ventilator-associated and hospital-acquired pneumonia.[7,8] The endotracheal-tube biofilm matures progressively, and the transition from simple colonization to clinically significant infection accelerates with the duration of intubation and intensive-care exposure.[8]

The major surgical stress of spine surgery also increases susceptibility to post-operative infection through transient immune and physiological perturbation, an effect amplified by host vulnerabilities such as sarcopenia, malnutrition, and comorbidity.[9,10] In the intensive-care environment, the respiratory flora of intubated patients is dominated by Gram-negative bacilli and Staphylococcus aureus, with multidrug-resistant organisms such as Acinetobacter baumannii, carbapenem-resistant Klebsiella pneumoniae, and Stenotrophomonas maltophilia of particular concern.[11-13] Crucially, colonization is not synonymous with infection: surveillance studies show that although airway colonization with pathogens is associated with subsequent pneumonia, many colonized patients never develop disease, so colonization status must be interpreted separately from active infection.[14,15]

In Indonesia, spinal surgery is increasingly performed at tertiary referral centres serving large populations with a high burden of trauma, infection, and advanced degenerative and oncologic disease. Dr. Moewardi Regional General Hospital in Surakarta is one such centre, functioning as the principal orthopedic and spine referral hospital for Central Java and receiving patients across the urban-rural spectrum, the majority covered under the national health-insurance scheme (BPJS Kesehatan). In this setting, locally generated surveillance data on respiratory colonization and resistance are essential to guide infection-prevention and antimicrobial-stewardship policy, given that ventilator-associated pneumonia incidence and etiology differ systematically by region and national income level.[16,17]

Despite the clinical importance of post-operative respiratory infection, the perioperative dynamics of airway flora in spine surgery patients have rarely been characterised. Few studies have paired pre- and post-operative respiratory cultures in the same patients to describe how surgery and intubation reshape colonization and resistance, and almost none have done so in Indonesian orthopedic practice; whether pre-operative pathogenic colonization predicts post-operative pneumonia, or whether the duration of intensive-care exposure is the more relevant determinant, remains unclear at tertiary centres in Central Java.[18,19]

We therefore conducted a prospective cohort study with two aims: first, to characterise the perioperative shift in respiratory bacterial colonization and antimicrobial resistance between the pre-operative and post-operative (intubated intensive-care) periods in spine surgery patients; and second, to examine the association of pre-operative colonization and of intensive-care exposure (ICU length of stay and endotracheal-tube duration) with post-operative

pneumonia. By providing paired, prospectively collected surveillance data from a high-volume Indonesian referral centre, this study aims to clarify the most appropriate target for pneumonia prevention in orthopedic critical care.

2. Methods

Study design and setting

This was a single-centre prospective observational cohort study conducted at the Department of Orthopedics and Traumatology, Faculty of Medicine, Universitas Sebelas Maret/Dr. Moewardi Regional General Hospital, Surakarta, Central Java, Indonesia, with data collection during 2024-2025. The study was designed and is reported in accordance with the STROBE guidance for observational research. All consecutive eligible patients undergoing elective spine surgery and requiring post-operative care in the intensive care unit (ICU) or paediatric intensive care unit (PICU) with endotracheal intubation were approached for enrolment.

Participants

Eligible patients were those scheduled for elective spine surgery (decompressive laminectomy, posterior spinal fusion, deformity correction, and related procedures) for any indication, anticipated to require post-operative intubated intensive care, who provided written informed consent. Patients were excluded if they had a pre-existing active pulmonary infection or pneumonia at admission, if respiratory sampling could not be performed at both time points, or if they withdrew consent. Surgical indications comprised spinal deformity, tumour or metastasis, degenerative disease, spinal stenosis, herniated nucleus pulposus, spinal infection, and trauma.

Participant flow and data completeness

During the recruitment window, all consecutive eligible patients were approached, and 34 were enrolled and analysed; there were no post-enrolment exclusions. Both paired pharyngeal cultures and complete outcome ascertainment were available for all 34 patients, with no loss to follow-up during the index ICU/PICU admission and no missing culture specimens. The unit of analysis was the patient for demographic and outcome variables and the isolate for microbiological frequency counts; because some patients yielded more than one organism, isolate totals (34 pre-operative, 37 post-operative) differ slightly from the patient total.

Sample size

The study enrolled all eligible patients over the predefined recruitment window, yielding 34 participants. With an anticipated low incidence of post-operative pneumonia, this sample was powered primarily to describe the perioperative colonization and resistance shift rather than to detect small associations with pneumonia; for a descriptive primary endpoint of colonization prevalence near 60%, 34 patients yield a 95% confidence-interval half-width of approximately 16 percentage points, judged adequate for surveillance purposes. The limited number of outcome events is acknowledged as a constraint on inferential analyses.

Surgical technique

All procedures were performed by the institutional spine surgery team under general endotracheal anaesthesia. Positioning was prone for posterior approaches and supine or lateral for anterior/lateral approaches, with padding and abdominal decompression to limit epidural venous engorgement and blood loss. The dominant procedure was posterior decompressive laminectomy with posterior spinal fusion (PSF), performed through a standard midline posterior approach as follows: (1) midline skin incision and subperiosteal exposure of the posterior elements; (2) decompression by laminectomy/laminotomy and foraminotomy to relieve neural compression; (3) placement of pedicle-screw and rod instrumentation at the planned levels; (4) intra-operative fluoroscopic verification of implant position and alignment; and (5) decortication and bone grafting for fusion, haemostasis, placement of a closed-suction drain, and

layered closure. Deformity correction with PSF additionally employed reduction and corrective manoeuvres, and one patient underwent non-fusion stabilization. Implants were titanium pedicle-screw-rod systems selected by level and pedicle morphology. Perioperative antibiotic prophylaxis (predominantly cefazolin) was administered per institutional protocol.

Post-operative protocol

Patients were transferred intubated to the ICU or PICU for monitored recovery. Standard care included thromboprophylaxis, continuation of prophylactic antibiotics, analgesia, early mobilisation when stable, and a structured weaning protocol with extubation as soon as respiratory and haemodynamic criteria were met. Infection-control measures comprised hand hygiene, head-of-bed elevation, oral care, and aseptic airway management consistent with ventilator-associated pneumonia prevention practice.[7] Follow-up during intensive care included daily clinical assessment, laboratory monitoring, and chest radiography when clinically indicated.

Microbiological sampling and outcome ascertainment

Two pharyngeal swab specimens were obtained from each patient: the first at induction of anaesthesia (pre-operative), and the second during post-operative intubated intensive care with the endotracheal tube in situ (post-operative). Swab tips were placed in transport medium, sealed, labelled, and transported to the hospital microbiology laboratory, where specimens were cultured on standard agar media. Isolates were identified by conventional methods, and antimicrobial susceptibility was determined by disk diffusion using Clinical and Laboratory Standards Institute (CLSI) breakpoints, reported as sensitive (S), intermediate (I), or resistant (R). Organisms were classified as commensal/normal flora (e.g., viridans streptococci, coagulase-negative staphylococci, Haemophilus influenzae, Neisseria spp.) or potential pathogens (e.g., S. aureus, P. aeruginosa, K. pneumoniae, A. baumannii, Enterobacterales).[11] Post-operative pneumonia, the primary clinical outcome, was defined as a new chest-radiographic infiltrate or air-bronchogram pattern interpreted by a consultant radiologist, accompanied by laboratory evidence of leukocytosis or leukopenia, during ICU/PICU care; the single event was additionally graded using the Clavien-Dindo classification.

Statistical analysis

Analyses were performed in Python 3.11 (SciPy 1.11 and statsmodels 0.14) and cross-checked. Categorical variables are summarised as counts and percentages and continuous variables as mean ± standard deviation. Pneumonia incidence and colonization prevalence are reported with Wilson 95% confidence intervals. The perioperative change in the proportion of pathogenic isolates was assessed with the chi-square test and quantified with Cohen's h. The association between pre-operative pathogenic colonization and pneumonia was tested with Fisher's exact test, with an odds ratio and 95% confidence interval estimated after Haldane-Anscombe correction owing to a zero cell. The associations of ICU length of stay >48 h and endotracheal-tube duration >24 h with pneumonia were assessed by Spearman rank correlation (equivalent to the phi coefficient for the 2x2 case) and by Fisher's exact test. Because only a single pneumonia event occurred, the data exhibit perfect separation; multivariable logistic regression and receiver-operating-characteristic analysis were therefore not estimable and were not performed, and the asymptotic Spearman p-value is reported only alongside the exact test. The colonization-shift description was the pre-specified primary analysis and the pneumonia associations were secondary and exploratory; no imputation or interim analysis was performed. A two-sided alpha of 0.05 was used; exact p-values are reported to three decimal places.

Ethics

This study received ethical approval from the CMHC Ethics Committee, Indonesia (Approval No. CMHC/EC/2024/071). Written informed consent was obtained from all participants, or from legal guardians

for paediatric patients, in accordance with the Declaration of Helsinki.

3. Results

Patient characteristics

Thirty-four patients undergoing elective spine surgery with post-operative intensive care were enrolled. Nineteen (55.9%) were female and 15 (44.1%) male. By age and care unit, 5 patients (14.7%) were ≤18 years and managed in the PICU, 17 (50.0%) were 19-59 years, and 12 (35.3%) were ≥60 years. The most frequent indications were spinal deformity (10 patients, 29.4%) and tumour/metastasis (10 patients, 29.4%), followed by degenerative disease and spinal stenosis (7 patients each, 20.6%), herniated nucleus pulposus and spinal infection (4 patients each, 11.8%), and trauma (1 patient, 2.9%). The dominant procedure was decompressive laminectomy with posterior spinal fusion (26 patients, 76.5%), followed by deformity correction with PSF (6 patients, 17.6%), PSF alone (1 patient, 2.9%), and deformity correction with non-fusion stabilization (1 patient, 2.9%). Full patient demographics and clinical characteristics are presented in Table 1.

Table 1. Patient demographics and clinical characteristics (N = 34).

Characteristic	n (%)
Gender	
Male	15 (44.1)
Female	19 (55.9)
Age group / care unit	
≤18 years (PICU)	5 (14.7)
19-59 years (ICU)	17 (50.0)
≥60 years (ICU)	12 (35.3)
Surgical indication	
Spinal deformity (scoliosis, ASD)	10 (29.4)
Tumour / metastasis	10 (29.4)
Degenerative disease (CSM, DDD, spondylosis)	7 (20.6)
Spinal stenosis	7 (20.6)
Herniated nucleus pulposus	4 (11.8)
Spinal infection (TB spondylitis, spondylodiscitis)	4 (11.8)
Trauma	1 (2.9)
Surgical procedure	
Decompressive laminectomy + PSF	26 (76.5)
Deformity correction + PSF	6 (17.6)
PSF alone	1 (2.9)
Deformity correction + non-fusion stabilization	1 (2.9)

*Notes: ASD, adult spinal deformity; CSM, cervical spondylotic myelopathy; DDD, degenerative disc disease; PSF, posterior spinal fusion. *Indications overlap in some patients; percentages exceed 100%.*

Perioperative shift in respiratory colonization

Pre-operative pharyngeal cultures yielded a flora in which commensal organisms were prominent (viridans streptococci, 4 isolates; *Staphylococcus epidermidis*, 4; *Haemophilus influenzae*, 3; *Streptococcus pneumoniae*, 1) alongside recognised pathogens, principally Staphylococcus aureus (6 isolates), *Pseudomonas aeruginosa* (6), and *Klebsiella pneumoniae* (5). At the patient level, pathogenic colonization was present pre-operatively in 21 of 34 patients (61.8%; 95% CI 45.0-76.1). Post-operative cultures during intubated intensive care demonstrated a shift toward pathogens: S. aureus increased from 6 to 9 isolates (+50%) and became the dominant organism, A. baumannii increased from 2 to 4 isolates, and Serratia marcescens and Proteus mirabilis were newly isolated, while the contribution of commensal flora declined, as illustrated in Figure 1. At the level of overall isolate counts, the proportion of pathogenic isolates changed only marginally (61.8% of 34 pre-operative isolates versus 64.9% of 37 post-operative isolates; chi-square =0.073, p=0.786; Cohen's h=0.064, a negligible effect), indicating that the salient change was in species composition and resistance rather than in the gross pathogen fraction. This perioperative species-level transition is consistent with reported ICU microbiome dynamics in intubated patients.[8,14]

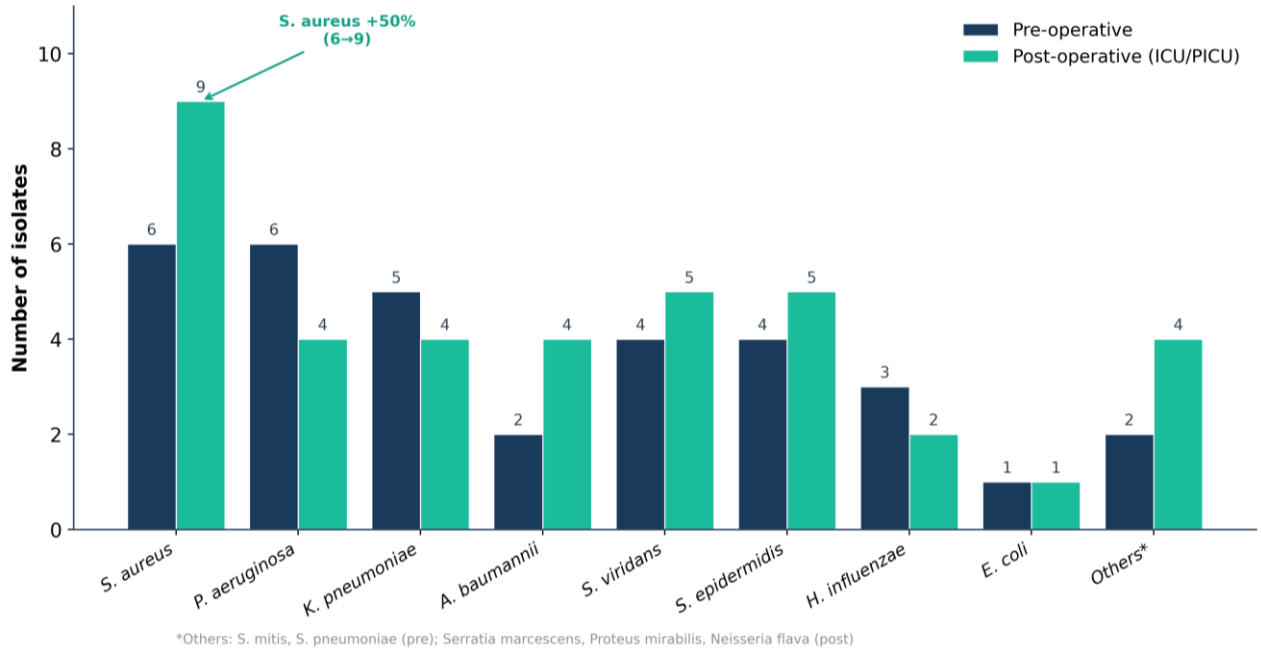

Figure 1. Perioperative shift in respiratory tract bacterial colonization (pre- vs post-operative isolate counts).

Antimicrobial resistance

Antimicrobial susceptibility testing revealed a clinically relevant resistance burden at both time points that increased after surgery, as detailed in Figure 2. Pre-operatively, intermediate resistance was noted to several agents (ceftriaxone, ciprofloxacin, ampicillin/sulbactam, ceftazidime), while full resistance was already evident and dominated by ciprofloxacin. Post-operatively, both intermediate and full resistance increased, with ciprofloxacin again showing the highest resistance frequency, followed by gentamicin and trimethoprim-sulfamethoxazole. These findings are concordant with the emergence of multidrug-resistant Gram-negative organisms during intensive care reported elsewhere.[12,13,17]

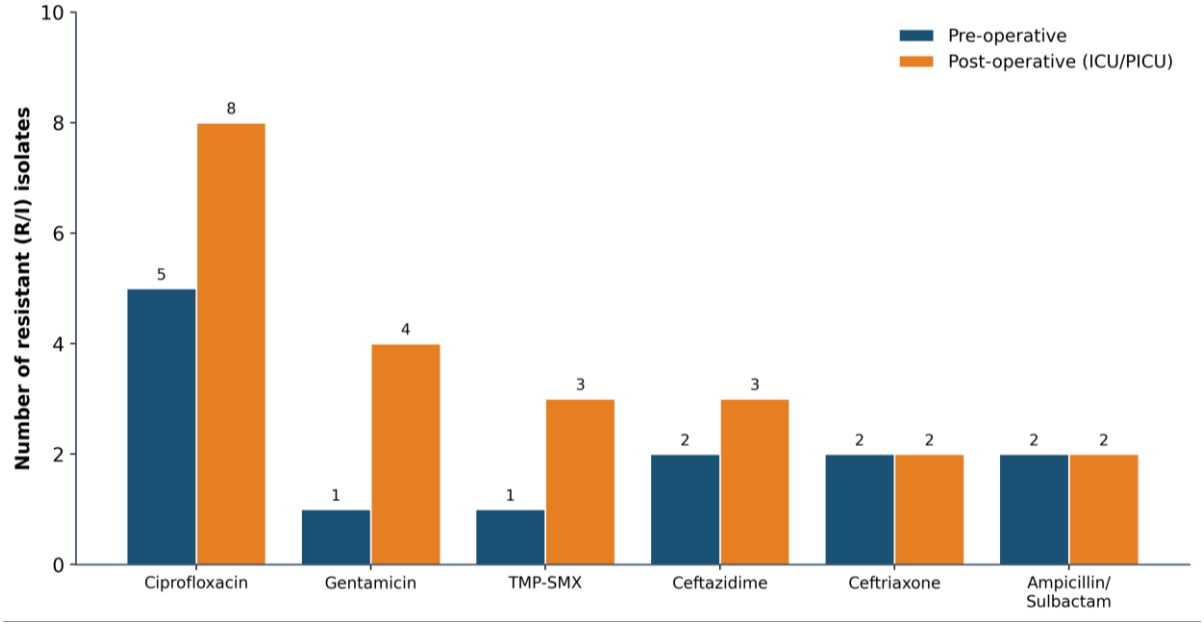

Figure 2. Antimicrobial resistance pattern, pre- versus post-operative.

Intensive-care exposure, antibiotics, and pneumonia

Most patients had a short intensive-care exposure: ICU/PICU stay was ≤48 h in 32 patients (94.1%) and >48 h in 2 (5.9%), and endotracheal-tube duration was ≤24 h in 32 patients (94.1%) and >24 h in 2 (5.9%). Antibiotic therapy during intensive care was predominantly cefazolin (30 patients, 88.2%), with ciprofloxacin (2, 5.9%), vancomycin (1, 2.9%), and levofloxacin (1, 2.9%) used selectively. Post-operative pneumonia occurred in a single patient (1/34; 2.94%; 95% CI 0.52-14.92), classified as Clavien-Dindo Grade II; this patient was the one individual with both prolonged ICU stay (>48 h) and prolonged intubation (>24 h). These microbiological and clinical outcome parameters are summarised in Table 2.

Table 2. Perioperative microbiological and clinical outcome parameters.

Parameter	Value	Statistic / 95% CI
Dominant pre-operative pathogens (isolates)	S. aureus 6; P. aeruginosa 6; K. pneumoniae 5	—
Dominant post-operative pathogens (isolates)	S. aureus 9; A. baumannii 4; P. aeruginosa 4; K. pneumoniae 4	—
S. aureus isolates (pre → post)	6 → 9 (+50%)	—
Pathogenic isolate proportion (pre vs post)	61.8% vs 64.9%	p = 0.786; h = 0.06
Pre-operative pathogenic colonization	21/34 (61.8%)	95% CI 45.0-76.1
ICU/PICU stay > 48 h	2 (5.9%)	—
Endotracheal-tube duration > 24 h	2 (5.9%)	—
Antibiotic — cefazolin	30 (88.2%)	—
Antibiotic — ciprofloxacin / vancomycin / levofloxacin	2 / 1 / 1 (5.9 / 2.9 / 2.9%)	—
Post-operative pneumonia (Clavien-Dindo II)	1/34 (2.94%)	95% CI 0.52-14.92

Notes: CI, confidence interval (Wilson for proportions); h, Cohen's h. Species names abbreviated.

Associations with post-operative pneumonia

Pre-operative pathogenic colonization was not associated with post-operative pneumonia: the single case arose among the 21 colonized patients and none among the 13 with commensal-only flora, giving a Fisher exact p=1.000 and a Haldane-Anscombe corrected odds ratio of 1.98 (95% CI 0.07-52.17), an estimate whose extremely wide interval reflects the single event. In contrast, both measures of intensive-care exposure showed a strong positive rank correlation with pneumonia: ICU stay >48 h and endotracheal-tube duration >24 h each yielded a Spearman/phi coefficient of rho=0.696, because the only patient who developed pneumonia was also the only patient with prolonged exposure on both measures. However, given the single outcome event and the resulting perfect separation, the exact test did not reach the conventional significance threshold (Fisher exact p=0.059), and multivariable and ROC analyses were not estimable. These risk-factor associations, with Haldane-corrected odds ratios and confidence intervals, are displayed in the forest plot in Figure 3 and summarised in Table 3.

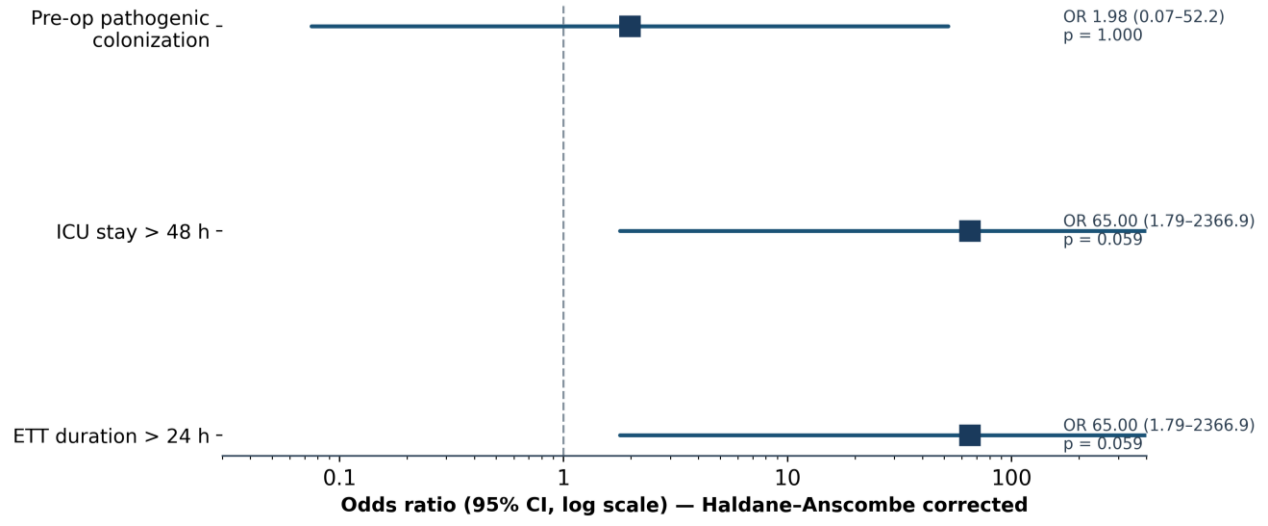

Figure 3. Forest plot of risk-factor associations with post-operative pneumonia (Haldane-corrected odds ratios; 95% CI).

Table 3. Association of risk factors with post-operative pneumonia.

Risk factor	Pneumonia (exposed vs unexposed)	Effect size (95% CI)	p-value
Pre-operative pathogenic colonization	1/21 vs 0/13	OR 1.98 (0.07-52.17)	1.000
ICU/PICU stay > 48 h	1/2 vs 0/32	rho = 0.696	0.059
Endotracheal-tube duration > 24 h	1/2 vs 0/32	rho = 0.696	0.059

*Notes: OR, odds ratio (Haldane-Anscombe corrected); rho, Spearman/phi coefficient. *Fisher exact test. Multivariable and ROC analyses were not estimable owing to a single outcome event (perfect separation).*

Clinical course of the pneumonia case

The single patient who developed post-operative pneumonia was an adult managed in the ICU after a tumour/metastasis spine procedure, with both prolonged intensive-care stay (>48 h) and prolonged intubation (>24 h). The infection met hospital-acquired pneumonia criteria with a new radiographic infiltrate and leukocytosis; it was treated pharmacologically

with a culture-guided antibiotic, did not require reintubation or vasopressor support, and resolved before discharge, consistent with a Clavien-Dindo Grade II complication. Benchmarked against published spine-surgery series, the observed pneumonia incidence of 2.94% lies within the reported range of approximately 1-6% for major spinal procedures.[1,5]

4. Discussion

In this prospective cohort of 34 spine surgery patients requiring post-operative intensive care, three findings emerged. First, the respiratory flora shifted perioperatively toward pathogens at the species level, with S. aureus rising by 50% to become dominant and with emergence of multidrug-resistant Gram-negative organisms (A. baumannii, and newly isolated S. marcescens and P. mirabilis), accompanied by an increase in antimicrobial resistance led by ciprofloxacin (Figures 1 and 2). Second, pre-operative pathogenic colonization, present in 61.8% of patients, did not predict post-operative pneumonia (Fisher p=1.000; Table 3). Third, the duration of intensive-care exposure (ICU stay >48 h and endotracheal-tube duration >24 h) was strongly rank-correlated with pneumonia (rho=0.696, Figure 3), although the single pneumonia event (2.94%; 95% CI 0.52-14.92) precludes firm inferential conclusions (exact p=0.059).

The perioperative transition from a commensal-predominant to a pathogen- and resistance-enriched flora that we observed (Figure 1) is consistent with the broader literature on the ICU microbiome and tracheal-tube colonization. Studies of intensive-care microbiology describe how surgical stress, antibiotic exposure, prolonged hospitalisation, and the endotracheal tube together reshape the respiratory community toward Gram-negative bacilli and S. aureus, frequently with multidrug-resistant phenotypes.[8,11] Our species-level findings mirror the organism distribution reported in ICU surveillance studies, in which the respiratory tract is a leading site of infection and Gram-negative organisms predominate.[12,14]

It is notable that, although the species composition and resistance pattern shifted, the gross proportion of pathogenic isolates changed little (Cohen's h=0.064). This dissociation underscores that the clinically meaningful perioperative change is qualitative, a move toward more virulent and more resistant organisms, rather than a simple increase in the pathogen fraction. The dominance of ciprofloxacin resistance, with rising gentamicin and trimethoprim-sulfamethoxazole resistance post-operatively (Figure 2), is concordant with regional reports of fluoroquinolone, aminoglycoside, and trimethoprim-sulfamethoxazole resistance among intensive-care Gram-negative isolates.[13,17,20] These data have direct stewardship implications for empirical therapy in orthopedic critical care.

Our second finding, the absence of an association between pre-operative pathogenic colonization and post-operative pneumonia, is best understood through the distinction between colonization and infection. Surveillance cohorts show that although airway colonization with pathogens is statistically associated with ICU pneumonia, the great majority of colonized patients do not progress to disease, so colonization must be interpreted separately from active infection.[14] Our null result contrasts with a large propensity-matched analysis in which pre-operative MRSA colonization more than doubled the risk of pneumonia after lumbar spine surgery, a discrepancy most plausibly explained by our very small sample and single event, by the specificity of MRSA versus mixed colonization, and by universal cefazolin prophylaxis.[15] Preserved host immunity in most patients and adherence to infection-control measures may further have uncoupled colonization from infection in our cohort.

Our third finding aligns with the established epidemiology of nosocomial and ventilator-associated pneumonia, in which the duration of invasive exposure is among the most consistent risk factors. The

thresholds we used (48 h of ICU stay and 24 h of intubation) are biologically grounded: endotracheal-tube biofilm maturation and the transition from colonization to infection accelerate with intubation time, after which the tube behaves as a microbial reservoir, while prolonged intensive-care exposure markedly increases the probability that colonization with hospital flora becomes invasive infection.[7,8] That only one of the two patients with prolonged exposure developed pneumonia reinforces that duration is a powerful but not sufficient cause, host and care-quality factors also being decisive.[9,10]

From a physiological standpoint, the endotracheal tube is central to this risk. By holding the glottis open, it abolishes protective cough and glottic-closure reflexes, impairs mucociliary transport, injures the tracheal mucosa, and permits micro-aspiration of contaminated subglottic secretions past the cuff; its luminal surface then supports biofilm formation that resists host defences and antibiotics.[7,8] Prone positioning and prolonged operative times in spine surgery compound this by promoting airway oedema and dependent secretion pooling.[4,5] These mechanisms together explain why the duration of intubation and intensive-care stay, rather than the mere presence of colonizing pathogens, emerged as the more relevant correlate of pneumonia.

Two methodological caveats merit emphasis. First, the duration of intubation and intensive-care stay may be a marker of underlying case complexity rather than an independent cause of pneumonia: longer, more complex procedures (for example, oncologic reconstructions) both prolong intubation and independently raise pulmonary risk.[3,6] Because operative duration, transfusion, and comorbidity were not modelled, and because a single event precludes multivariable adjustment, the intensive-care-exposure association is unadjusted and exploratory, and residual confounding cannot be excluded. Second, the perioperative colonization comparison was performed at the level of pooled isolates; a patient-level paired (McNemar) analysis would be the preferred inferential complement, although the descriptive species-level shift we report is robust to this consideration.

These findings carry practical implications for orthopedic surgeons and intensivists, particularly in resource-variable Indonesian settings. They argue for duration-focused prevention, minimising operative time and blood loss, protocolised early weaning and extubation, head-of-bed elevation, oral care, and structured ventilator-associated-pneumonia bundles from the outset of post-operative care, rather than reliance on pre-operative colonization screening as a triage tool.[7,11] Recommendations should be tiered by resource level: some measures, such as subglottic-secretion-drainage tubes, may be beyond many district hospitals, but head-of-bed elevation, oral hygiene, early-extubation pathways, and local-antibiogram-guided prophylaxis are universally feasible.

In the Indonesian context these data are especially relevant. Dr. Moewardi Regional General Hospital serves as the principal spine-surgery referral centre for Central Java, managing complex deformity, oncologic, infective, and traumatic disease, the majority under BPJS Kesehatan coverage that shapes implant choice, intensive-care access, and antibiotic availability. Local surveillance of airway colonization and resistance, as reported here, provides actionable information for empirical-therapy policy and prevention investment in a region where ventilator-associated-pneumonia epidemiology differs from high-income settings.[16]

This study has several strengths. To our knowledge it is among the first to pair pre- and post-operative respiratory cultures within the same spine surgery patients in Indonesian practice, allowing direct description of the perioperative colonization and resistance shift. The prospective design with standardised sampling, consultant-radiologist adjudication of the pneumonia outcome, and an explicit, statistically honest analytic plan that reports effect sizes and confidence intervals and refrains from fitting unstable models lend the findings credibility within their descriptive scope.

Several limitations must be acknowledged. First and most importantly, the sample was small (n=34) and only a single pneumonia event occurred, producing perfect separation that precludes multivariable adjustment and ROC modelling and renders the intensive-care-exposure association suggestive rather than confirmatory. Second, the single-centre design and heterogeneity of surgical indications limit generalisability and preclude indication-specific inference. Third, pharyngeal swabs sample the upper airway and may not fully represent lower-respiratory flora, and culture-based identification may underestimate fastidious or anaerobic organisms relative to molecular methods. Fourth, potential confounders, including nutritional status, comorbidity burden, transfusion, operative duration, and specific antibiotic exposures, were not modelled. Larger, multicentre studies with more outcome events, molecular microbiology, and prospective confounder capture are needed to confirm these observations.[13,16]

5. Conclusion

In this prospective cohort of spine surgery patients requiring post-operative intensive care, the respiratory flora shifted perioperatively toward pathogens and increased antimicrobial resistance, with Staphylococcus aureus rising by 50% and multidrug-resistant Gram-negative organisms emerging during intubated intensive care. Pre-operative pathogenic colonization, present in 61.8% of patients, did not predict post-operative pneumonia (Fisher p=1.000), whereas prolonged intensive-care exposure (ICU stay >48 h and endotracheal-tube duration >24 h) was strongly rank-correlated with the single pneumonia event (rho=0.696), which occurred in 2.94% of patients (95% CI 0.52-14.92) and was of Clavien-Dindo Grade II. Although the low event rate precludes definitive inference, these findings indicate that the duration of invasive intensive-care exposure, rather than pre-operative colonization status, is the more relevant target for pneumonia prevention in this population. Orthopedic surgeons and intensivists should prioritise duration-focused prevention, minimising operative time, protocolised early extubation, and structured ventilator-associated-pneumonia bundles, together with local microbiological surveillance and antimicrobial stewardship. Larger multicentre studies with more outcome events are required to confirm the independent contribution of intensive-care exposure to post-operative pneumonia after spine surgery.

Declarations

Ethics approval and consent to participate

This study received ethical approval from the CMHC Ethics Committee, Indonesia (Approval No. CMHC/EC/2024/071). Written informed consent was obtained from all participants, or from legal guardians for paediatric patients, in accordance with the Declaration of Helsinki.

Data availability

The de-identified data supporting the findings of this study are available from the corresponding author on reasonable request.

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Conflicts of interest

The authors declare no conflicts of interest.

Author contributions

All authors contributed to the conception and design of the study, data acquisition, analysis and interpretation, drafting and critical revision of the manuscript, and approved the final version.

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