Journal of Clinical and Nursing Research, 2024, Volume 8, Issue 2
http://ojs.bbwpublisher.com/index.php/JCNR
Online ISSN: 2208-3693
Print ISSN: 2208-3685

Analysis of the Current Situation and Risk Factors of Lower Respiratory Tract Infection among ICU Patients in Guizhou, China During 2019–2022

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Abstract: *Objective:* This study aims to explore the prevalence, features, and risk factors of lower respiratory tract infections (LRTIs) in the intensive care unit (ICU) of a newly established hospital in Zunyi City. The goal is to devise strategies for preventing LRTIs in the ICU of new hospitals, thereby mitigating the incidence of nosocomial LRTIs in ICU patients. *Methods:* A case-control study was conducted from March 2019 to December 2022 to investigate the incidence rate of LRTIs in the ICU of a newly constructed hospital in Zunyi City. Patients with LRTIs constituted the case group, while those without LRTIs constituted the control group, where a 1:1 matching principle was adhered to. A single-factor chi-square (χ^2) test was employed to analyze the risk factors, with independent risk factors being explored using a multivariate logistic regression analysis. *Results:* A total of 169 strains of pathogenic bacteria were isolated, comprising 66.28% gram-negative bacteria, 17.75% gram-positive bacteria, and 15.97% fungi. The most prevalent pathogens included *Acinetobacter baumannii* (43.20%), *Candida albicans* (10.65%), and *Pseudomonas aeruginosa* (8.88%). Of the 82 strains infected by multidrug-resistant bacteria in patients with LRTIs, 81.7% were carbapenem-resistant *Acinetobacter baumannii*, 9.8% were multidrug-resistant *Pseudomonas aeruginosa*, and 6.1% were carbapenem-resistant *Escherichia coli*. Identified risk factors included smoking history, total hospitalization days, ICU stay length, hypoproteinemia, indwelling gastric tube, intubation type, duration of mechanical ventilation, usage of antibacterial drugs, and administration of protein drugs ($P < 0.05$). Multivariate logistic regression analysis demonstrated that these factors were independent risk factors for nosocomial LRTIs in ICU patients ($P < 0.05$). *Conclusion:* ICU patients in our hospital were mainly infected by carbapenem-resistant *Acinetobacter baumannii*. To prevent LRTIs in patients, tailored preventive measures should be developed and the rational use of antibacterial drugs should be promoted.

Keywords: Lower respiratory tract infection; Risk factors; New hospital; Intensive care unit

Online publication: February 26, 2024

1. Introduction

Infection control poses a significant challenge for newly constructed hospitals undergoing rapid expansion and organizational changes. Nosocomial infections, particularly lower respiratory tract infections (LRTIs), pose a major hurdle in hospital management. The majority of these patients necessitate invasive procedures such as intubation and mechanical ventilation. These measures not only compromise the standard barrier structure of the respiratory tract but also impose physiological stress, undermining the body's defensive capacity and enabling direct bacterial invasion [1]. The management of LRTIs in the ICU is fraught with complexity. A comprehensive understanding of this area is instrumental in devising targeted interventions and a scientifically validated and efficacious approach towards the prevention and control of hospital-acquired infections [2]. This study analyzed LRTIs in the intensive care unit (ICU) of a newly established hospital in Zunyi city and identified clinically relevant insights for effective treatment.

2. Materials and methods

2.1. Research subjects

Between March 2019 and December 2022, a total of 95 patients who met the inclusion criteria were selected for treatment of nosocomial LRTIs at a newly established hospital in Zunyi City.

2.2. Inclusion and exclusion criteria

This study included patients who were treated in the ICU for a period exceeding 72 hours and were diagnosed with nosocomial LRTIs, as confirmed by the pathogenic examination of sputum samples according to the Diagnostic Criteria for Hospital Infection by the Ministry of Health [3].

The exclusion criteria comprised patients present with lower respiratory tract infections or those in the incubation period of infection before their admission to the ICU. Patients diagnosed with autoimmune and hematological diseases, severe hepatic and renal insufficiency, as well as those with incomplete clinical data were also excluded.

2.3. Research methods

A combination of retrospective analysis and a case-control study was employed to evaluate the prevalence of LRTIs among inpatients in the ICU of a newly built hospital in Zunyi City, along with factors influencing its occurrence. Patients diagnosed with LRTIs constituted the case group, while those without constituted the control group. A 1:1 matching principle was adhered to. Matching was carried out based on the same primary diagnosis, severity of illness, gender, age (within a 5-year difference), and year of admission.

2.4. Statistical analysis

Data was gathered and statistically analyzed using SPSS 25.0 software. Data conforming to a normal distribution were expressed as mean ± standard deviation and analyzed using the *t*-test and chi-square (χ^2) test. The univariate analysis incorporated 18 clinical data points, including smoking history, total hospitalization days, ICU stay length, hypoproteinemia, indwelling gastric tube, type of intubation, duration of mechanical ventilation, and duration of antibacterial drug use. A multi-factorial logistic regression analysis was performed to explore the risk factors for LRTIs. Results were considered statistically significant at $P < 0.05$.

3. Results

3.1. Comparison of general data between the two groups of patients

As shown in **Table 1**, no significant differences were observed between the two groups in terms of gender, Acute Physiology and Chronic Health Evaluation (APACHE II) score, age, primary diagnosis, concurrent underlying diseases, and patient outcomes ($P > 0.05$).

Table 1. Comparison of general data balance between two groups of patients [case, *n* (%)]

Factor	Case group (*n* = 95)	Control group (*n* = 95)	c^2	*P*
Gender			0.022	0.881
Male	60 (63.16)	59 (61.11)		
Female	35 (36.84)	36 (37.89)		
APACHE II (Points)	21.24 ± 5.12	20.02 ± 5.38	1.602	0.111
Age	62.05 ± 15.82	58.25 ± 16.21	1.753	0.080
Main diagnosis			0.998	0.995
Wound	15 (15.79)	19 (20.00)		
Septicopyemia	15 (15.79)	14 (14.74)		
Severe pneumonia	16 (16.84)	14 (14.74)		
Chronic obstructive pulmonary disease (COPD)	9 (9.47)	10 (10.53)		
Diseases of the digestive system	10 (10.53)	11 (11.58)		
Tumor	10 (10.53)	8 (8.42)		
Craniocerebral injury	6 (6.31)	6 (6.31)		
Other	14 (14.74)	13 (13.68)		
Combined with basic diseases			0.021	0.884
Yes	43 (45.26)	42 (44.21)		
Without	52 (54.74)	53 (55.79)		
Final result			0.419	0.811
(Of a patient) transfer from one department (of a hospital) to another	25 (26.32)	29 (30.53)		
To be discharged from the hospital	58 (61.05)	55 (57.89)		
Died	12 (12.63)	11 (11.58)		

3.2. Pathogen distribution in lower respiratory tract infections

As shown in **Table 2**, a total of 169 strains of pathogenic bacteria were isolated from patients with LRTIs in the ICU of a newly established hospital in Zunyi City. Among these, gram-negative bacteria accounted for 66.28%, gram-positive bacteria accounted for 17.75%, and fungi comprised 15.97%. The five most common pathogens isolated were *Acinetobacter baumannii* (43.20%), *Candida albicans* (10.65%), *Pseudomonas aeruginosa* (8.88%), and *Escherichia coli* (5.23%).

Table 2. Distribution of pathogens causing nosocomial LRTIs in ICU patients at a newly established hospital from March 2019 to December 2022.

Pathogenic bacteria	Number of plants	Composition ratio (%)
Gram-positive		
Staphylococcus aureus	9	5.32
Staphylococcus epidermidis	7	4.14
Enterococcus faecalis	3	1.78
Staphylococcus haemolyticus	2	1.18
Staphylococcus hominins	3	1.78
Staphylococcus ludden	2	1.18
Other	4	2.37
Gram-negative		
Acinetobacter baumannii	73	43.20
Pseudomonas aeruginosa	15	8.88
Escherichia coli	9	5.32
Klebsiella pneumoniae	8	4.73
Stenotrophomonas maltophilia	4	2.37
Other	3	1.78
Fungus		
Candida albicans	18	10.65
Candida krusei	2	1.18
Other	7	4.14
Total	169	100.00

3.3. Distribution of drug-resistant bacteria in LRTIs

As shown in **Table 3**, 82 strains of multidrug-resistant bacteria were identified in patients with LRTIs admitted to the ICU of the newly established hospital. This encompassed 81.70% carbapenem-resistant *Acinetobacter baumannii* (CRAB), 9.80% multidrug-resistant *Pseudomonas aeruginosa*, 6.10% carbapenem-resistant *Escherichia coli*, 1.20% methicillin-resistant *Staphylococcus aureus*, and 1.20% carbapenem-resistant *Klebsiella pneumoniae*.

Table 3. Distribution and proportional composition of multidrug-resistant bacterial strains in LRTIs in ICU patients at a newly established hospital from March 2019 to December 2022

Pathogenic bacteria	Number of infected strains of multidrug-resistant bacteria	Proportion of infection with multidrug-resistant bacteria (%)
Carbapenem-resistant *Acinetobacter baumannii*	67	81.70
Methicillin-resistant *Staphylococcus aureus*	1	1.20
Multidrug-resistant *Pseudomonas aeruginosa*	8	9.80
Carbapenem-resistant *Escherichia coli*	5	6.10
Carbapenem-resistant *Klebsiella pneumoniae*	1	1.20
Total	82	100.00

3.4. Single factor analysis of hospital LRTIs

As shown in **Table 4**, the identified risk factors for LRTIs in ICU patients include smoking history, total hospitalization days, ICU stay duration, hypoproteinemia, presence of an indwelling gastric tube, intubation type, duration of mechanical ventilation, duration of antibacterial drug usage, administration of antibacterial drugs, and use of protein drugs.

Table 4. Univariate analysis of risk factors for nosocomial LRTIs in ICU patients at a newly established hospital from March 2019 to December 2022

Factor	Case group (n = 95)	Control group (n = 95)	c^2	P
Age (years)			0.085	0.771
≤ 60	43	45		
> 60	52	50		
APACHE II Score			0.783	0.376
< 20	36	42		
≥ 20	59	53		
Smoking History			6.032	0.014
Yes	20	8		
No	75	87		
Consciousness			0.021	0.884
Stuporous	45	44		
Sober	50	51		
Total hospitalization days (days)			5.071	0.024
< 30	61	75		
≥ 30	34	20		
Days in ICU (days)			15.575	< 0.001
< 14	36	63		
≥ 14	59	32		
Complicated with hypertension			0.814	0.367
Yes	38	32		
No	57	63		
Complicated with diabetes			3.497	0.061
Yes	18	9		
No	77	86		
Hypoproteinemia				
Yes	58	35	11.142	0.001
No	37	60		
Complicated with lung diseases			0.106	0.745
Yes	27	25		
No	68	70		
Complicated with cardiovascular disease			0.072	0.788

Table 4. (Continue)

Factor	Case group (n = 95)	Control group (n = 95)	c^2	P
Yes	7	8		
No	88	87		
Combined with cerebrovascular disease			0.526	0.468
Yes	11	8		
No	84	87		
Need for operation			1.708	0.191
Yes	54	45		
No	41	50		
Transfuse blood			3.243	0.072
Yes	75	64		
No	20	31	1.810	0.179
Indwelling gastric tube	81	64	8.415	0.004
Intubation type			11.053	0.011
Tracheal intubation	71	58		
Tracheotomy	5	3		
Tracheotomy after tracheal intubation	17	20		
Tracheal intubation ≥ 2 Times	5	10		
Mechanical ventilation time (days)			9.715	0.002
< 7	27	48		
≥ 7	68	47		
Antibacterial drug use time (days)	24.53 ± 19.69	14.31 ± 13.59	-5.192	< 0.001
Use antibacterial drugs			1.4810	0.001
Single drug	6	22		
Two kinds	11	18		
3 kinds and above	78	55		
Use hormone drugs			0.977	0.323
Yes	73	67		
No	22	28		
Use protein drugs			14.902	< 0.001
Yes	80	56		
No	15	39		

3.5. Multivariate analysis of risk factors of LRTIs

As shown in **Table 5**, the duration of stay in the ICU, the type of intubation, the number of days of antimicrobial usage, and the types of antimicrobials used were identified as independent risk factors for LRTIs in ICU patients at newly established hospitals ($P < 0.05$).

Table 5. Logistic regression analysis of risk factors for nosocomial LRTIs in ICU patients at a newly established hospital from March 2019 to December 2022

Factor	β value	Standard error (SE)	Wald	Odds ratio (OR)	95% confidence interval (CI)	*P*
Number of days in ICU	-5.703	1.562	13.332	0.003	0.000–0.071	< 0.001
Intubation type	-2.782	0.742	14.066	0.062	0.014–0.265	< 0.001
Antibacterial drug use duration (days)	0.034	0.012	8.667	1.035	1.012–1.059	0.003
Types of antibacterial drugs used	0.584	0.281	4.334	1.793	1.035–3.107	0.037

4. Discussion

Gram-negative bacteria, especially CRAB, are the main pathogens causing LRTIs in the ICU of newly built hospitals. Gram-positive bacteria and fungi also contribute to LRTIs. The top five pathogens identified in this study were *Acinetobacter baumannii*, *Candida albicans*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus aureus*, and *Klebsiella pneumoniae*. The leading three strains found in the ICU were CRAB, multidrug-resistant *Pseudomonas aeruginosa*, and carbapenem-resistant *Escherichia coli*, corroborating findings from other investigations [4]. *Acinetobacter baumannii*, a Gram-negative bacterium, is a common nosocomial pathogen and is a significant threat to human health due to its robust adhesion, resistance, environmental adaptability, and high drug resistance [5,6]. Concerning earlier studies, our results confirmed that *Acinetobacter baumannii* and *Pseudomonas aeruginosa* were among the three principal pathogens involved in LRTIs [7].

Acinetobacter baumannii, commonly found in both hospital and natural environments, exhibits a marked propensity for respiratory tract infections [8]. In our study, *Candida albicans* emerged as the second leading cause of LRTIs, a trend associated with the deterioration of patient's systemic defenses and misuse of antibiotics. *Candida albicans*, a common opportunistic pathogenic fungus, typically remains harmless in healthy individuals. However, when the host's immune function is compromised, or the fungus invades an abnormal site, it can lead to severe infections [9]. Hence, enhanced clinical monitoring for *Candida albicans* is advocated.

Acinetobacter baumannii is known to harbor the ISAba1 and OXA-51 genes. The strong promoter provided by ISAba1 facilitates the elevated expression of the OXA-51 genes, which results in carbapenem resistance [10]. The global detection rate of carbapenem-resistant gram-negative bacteria has exhibited an upward trend in recent years [11]. *Acinetobacter baumannii* is a potent source of nosocomial infections such as pneumonia and bloodstream infections and is a leading cause of wound infections and nosocomial meningitis, contributing significantly to patient mortality [12]. Due to this, research regarding antibiotic resistance has garnered increased attention [13].

A domestic bacterial resistance survey from 2016 revealed that the resistance of *Acinetobacter baumannii* towards carbapenems had surged to 70% [14]. *Acinetobacter baumannii* nosocomial infections have emerged as a global challenge in ICUs and are associated with high mortality rates [15]. Consequently, the detection of CRAB has become a growing concern. Current clinical practices often resort to traditional culture methods and real-time fluorescence quantitative polymerase chain reaction to detect drug-resistant genes, thereby enabling clinicians to administer appropriate therapeutic drugs [16].

The rational use of antibiotics, based on drug sensitivity tests, and resistance to antibiotic misuse is strongly advocated. Patients infected with multi-drug resistant bacteria should be isolated, and healthcare staff

should adhere to the standard protective measures. Emphasizing hospital hygiene knowledge and hand hygiene management among medical staff, nurses, and cleaning personnel is vital. Given the recent surge in CRAB and multidrug-resistant Acinetobacter baumannii (MDRAB), the prevention and control of multidrug-resistant bacteria have become critical components of hospital infection management. With the proper interventions, hospitalization duration, hospital expenses, and patient mortality can be reduced. Enhanced monitoring of CRAB and the implementation of early intervention strategies can effectively curb the emergence and spread of multidrug-resistant bacteria in hospitals, thus reducing the incidence of nosocomial infections [17].

Our study identified several risk factors for nosocomial LRTIs in ICU patients. These include a history of smoking, total hospitalization days, 14 or more days of ICU hospitalization, hypoproteinemia, presence of a gastric tube, intubation type, mechanical ventilation exceeding 7 days, duration of antibacterial drug use, type of antibacterial drugs, and the use of protein drugs. The relevance of a patient's smoking history is aligned with international research [18]. The duration and type of antibiotic used also concurred with existing literature [19].

Based on logistic regression analysis, preventive measures should include enhancing ICU nurses' skills, shortening hospital stays, strict adherence to aseptic procedures, improving ICU hygiene, regulating temperature settings, adjusting antibiotic treatment based on culture and sensitivity results, and minimizing the use of invasive procedures. Risk factors for LRTIs in ICU patients include smoking history, prolonged ICU stay, intubation, mechanical ventilation, duration and type of antibiotic use, and protein drug use. These factors should be considered in daily evaluations and preventive strategies to reduce the incidence of nosocomial infections.

This study had several limitations. The sample size was relatively small as subjects were selected exclusively from a single hospital. Consequently, the research findings may lack comprehensive generalizability. Future studies should aim to broaden the spectrum of sample selection and increase the sample size to enhance the precision and accuracy of the research outcomes.

Furthermore, this study adopted a retrospective analysis methodology, which posed challenges in attaining a high degree of consistency in gathering clinical data from patients. The presence of confounding factors could also potentially impact the analysis of pertinent risk factors in this study. In subsequent research endeavors, it is imperative to meticulously delineate the parameters for sample inclusion to mitigate the influence of confounding factors on the research outcomes.

5. Conclusion

Gram-negative bacteria, primarily CRAB, are the major pathogens causing LRTIs in ICU patients in newly established hospitals. The infections were associated with various factors including the patient's internal body environment, invasive treatment measures, and the hospital environment. Thus, it is crucial to develop targeted preventive measures based on these risk factors to effectively prevent LRTIs in ICU patients.

Declarations

Ethical Approval: The ethical approval was obtained from the review by the Medical Ethics Committee of Zunyi Medical University, No. Zunyi Lunshen (2020) 1-055. All participants provided written informed consent prior to participation in the study.

Authors' contributions

Rong Liu, Hui Zeng, Sheng-shuang Long, Lu-Wen Luo, and Lorna K.P. Suen were involved in the conception and design of the study. Sheng-shuang Long and Lu-Wen Luo collected the data. Min-jiang Qian, Jing Zhou, and Jie Wan were responsible for data analysis. Rong Liu and Hui Zeng drafted the manuscript supported by all authors. All authors read and approved the final manuscript.

Funding

This article is a project of the Department of Science and Technology of Guizhou Province. The title of the project is: Analysis of influencing factors and direct economic losses of ICU infection in a newly built tertiary comprehensive hospital (Project No: Qiankehe Support [2021] General 043)

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Disclosure statement

The authors declare no conflict of interest.

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