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Analysis Of Germs Patterns Of Pneumonia Incidents In Spine Surgery Patients With Post-Operative Care In The ICU/PICU Of Dr. Moewardi Hospital

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Abstract

Spine surgery carries a risk of infectious complications, including pneumonia, during postoperative care in the ICU/PICU. Changes in bacterial patterns due to surgery and endotracheal tube use are suspected to contribute to these events, but evidence in spine surgery patients is still limited. This study aims to analyze pre- and postoperative bacterial patterns and their relationship to the incidence of pneumonia, duration of ICU/PICU stay, and duration of endotracheal tube use. The study used an observational analytical design with a prospective cohort approach. The population was all spine surgery patients at Dr. Moewardi Hospital, Surakarta, from August 2024 to August 2025. A sample of 34 patients was obtained using a total sampling technique. The research instruments included medical records, observation sheets, pharyngeal swab cultures, sputum or tracheal aspirate cultures, and chest radiographs. Data analysis was performed descriptively, using the Chi-Square test, and Spearman correlation. The results showed changes in bacterial patterns after surgery with an increased dominance of pathogenic bacteria, especially Staphylococcus aureus. No significant correlation was found between preoperative bacterial patterns and the incidence of pneumonia ($p = 1.000$). In contrast, ICU stays of more than 48 hours and endotracheal tube use of more than 24 hours were strongly correlated with pneumonia ($\rho = 0.696$; $p < 0.001$). It was concluded that intensive care duration and endotracheal tube use were more influential factors in the incidence of pneumonia than preoperative bacterial patterns, so infection control and limiting the duration of invasive procedures should be prioritized in post-spinal surgery management.

Keywords: Endotracheal Tube, Intensive Care Unit, Pneumonia, Spine Surgery, Surgical Site Infection

INTRODUCTION

Spinal surgery is a surgical procedure performed on the spine and its surrounding tissues to manipulate and modify the bones, intervertebral discs, and other supporting tissues in the management of various conditions, such as infection, trauma, neurological dysfunction, tumors, herniated discs, spinal stenosis, spondylolisthesis, osteoporosis, degenerative disc disease, scoliosis, and spondylitis (Hansson et al., 2008; Hussain et al., 2011). In recent decades, the number of spinal surgeries has continued to increase along with the development of surgical technology and the increasing use of spinal fusion devices (Wennberg & Cooper, 2006). This increase in the number of procedures indicates that spinal surgery has become an important procedure in the management of various musculoskeletal and neurological diseases that require operative intervention.

Despite this, spinal surgery still has a relatively high complication rate, ranging from 7% to 20%, higher than the average complication rate for orthopedic surgery, which is around 5% (Barbanti-Brodano et al., 2020). These complications can include postoperative hematoma, surgical wound infection, cerebrospinal fluid leak, mechanical complications, neurological complications, systemic complications, and even surgical-related death. Furthermore, complications can arise from perioperative procedures, including endotracheal intubation performed as part of airway management during surgery (Dhillon, 2016). This condition indicates that the success of spinal surgery is not only determined by the surgical procedure, but also influenced by the management of complications that arise during the perioperative period.

Spinal surgery is generally a major surgical procedure involving extensive tissue dissection and bone decortication, often causing significant blood loss and requiring a longer

surgical duration (Dhillon, 2016). This condition increases the likelihood of patients requiring tracheal intubation, especially when performed in the prone position (Ahmed & Boyer, 2024). However, the use of an endotracheal tube (ETT) also carries the consequence of an increased risk of respiratory tract infection complications. Furthermore, the perioperative period of major surgery is known to cause immune system suppression due to activation of the inflammatory response, the sympathetic nervous system, and the hypothalamic, pituitary, and adrenal axes, which influence decreased T cell responses and cytokine production. This situation has implications for an increased risk of postoperative infection and sepsis during the hospitalization period (Amodeo et al., 2018; Menges et al., 2012).

Studies of patients undergoing intubation in the ICU have shown that Gram-negative bacilli are the most frequently encountered organisms, followed by Gram-positive bacteria, fungi, and viruses, with potential co-infections, multiresistant Gram-negative bacterial infections, and recurrent pneumonia during hospitalization (Rello et al., 1999; Li et al., 2017). However, these bacterial patterns can vary between regions and hospitals due to various factors. Previous studies have focused more on the incidence of respiratory complications after spinal surgery (Murgai et al., 2018; Boddapati et al., 2021) or the characteristics of microbial colonization in intubated patients in the ICU in general (Samieeifard et al., 2014). To date, no studies have specifically analyzed the respiratory bacterial patterns in spinal surgery patients undergoing ICU or PICU care and their relationship to the incidence of pneumonia during their stay.

Based on these conditions, this study aims to analyze the bacterial patterns in patients undergoing spinal surgery and receiving postoperative care in the ICU and PICU of Dr. Moewardi Regional Hospital, including differences in bacterial patterns before surgery and after treatment with ETT intubation, the relationship between preoperative bacterial patterns and the incidence of pneumonia, and the relationship between the length of stay in the ICU or PICU and the duration of ETT use with the incidence of pneumonia. This study is important to conduct as a basis for compiling a map of bacteria and antibiotic sensitivity in post-spinal surgery patients at Dr. Moewardi Regional Hospital. The novelty of this study lies in the analysis of respiratory tract bacterial patterns specifically in spinal surgery patients treated in the ICU or PICU and their relationship with the incidence of pneumonia, which has not been reported in previous studies.

RESEARCH METHODS

This study is an analytical observational study with a prospective cohort design in patients undergoing spinal surgery at Dr. Moewardi Regional General Hospital, Surakarta. Analytical observational research is used to examine the relationship between two or more variables without providing intervention to the research subjects. The prospective cohort design was chosen because the study was conducted by following subjects from risk factors to events observed at a later time, allowing researchers to evaluate the relationship between germ patterns, duration of treatment, use of endotracheal tubes (ETT), and the incidence of pneumonia during treatment in the ICU/PICU (Notoatmodjo, 2014). The study was conducted at Dr. Moewardi Regional General Hospital and the Clinical Microbiology Laboratory of Dr. Moewardi Regional General Hospital, Surakarta, from August 2024 to August 2025. Observations were conducted while patients were undergoing treatment in the ICU/PICU, while follow-up care in the inpatient ward was not included in the scope of the study.

The target population of the study was all patients undergoing spinal surgery, while the accessible population was all patients undergoing spinal surgery at Dr. Moewardi Regional

General Hospital, Surakarta during the period of August 2024 to August 2025. The study sample was taken using a total sampling technique, namely all patients who met the inclusion and exclusion criteria were made research subjects. Inclusion criteria included patients undergoing spinal surgery under general anesthesia, a minimum surgery duration of three hours, undergoing postoperative care in the ICU/PICU, using ETT intubation during treatment, and willing to participate in the study by signing an informed consent. Meanwhile, patients with pneumonia or lower respiratory tract infections before surgery, immunodeficiency, comorbid diabetes mellitus, heart disease, chronic cerebrovascular disease, or a history of antibiotic use in the two weeks before surgery were excluded from the study. The sample size calculation used the proportion of post-spinal surgery pneumonia incidence of 1.98% as reported by Murgai et al. (2018), thus obtaining a minimum requirement of 30 subjects. To anticipate the loss of subjects during the observation period, the sample size was increased by around 10 to 20% so that the sample requirement became 33 to 36 patients.

The research instruments included a research sheet, patient medical records, informed consent forms, pharyngeal swab samples, agar culture media, plain chest radiographs, and stationery. The independent variables consisted of bacterial patterns from preoperative pharyngeal swab cultures, bacterial patterns during ICU/PICU care, ICU/PICU care duration, and duration of ETT use. The dependent variable was the incidence of pneumonia during ICU/PICU care. The diagnosis of pneumonia was established based on chest radiographs showing infiltrates or air bronchograms interpreted by a radiologist, accompanied by findings of leukocytosis or leukopenia from laboratory examinations. Data were analyzed using SPSS version 20.0 for Windows. Descriptive analysis was used to present frequency distributions, percentages, means, and standard deviations according to data characteristics. Inferential analysis was performed using the Chi-Square test to assess the relationship between preoperative bacterial patterns and pneumonia incidence, while the relationship between ICU/PICU care duration and ETT use duration with pneumonia incidence was analyzed using the Spearman Rank correlation test. A p-value of less than 0.05 was set as the limit of statistical significance.

The study began with a patient selection process based on inclusion and exclusion criteria, followed by data collection on subject characteristics, including age, gender, diagnosis, medical history, and planned surgical procedures. Prior to surgery, pharyngeal swab samples were taken by researchers trained by ENT-KL specialists to identify preoperative bacterial patterns through microbiological culture examination. After undergoing spinal surgery, patients were admitted to the ICU/PICU with monitoring of their clinical condition, duration of endotracheal tube (ETT) use, and the development of signs and symptoms of respiratory tract infection. If pneumonia was suspected during treatment, a chest X-ray and sputum or tracheal aspirate samples were collected for culture examination to determine postoperative bacterial patterns. All culture results, antibiotic use data, duration of ICU/PICU stay, duration of ETT use, and pneumonia incidence were then recorded and analyzed to compare preoperative and postoperative bacterial patterns and to evaluate the relationship between bacterial patterns, length of ICU/PICU stay, and duration of ETT use with the incidence of pneumonia in spinal surgery patients.

RESULTS AND DISCUSSION

Subject CharacteristicsStudy

Table 1. Characteristics of research subjects.

Characteristics	n	%
Gender		
L	15	45.7
P	19	54.3
Age		
≤18 years (PICU)	5	14.7
19-59 years (ICU)	17	50
≥60 years (ICU)	12	35.39
Diagnosis/Indications for spinal surgery		
Spinal deformities (Scoliosis, ASD)	10	29.41
Tumor/metastasis	10	29.41
Spinal degenerative disorders (CSM, DDD, spondylosis)	7	20.59
Spinal stenosis (canal/foramen/tandem stenosis)	7	20.59
HNP	4	11.76
Infections (TB spondylitis, spondylodiscitis, etc.)	4	11.76
Trauma	1	2.94
Spinal surgery		
Decompression laminectomy+PSF	26	76.47
Deformity correction+PSF	6	17.65
PSF	1	2.94
Deformity correction + non-fusion stabilization	1	2.94

The majority of patients were female, at 54.3%, while 45.7% were male. For age distribution, the majority of patients were in the 19-59 years age group (50%), followed by the ≥60 years age group which included 35.39% of patients, and 14.7% of patients were under 18 years of age, who were treated in the PICU.

In terms of diagnosis, the most common conditions found were spinal deformities (such as scoliosis and adult spinal deformity/ASD) and tumors/metastases, each recorded in 29.41% of patients. Other patients were diagnosed with degenerative spinal disorders (including CSM, DDD, and spondylosis) and spinal stenosis (canal, foraminal, and tandem stenosis), each found in 20.59% of patients. Disc herniation (HNP) and infections (such as tuberculous spondylitis and spondylodiscitis) were each found in 11.76% of patients, while trauma was found in only 1 patient.

Regarding surgical procedures, the most frequently performed procedure was decompressive laminectomy + PSF, which was performed in 76.47% of patients. Deformity correction + PSF was performed in 17.65% of patients, while PSF without decompression and deformity correction without fusion were recorded in only one patient each.

Pre-Operative and Post-Operative Germ Patterns

Pre-operative culture results revealed various types of microorganisms found in nasopharyngeal samples. Some of these were normal flora naturally found in the human body, such as Streptococcus viridans (4 cases), Staphylococcus epidermidis (4 cases), Haemophilus influenzae (3 cases), and others. Meanwhile, Streptococcus pneumoniae, which can be found as normal flora but has the potential to become pathogenic if the body's condition is compromised, was found in one patient.

On the other hand, several pathogenic bacteria were also found, which can cause serious infections, with the most common pathogens being Staphylococcus aureus (6 cases), Pseudomonas aeruginosa (6 cases), and Klebsiella pneumoniae (5 cases). The full details of the preoperative bacterial patterns are presented in Figure 1.

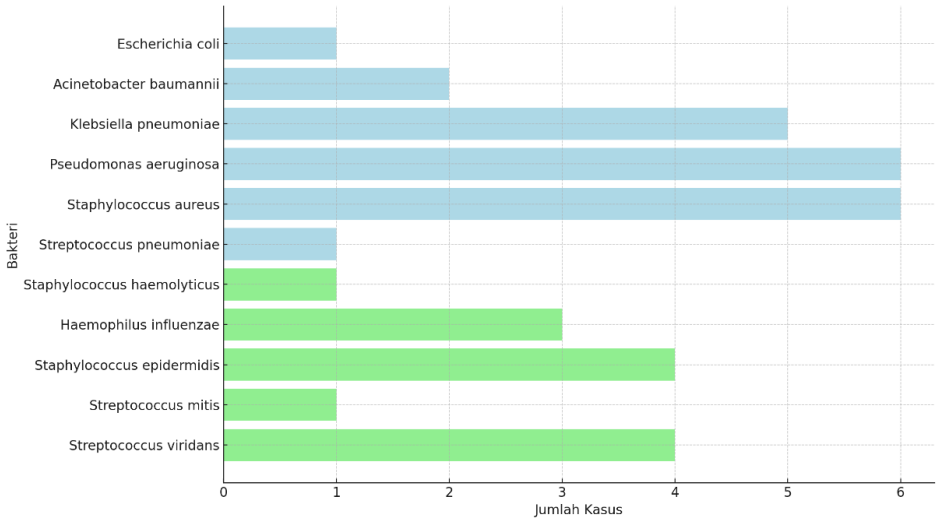


Figure 1. Pre-operative bacterial pattern graph.

Post-operative cultures revealed some normal flora, which are generally found in the human body without causing disease, but in smaller numbers than those found pre-operatively. Streptococcus viridans was found in three cases, while Staphylococcus epidermidis was recorded in four.

Pathogenic bacteria were more frequently found in postoperative cultures. Staphylococcus aureus was the dominant pathogenic bacteria found in 9 cases. Furthermore, pathogenic bacteria were also dominated by Acinetobacter baumannii, Pseudomonas aeruginosa, and Klebsiella pneumoniae, each recorded in 4 cases. Other bacteria found included Proteus mirabilis, Neisseria flava, Serratia marcescens, and others. Details of the types of bacteria found in postoperative cultures can be seen in Figure 2.

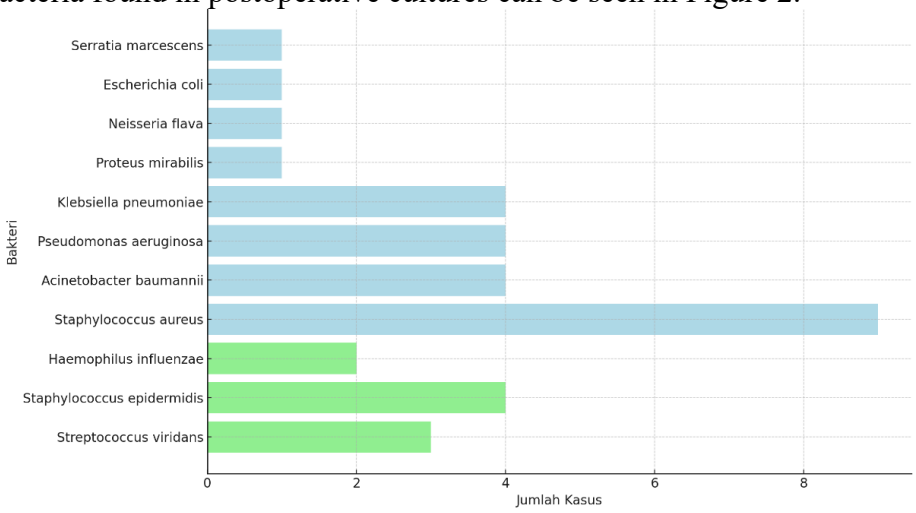


Figure 2.Post-operative bacterial pattern graph.

Types of Germs Based on Diagnosis

Based on the distribution table of bacterial types according to patient diagnosis, there appears to be variation in the pattern of bacterial presence between pre-operative and post-operative conditions in various spinal diagnoses. In patients with spinal deformities (such as scoliosis and ASD), the most frequently found bacteria pre-operatively were Streptococcus viridans and Staphylococcus epidermidis (2 cases each), followed by Klebsiella pneumoniae, Haemophilus influenzae, Pseudomonas aeruginosa, and Streptococcus mitis (1 case each). This pattern remained relatively stable after surgery, although there were additional isolations of Acinetobacter baumannii and Staphylococcus aureus.

In patients diagnosed with tumors or metastases, Staphylococcus aureus and Pseudomonas aeruginosa dominated preoperative findings (3 cases each), followed by Klebsiella pneumoniae (2 cases). After surgery, the number of Staphylococcus aureus cases increased to 4, and new bacteria such as Escherichia coli and Serratia marcescens emerged, which were previously undetected. Meanwhile, in the degenerative spinal disorder group, Staphylococcus epidermidis, Haemophilus influenzae, and Streptococcus pneumoniae were found preoperatively (1 case each). After surgery, Staphylococcus aureus and Pseudomonas aeruginosa emerged.

Table 2. Pre-operative and post-operative germ types based on diagnosis.

Diagnosis	Types of Germs			
	Pre-Operation	n	Post-Operation	n
Spinal deformities (Scoliosis, ASD)	*Streptococcus viridans*	2	*Streptococcus viridans*	2
	Staph. epidermidis	2	*Staph. epidermidis*	2
	Klebsiella pneumoniae	1	*Klebsiella pneumoniae*	1
	Haemophilus influenzae	1	*Haemophilus influenzae*	1
	Pseudomonas aeruginosa	1	*Staphylococcus aureus*	1
	Streptococcus mitis	1	*Acinetobacter baumannii*	1
Tumor/metastasis	*Staphylococcus aureus*	3	*Staphylococcus aureus*	4
	Pseudomonas aeruginosa	3	*Pseudomonas aeruginosa*	2
	Klebsiella pneumoniae	2	*Klebsiella pneumoniae*	1
	Acinetobacter baumannii	1	*Acinetobacter baumannii*	1
	Staph. haemolyticus	1	*Escherichia coli*	1
			Serratia marcescens	1
Spinal degenerative disorders (CSM, DDD, spondylosis)	*Staph. epidermidis*	1	*Staph. epidermidis*	1
	Haemophilus influenzae	1	*Pseudomonas aeruginosa*	1
	Streptococcus pneumoniae	1	*Staphylococcus aureus*	1
Spinal stenosis (canal/foramen/tandem stenosis)	*Staph. epidermidis*	1	*Staph. epidermidis*	1
	Streptococcus viridans	1	*Neisseria flava*	1
	Haemophilus influenzae	1	*Haemophilus influenzae*	1
	Staphylococcus aureus	1	*Staphylococcus aureus*	1
	Pseudomonas aeruginosa	1	*Pseudomonas aeruginosa*	1
HNP	*Streptococcus viridans*	1	*Streptococcus viridans*	1
	Pseudomonas aeruginosa	1	*Acinetobacter baumannii*	2
	Staphylococcus aureus	1		
Infections (TB spondylitis, spondylodiscitis, etc.)	*Staphylococcus aureus*	1	*Staphylococcus aureus*	2
	Escherichia coli	1	*Proteus mirabilis*	1
	Klebsiella pneumoniae	1	*Klebsiella pneumoniae*	1
	Acinetobacter baumannii	1		
Trauma	*Klebsiella pneumoniae*	1	*Klebsiella pneumoniae*	1

For other diagnoses such as spinal stenosis, HNP, spinal infection, and trauma, changes in bacterial composition were observed after surgery. For example, in HNP patients, the bacteria detected preoperatively were Streptococcus viridans, Pseudomonas aeruginosa, and Staphylococcus aureus (1 case each), but postoperatively an increase in Acinetobacter baumannii cases was found (2 cases). In spinal infection patients, Proteus mirabilis appeared postoperatively, while in trauma cases, Klebsiella pneumoniae remained the dominant bacteria before and after surgery. These findings indicate that surgical procedures can influence the variation of microorganisms, either through changes in dominance or the emergence of new pathogens. The full details of the preoperative and postoperative bacterial types based on patient diagnoses are presented in Table 6.

Pre-Operative and Post-Operative Antibiotic Resistance

In the pre-operative antibiotic resistance test results, several antibiotics showed moderate resistance (I) to the bacteria found in the samples. Ceftriaxone showed 2 cases, followed by Ciprofloxacin with 4 cases and Ampicillin/Sulbactam and Ceftazidime, each with 1 case. Meanwhile, there were several antibiotics that showed higher resistance (R) to bacteria. Ciprofloxacin was recorded as the antibiotic with the highest resistance, found in 6 cases. In addition, Erythromycin, Levofloxacin, Ampicillin/Sulbactam, Ceftriaxone, Gentamicin, Trimethoprim/Sulfamethoxazole, Meropenem, and Amikacin also showed varying levels of resistance, each with a lower number of cases, but still reflecting resistance to treatment. The complete data is shown in Figure 9.

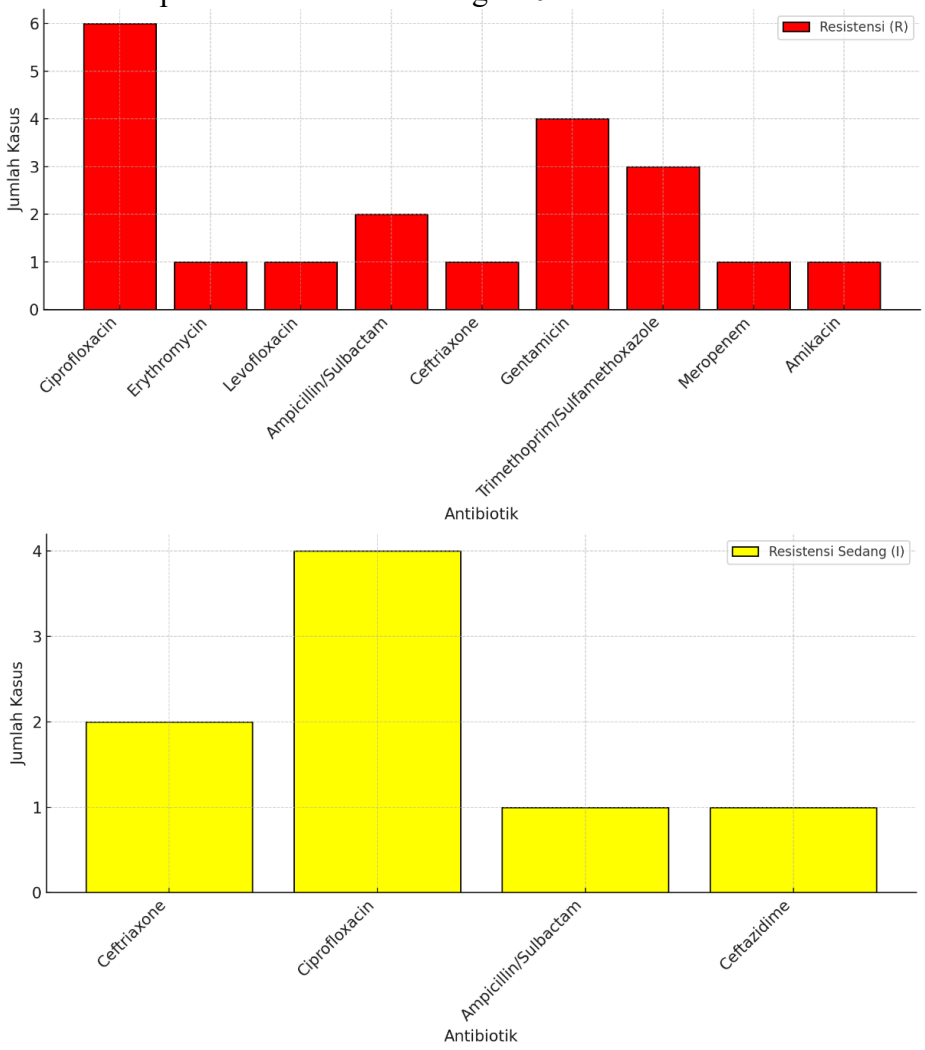


Figure 3. Graph of pre-operative antibiotic resistance cases. Red (R), Yellow (I).

In the post-operative antibiotic resistance results, several noteworthy patterns were found. Moderate resistance (I) was recorded in 5 cases involving antibiotics such as Ceftriaxone (1 case), Ciprofloxacin (3 cases), and Ampicillin/Sulbactam (1 case). This change indicates a consistency and even an increase in the moderate resistance pattern compared to pre-operative conditions. Meanwhile, for resistance (R), 34 cases were recorded divided into various antibiotics, with Ciprofloxacin showing the highest number at 10 cases, followed by Gentamicin (7 cases) and Trimethoprim/Sulfamethoxazole (6 cases). Other antibiotics showing a significant number of resistance (R) cases included Levofloxacin (3 cases) and Ampicillin/Sulbactam (2 cases). Some antibiotics, such as Moxifloxacin, Tigecycline, Meropenem, and Amikacin, each showed 1 case. Furthermore, post-operative antibiotic resistance data are presented in Figure 4.

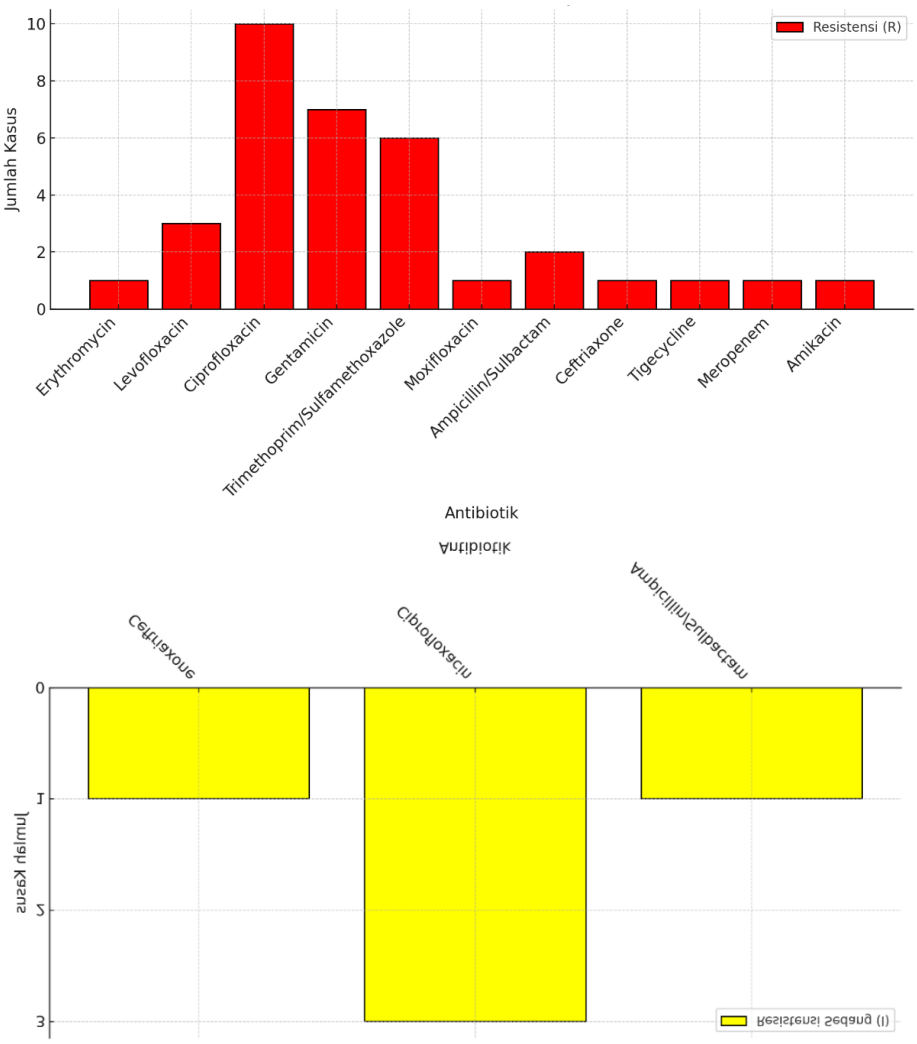


Figure 5. Graph of post-operative antibiotic resistance cases. Red (R), Yellow (I).

The increasing number of resistance (R) cases for several postoperative antibiotics, such as ciprofloxacin and gentamicin, reflects the potential differences in infection patterns that emerge after surgical procedures. This indicates that antibiotic use after surgery requires greater attention to prevent nosocomial infections or the further development of resistance.

Length of ICU Stay, Duration of ETT Use, Antibiotic Administration, and Pneumonia Incidence

Of the 34 patients studied, most patients (94.11%) had a length of stay in the ICU of ≤48 hours, while only 2 patients (5.88%) were treated for more than 48 hours. Similarly, with regard to the duration of ETT use, most patients (94.11%) used ETT for ≤24 hours, while only 2 patients (5.88%) had a duration of ETT use for more than 24 hours. Regarding antibiotic administration during the ICU/PICU, Cefazolin was the most commonly administered antibiotic with 30 patients (88.23%), followed by Ciprofloxacin (2 patients, 5.88%). Other antibiotics such as Vancomycin and Levofloxacin were each given to 1 patient (2.94%). Regarding the incidence of pneumonia, only 1 patient experienced pneumonia, while 33 patients (97.05%) did not experience this complication. There were 2 patients with a length of stay in the ICU/PICU >48 hours and 1 person experienced pneumonia (50%). Two patients were also counted with ETT use for >24 hours, with one (50%) experiencing pneumonia. Of the 32 patients treated for <48 hours in the ICU, none developed pneumonia.

Furthermore, 32 patients with ETT use for <24 hours did not develop pneumonia. More detailed data are presented in Table 3.

Table 3. Length of ICU stay, duration of ETT use, type of antibiotic administration, and incidence of pneumonia in research subjects.

Variables	n	%
Length of ICU Stay		
≤48 hours	32	94.11
>48 hours	2	5.88
Duration of ETT Use		
≤24 hours	32	94.11
>24 hours	2	5.88
Administration of Antibiotics during ICU/PICU		
Cefazolin	30	88.23
Ciprofloxacin	2	5.88
Vancomycin	1	2.94
Levofloxacin	1	2.94
Pneumonia Incident		
Yes	1	2.94
No	33	97.05
Use of ETT >24 hours and Pneumonia		
Yes	1	50%
No	1	50%
ETT use <24 hours and Pneumonia		
Yes	0	0%
No	32	100%
ICU length of stay >48 hours and Pneumonia		
Yes	1	50%
No	1	50%
ICU stay < 48 hours and Pneumonia		
Yes	0	0
No	32	100%

Statistical Analysis Results

Statistical analysis was performed to assess the relationship between several independent variables—preoperative bacterial pattern, ICU length of stay, and ETT duration—and the dependent variable, post-spinal surgery pneumonia. Due to the non-parametric nature of the data and the small number of pneumonia cases, the Chi-square test was used for categorical variables, and the Spearman Rank Correlation test was used to determine the strength of the relationship between ordinal variables.

The Relationship between Pre-Operative Germ Patterns and the Incidence of Pneumonia

The relationship between the types of pre-operative microorganisms (grouped into normal flora and pathogenic bacteria) and the incidence of pneumonia was tested using the Chi-square test.

Table 4. The Relationship between Pre-Operative Germ Patterns and the Incidence of Pneumonia

Pre-Operative Germ Pattern	Pneumonia (n=1)	No Pneumonia (n=33)	Total
Normal flora	0	12	13
Pathogen	1	20	21

Chi-square test: p = 1,000

Interpretation:

There was no statistically significant association between preoperative bacterial patterns and the incidence of pneumonia ($p > 0.05$). This indicates that the presence of

normal or pathogenic flora before surgery does not directly influence the occurrence of postoperative pneumonia.

Correlation between ICU Duration of Care and Pneumonia Incidence

Analysis using the Spearman test showed a strong and significant correlation between ICU length of stay (>48 hours) and the incidence of pneumonia. Although only one patient developed pneumonia, that patient was included in the ICU group with a length of stay of more than 48 hours.

Correlation between Duration of ETT Use and Incidence of Pneumonia

Similar results were found for the duration of ETT use. Spearman's test showed a strong and significant correlation between ETT use for >24 hours and the incidence of pneumonia. Patients who developed pneumonia also came from this group.

Table 5. The Relationship between Pre-Operative Germ Patterns and the Incidence of Pneumonia

Variable 1	Variable 2	Number of Data (n)	Spearman's rho (p)	p-value	Interpretation
Duration of ICU Stay	Pneumonia Incident	34	0.696	0.000005	Strong, significant correlation
Duration of ETT Use	Pneumonia Incident	34	0.696	0.000005	Strong, significant correlation

Interpretation:

A ρ (rho) value of 0.696 for both variables indicates a strong correlation between duration of exposure (both ICU and ETT) and the onset of pneumonia. A p value <0.05 indicates that this relationship is statistically significant. Although only one patient developed pneumonia, the unique position of this case, occurring in the patient with the longest duration of ICU and ETT stay, resulted in a consistent pattern of data sequences and allowed a strong correlation to be detected by Spearman analysis.

Discussion

Of the total study subjects, there were 15 male patients (45.7%) and 19 female patients (54.3%), indicating a nearly balanced gender distribution. In terms of age, the majority of patients were in the 19-59 years category (ICU) with a total of 17 patients (50%). Meanwhile, there were 12 patients (35.39%) in the ≥60 years group (ICU) and 5 patients (14.7%) in the ≤18 years age group (PICU). This illustrates that the majority of patients in this study were adults to elderly, who are at higher risk of post-operative complications.

In this study, spinal deformity (including scoliosis and adult spinal deformity/ASD) was the most common diagnosis, found in 10 patients (29.41%). These spinal deformities can affect posture and cause functional problems. Tumors/metastases were also noted in 10 patients (29.41%), indicating the presence of a primary or metastatic tumor spreading to the spine, potentially compressing nerves and causing neurological impairment.

Other conditions that were quite common were degenerative spinal disorders such as Cervical Spondylotic Myelopathy (CSM), Degenerative Disc Disease (DDD), and spondylosis, which were recorded in 7 patients (20.59%). These conditions are associated with aging or injury that causes damage to the discs and spinal structures. Furthermore, spinal stenosis, which involves narrowing of the spinal canal (canal stenosis) or narrowing of the space where nerves exit (foraminal stenosis), and tandem stenosis, which involves two areas of narrowing (e.g., cervical and lumbar), were found in 7 patients (20.59%), indicating that nerve compression was a significant problem in this study. Herniated Nucleus Pulposus (HNP) was found in 4 patients (11.76%), indicating a prolapsed disc compressing the nerve

and causing pain. Spinal infections, such as tuberculous spondylitis and spondylodiscitis, were also found in 4 patients (11.76%), adding to the complexity of spinal infection cases. Lastly, spinal trauma was noted in 1 patient (2.94%), indicating a spinal injury that may affect stability and function.

Most patients in this study underwent decompressive laminectomy + PSF (posterior spinal fusion), which was performed on 26 patients (76.47%). This procedure aims to reduce nerve compression by removing the compressed portion of the spine, while simultaneously performing spinal fusion to provide stability after decompression. Deformity correction + PSF was performed on 6 patients (17.65%), where this procedure not only corrects the deformed spine but also fuses the affected vertebrae. In addition, 1 patient (2.94%) underwent PSF alone, which is a posterior spinal fusion without decompression. Finally, 1 other patient (2.94%) underwent deformity correction + non-fusion stabilization, which aims to correct spinal deformities without using fusion techniques, but with non-fusion stabilization methods.

Bacterial culture results in patients with pre-operative and post-operative spinal deformities are dominated by gram-positive bacteria, such as Streptococcus viridans and Staphylococcus epidermidis. In patients with tumors/metastases, the most common bacteria found both pre-operatively and post-operatively are Staphylococcus aureus and Pseudomonas aeruginosa. A study by Yang et al., in 2017, reported that in cases of infectious spondylitis involving spinal deformities and tumors/metastases, of 20 patients, 50% were infected with Staphylococcus aureus, 15% with Mycobacterium tuberculosis, 10% with Pseudomonas aeruginosa, Escherichia coli, Streptococcus viridans, and Enterococcus faecalis.

Meanwhile, in other diagnoses such as degenerative spinal disorders, spinal stenosis, herniated nucleus pulposus (HNP), spinal infections (tuberculous spondylitis, spondylodiscitis, etc.), and trauma, the diversity of pathogens is much higher, and no single bacterial species is dominant. This reflects the complexity and heterogeneity of infections that can occur in these conditions.

The results of this study indicate a fairly high pattern of antibiotic resistance in both the pre-operative and post-operative phases. In the pre-operative phase, although moderate resistance (I) was only recorded for a few antibiotics such as Ceftriaxone, Ciprofloxacin, Ampicillin/Sulbactam, and Ceftazidime, full resistance (R) began to appear with Ciprofloxacin dominating. After surgery, there was an increase in cases of resistance in both the moderate and full categories, with Ciprofloxacin as the antibiotic with the highest level of resistance, followed by Gentamicin and Trimethoprim/Sulfamethoxazole.

Although the study results showed a relatively high pattern of antibiotic resistance, the incidence of postoperative pneumonia remained low, with only one case recorded. This can be explained because antibiotic resistance is not directly related to the number of infections, but rather reflects the potential for treatment failure if an infection occurs. The occurrence of postoperative pneumonia is strongly influenced by various other risk factors, such as the patient's immune system, nutritional status, the presence of comorbidities, and iatrogenic factors such as length of stay in the ICU, use of an endotracheal tube (ETT), transfusion, and duration of surgery (Xiang et al., 2022). In this study, only one patient had a high-risk combination of ICU stay of more than 48 hours and use of an ETT of more than 24 hours. Therefore, despite the relatively high resistance pattern, the incidence of pneumonia remained low. These findings demonstrate that antibiotic resistance is important to be aware of, but host and clinical environmental factors remain the main factors in the occurrence of postoperative infections.

The results of this study indicate differences in the bacterial patterns found in patients before and after spinal surgery. In pre-operative cultures, various microorganisms were

found, most of which were normal flora naturally present in the human body. Some of the microorganisms found included Streptococcus viridans (4 cases), Staphylococcus epidermidis (4 cases), Haemophilus influenzae (3 cases), and Streptococcus pneumoniae (1 case). Although Streptococcus pneumoniae can be found as normal flora, it has the potential to become pathogenic when the body's condition is disturbed (Subramanian et al., 2019). In addition to normal flora, several pathogenic bacteria were also found that have the potential to cause serious infections, such as Staphylococcus aureus (6 cases), Pseudomonas aeruginosa (6 cases), and Klebsiella pneumoniae (5 cases), which are bacteria known to be frequently involved in post-operative nosocomial infections (Raoofi et al., 2023).

In postoperative cultures, although normal flora such as Streptococcus viridans and Staphylococcus epidermidis were still found, their numbers were lower than those found preoperatively. This suggests a change in the pattern of microorganisms after surgery, with pathogens becoming more dominant. Staphylococcus aureus was the dominant postoperative pathogen with 9 cases, followed by Acinetobacter baumannii, Pseudomonas aeruginosa, and Klebsiella pneumoniae, each with 4 cases. This decrease in the number of normal flora and increase in the number of pathogens postoperatively is consistent with findings in the literature showing that surgical procedures, especially those involving endotracheal tube (ETT) intubation and long operating times, can alter the body's microbial composition (Krezalek et al., 2016; Motallebirad et al., 2024).

These findings also align with research conducted by Calvo et al., in 2024, which stated that the pattern of microorganisms in the respiratory tract of ICU/PICU patients is significantly influenced by various factors, including antibiotic use, length of hospitalization, and patient immune status. Their research showed that although nosocomial infections often involve pathogenic bacteria, normal flora can still be found in patients undergoing long-term intubation. This may explain why in this study, normal flora were still present even in the post-operative phase, adding complexity to the analysis of bacterial patterns.

Another factor that may influence the results is the presence of unidentified confounding factors. For example, a 2014 study by Dąbrowska & Słotwiński explained that surgical stress can disrupt the immune system, which affects the body's response to infection and can influence bacterial culture results. The influence of antibiotics administered during or after surgery may also be a factor influencing the bacterial patterns found in patients. In this study, although there was an increase in postoperative pathogenic bacteria, the many factors involved in postoperative treatment, including antibiotic management and infection control, may have contributed to the insignificant results.

Statistical analysis using the Chi-square test also showed no significant association between preoperative bacterial types and the incidence of pneumonia ($p = 1.000$). This suggests that the presence of pathogenic bacteria in the preoperative phase did not directly predict the occurrence of postoperative pneumonia in this study. Clinically, these results can be explained by several factors. First, colonization of the upper respiratory tract by pathogenic flora does not necessarily develop into active infection, especially if the patient's immune status is adequate and infection prevention measures are optimally implemented. As noted by Paling et al. (2020), colonization by S. aureus or P. aeruginosa in ICU patients often occurs without causing infection, except in cases of immune disorders, damage to the respiratory mucosa, or prolonged use of invasive devices (Hoang et al., 2018).

Second, all patients in this study underwent elective surgery under general anesthesia and received a prophylactic antibiotic protocol. These antibiotics were likely effective in suppressing bacterial multiplication before infection could develop. This aligns with IDSA/ATS guidelines, which state that perioperative antibiotic administration is effective in reducing the risk of early pneumonia, especially if administered before contamination occurs (American Thoracic Society & Infectious Diseases Society of America, 2005). Third, not all

bacteria categorized as community-acquired pathogens are virulent in the hospital setting. For example, although Klebsiella pneumoniae is a common cause of nosocomial pneumonia, its presence as an initial colonizer in the absence of additional risk factors such as prolonged intubation, immunodeficiency, or aspiration may not be sufficient to cause lower respiratory tract infection (Ayan & Çelik, 2025).

These results are also consistent with a 2025 study by Gracheva et al., which showed that although some intubated patients had airway colonization with pathogenic bacteria, not all developed pneumonia. They concluded that colonization needs to be distinguished from active infection because not all patients developed pneumonia. Although the statistical analysis in this study did not show a significant association, it is important to note that the very low number of pneumonia cases (only 1 case) contributed to the low statistical power of the Chi-square test. With a higher number of cases, a clearer pattern may emerge between preoperative bacterial type and pneumonia risk.

Based on the study results, of the 34 patients studied, only one patient (2.9%) experienced pneumonia during post-operative care in the ICU/PICU. This patient had a duration of stay in the ICU of more than 48 hours and an endotracheal tube (ETT) of more than 24 hours. The Spearman correlation test showed a strong and statistically significant relationship between the duration of ICU stay and the incidence of pneumonia ($\rho = 0.696$; $p = 0.000005$). This is because the Spearman correlation test does not calculate the number of cases, but rather the pattern of relationships between variables. In this data, patients with pneumonia were the only patients with an ICU stay of more than 48 hours and an ETT of more than 24 hours, while all patients with shorter durations did not experience pneumonia. This consistent pattern produces a statistically strong correlation, despite the very small number of pneumonia cases.

Clinically, these results align with literature stating that the longer a patient is hospitalized in the intensive care unit, the greater the risk of developing nosocomial infections. The ICU is an environment with high exposure to hospital flora, including multidrug-resistant organisms (MDROs). The longer a patient is exposed, the greater the risk of colonization progressing to active infection. A 2019 study by Wu et al. found that >48 hours of ICU stay is a major risk factor for ventilator-associated pneumonia (VAP). This risk is exacerbated by immobilization, nutritional deficiencies, or postoperative systemic inflammation (Ścisło et al., 2022).

Spearman's test also showed an identical correlation between the duration of ETT use and the incidence of pneumonia ($\rho = 0.696$; $p = 0.000005$). All patients who used ETT for ≤24 hours did not experience pneumonia, while the patient with ETT duration >24 hours experienced the only pneumonia incident in this study. Physiologically, ETT interferes with airway defense mechanisms, such as effective coughing, mucociliary transport, and mucosal integrity. ETT also acts as a foreign body that can become a surface for microorganism colonization, including biofilm formation (Diaconu et al., 2018).

The duration of ETT use is divided into ≤24 hours and >24 hours due to the significant difference in the risk of airway colonization. According to Diaconu et al. (2018), the risk of transition from colonization to infection increases significantly after 24 hours, especially if microaspiration, accumulation of secretions, or cuff leakage occurs. ETT use for less than 24 hours generally does not allow for significant biofilm formation, so the risk of colonization remains relatively low. However, after 24 hours, the ETT begins to function as a bacterial reservoir, where biofilm formation occurs and increases the likelihood of colonization progressing to pneumonia. This explains why the duration of ETT use is an important factor in assessing the risk of post-intubation airway infection.

In this study, there were two patients with prolonged ICU stay and use of an endotracheal tube (ETT), but only one patient developed pneumonia. This suggests that

length of ICU stay and ETT are important risk factors, but not the sole determinants of pneumonia. Other factors such as host condition (immune system, nutritional status, underlying or hidden comorbidities), antibiotic use, and the quality of infection control in the ICU also play a significant role (Xiang et al., 2022). Therefore, even with prolonged ICU stay and ETT use, not all patients will automatically develop pneumonia.

The analysis in this study was conducted on the entire sample (34 patients), not just the high-risk subgroup. This is because the study aimed to assess the relationship between ICU length of stay and ETT use with the incidence of pneumonia in the entire population of spine surgery patients. If the analysis were based on only one of two patients with long durations, the results would be unrepresentative and could not be statistically tested due to the small sample size. By including all patients, the pattern of association became clearer: no pneumonia was found in the short duration group, while the only case of pneumonia occurred in the long duration group. This consistent pattern allows the correlation to be calculated statistically despite the small number of pneumonia cases.

Several reasons may underlie the low incidence of pneumonia in this study, suggesting that effective infection control in the ICU/PICU can play a significant role in reducing the risk of more severe infections in post-spinal surgery patients. Although patients undergoing major surgical procedures and using an endotracheal tube (ETT) are susceptible to immunosuppression and the risk of nosocomial infections, effective infection management, including appropriate antibiotic administration and close monitoring of microbial status, has proven its effectiveness in controlling infections, as demonstrated by the results of this study at Dr. Moewardi General Hospital.

This factor is consistent with literature findings showing that although ICU patients are at high risk for infection, good infection management and appropriate antibiotic protocols can reduce the incidence of further infections (Rawson et al., 2023). Therefore, although respiratory infections can still occur, good control in the ICU/PICU can mitigate their impact, even in patients with weakened immune systems due to major surgical procedures.

In addition to appropriate therapy and good infection control, another factor that can contribute to infection control in post-spinal surgery patients is the implementation of strict sterilization and wound care protocols in the ICU/PICU. Proper sterilization techniques during surgical procedures and optimal wound management reduce the risk of bacterial contamination that can lead to further infection. Strict hygiene and sanitation in the ICU/PICU, including hand hygiene by medical personnel and the use of personal protective equipment, also play a significant role in reducing the risk of infection (Spatenkova et al., 2023).

Furthermore, although post-operative patients experience decreased immunity, immunological support provided through intensive care, including adequate fluids and good nutrition, can help strengthen the patient's immune system and accelerate the recovery process. Appropriate ventilation management, with regular endotracheal tube changes and intensive patient monitoring, also plays a crucial role in preventing respiratory tract infections, such as ventilator-associated pneumonia (VAP) (Rosenthal et al., 2025).

Overall, the results of this study indicate that although the preoperative bacterial pattern was dominated by pathogenic bacteria, there was no significant association with the incidence of postoperative pneumonia. In contrast, the duration of ICU stay and the duration of ETT use showed a strong and significant correlation with the incidence of pneumonia, reinforcing the understanding that prolonged exposure to the intensive care environment and invasive respiratory devices are major risk factors for lower respiratory tract infections.

These findings emphasize the importance of nosocomial infection prevention strategies based on the duration of invasive interventions, control of airway colonization, and strengthening VAP prevention protocols early in postoperative care. Although this study

is limited by the number of pneumonia cases, the results provide a significant contribution to clinical understanding and direction for improving the management of post-spine surgery patients in the ICU/PICU.

This study has several limitations, including a relatively small sample size and the failure to consider in detail the characteristics of the patients' underlying diseases or variations in sample sources, such as blood, skin, or other body fluids. Therefore, the bacterial patterns obtained may not be fully representative of the broader population. Further analysis of other risk factors, such as duration of ventilator use and antibiotic management, was also not conducted in depth. Furthermore, limitations in the robustness of the statistical analysis methods used could potentially impact the accuracy of interpreting the relationship between bacterial patterns and postoperative infection incidence.

CONCLUSION

This study shows that the respiratory tract bacterial pattern in spinal surgery patients changes after postoperative care in the ICU/PICU, characterized by an increased dominance of pathogenic bacteria, especially Staphylococcus aureus, accompanied by the emergence of Acinetobacter baumannii, Pseudomonas aeruginosa, and Klebsiella pneumoniae. However, the preoperative bacterial pattern was not significantly associated with the incidence of pneumonia. In contrast, ICU stays of more than 48 hours and endotracheal tube (ETT) use of more than 24 hours showed a strong association with the incidence of pneumonia. These results confirm that the duration of exposure to the intensive care environment and the use of invasive devices are more important factors in the development of pneumonia than preoperative bacterial colonization.

This study has limitations in the form of a relatively small sample size and only one case of pneumonia, thus limiting the power of inferential analysis. The study also did not evaluate other factors that could potentially influence the incidence of pneumonia, such as nutritional status, disease severity, duration of mechanical ventilation, adherence to the ventilator-associated pneumonia prevention bundle, and antibiotic use patterns in more detail. Future studies are recommended to involve a larger sample size, a multicenter design, a longer observation period, and multivariate analysis to identify independent risk factors. Practically, the results of this study support the importance of optimizing infection control in the ICU/PICU by accelerating safe extubation, minimizing the length of intensive care, strengthening surveillance programs for bacterial patterns and antibiotic resistance, and consistently implementing ventilator-associated pneumonia prevention strategies in spinal surgery patients.

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