Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/sjhrafrica.v7i2.2766
Original Article

Clinical Profile, Risk Factors, and Outcomes of Ventilator-Associated Pulmonary Complications in Mechanically Ventilated ICU Patients: A Hospital-Based Prospective Cross-Sectional Study.

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Abstract

Background:

Ventilator-associated pulmonary complications are important causes of morbidity and mortality among mechanically ventilated intensive care unit patients. These complications include ventilator-associated pneumonia, atelectasis, acute respiratory distress syndrome, aspiration-related lung injury, pulmonary edema, and barotrauma.

Objectives:

To assess the clinical profile, risk factors, and outcomes of ventilator-associated pulmonary complications among mechanically ventilated ICU patients.

Methods:

This hospital-based cross-sectional study used prospective data collection in the adult ICU of Government Medical College, Suryapet, Telangana, India, from February 2025 to January 2026. A total of 100 mechanically ventilated patients were included. Demographic variables, comorbidities, indications for ventilation, ventilator-related factors, pulmonary complications, and clinical outcomes were recorded and analysed.

Results:

The mean age was 56.8 ± 15.4 years, and males constituted 62.0% of patients. Sepsis with respiratory failure was the most common indication for mechanical ventilation. Ventilator-associated pulmonary complications occurred in 42.0% of patients. Ventilator-associated pneumonia was the commonest complication, followed by atelectasis, acute respiratory distress syndrome, and aspiration-related lung injury. Complications were significantly associated with age above 60 years, COPD, smoking, sepsis, prolonged ventilation, reintubation, prolonged sedation, and prior antibiotic exposure. Patients with complications had longer ventilation duration, longer ICU and hospital stay, higher tracheostomy requirement, and higher ICU mortality.

Conclusion:

Ventilator-associated pulmonary complications were frequent among mechanically ventilated ICU patients and were linked to prolonged ventilation, reintubation, chronic lung disease, sepsis, and adverse clinical outcomes.

Recommendations:

Early risk recognition, strict ventilator care bundle adherence, daily sedation assessment, timely weaning, aspiration prevention, and infection-control strengthening are recommended.

Keywords: *Ventilator-associated pulmonary complications; Ventilator-associated pneumonia; Mechanical ventilation; Intensive care unit; Risk factors; Outcomes*

Submitted: April 02, 2026 **Accepted:** May 30, 2026 **Published:** June 30, 2026

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Introduction

Mechanical ventilation is a lifesaving intervention for patients with acute respiratory failure, severe sepsis, postoperative respiratory compromise, neurological depression, trauma, and other critical illnesses. However, invasive ventilation also creates a vulnerable physiological

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state in which normal airway defence mechanisms are bypassed, mucociliary clearance is impaired, the cough reflex is reduced, and non-immunized secretions can enter the lower respiratory tract. As a result, mechanically ventilated patients are exposed to a spectrum of pulmonary complications that extend beyond ventilator-associated pneumonia alone. These complications include atelectasis, aspiration-related lung injury, acute respiratory distress syndrome, pulmonary edema, and barotrauma, each of which contributes to delayed recovery and greater resource use in the ICU [1,2].

Ventilator-associated pneumonia remains the most widely studied ventilator-related pulmonary complication. It is generally defined as pneumonia developing after at least 48 hours of endotracheal intubation and mechanical ventilation, and its diagnosis requires a combination of clinical, radiological, microbiological, and oxygenation-related parameters [3,4]. Reported incidence varies markedly across countries, ICU categories, patient profiles, diagnostic criteria, and surveillance methods. This variation explains why newer surveillance frameworks have widened attention from VAP alone to ventilator-associated events and ventilator-associated conditions, which capture both infectious and non-infectious respiratory deterioration during mechanical ventilation [5,6].

Risk factors for ventilator-associated pulmonary complications are multifactorial. Patient-related factors include older age, COPD, diabetes mellitus, smoking, sepsis, altered sensorium, immune suppression, and severity of illness. Ventilator- and care-related factors include prolonged mechanical ventilation, reintubation, supine positioning, aspiration risk, enteral feeding, excessive sedation, prior antibiotic exposure, and delayed weaning [7,8]. These factors often coexist in real ICU practice, making prospective observation useful for identifying clinically important patterns that can guide prevention and early intervention.

The clinical importance of these complications lies in their effect on outcomes. Previous studies have shown that ventilator-associated pneumonia and related respiratory deterioration increase the duration of mechanical ventilation, ICU stay, hospital stay, antimicrobial exposure, healthcare cost, and mortality risk [9-11]. Delayed initiation of appropriate therapy in suspected VAP has also been associated with worse outcomes, while structured care bundles, sedation nonymizedn, head-end elevation, oral hygiene, aspiration prevention, and daily readiness-to-wean assessments reduce the burden of preventable complications [12,13].

The present study was conducted to assess the clinical profile, risk factors, and outcomes of ventilator-associated pulmonary complications among mechanically ventilated ICU patients at Government Medical College, Suryapet, Telangana, India. The study specifically aimed to describe the demographic and clinical characteristics of ventilated patients, determine the pattern of pulmonary complications, identify associated risk factors, and compare key clinical outcomes between patients with and without ventilator-associated pulmonary complications.

Materials and Methods

Study design and setting

This hospital-based cross-sectional study used prospective data collection and was conducted in the adult intensive care unit of Government Medical College, Suryapet, Telangana, India. The study was carried out over 12 months from February 2025 to January 2026. The institution is a tertiary care teaching hospital that receives critically ill medical, surgical, postoperative, neurological, trauma, and poisoning-related cases from Suryapet and surrounding areas. The study followed routine ICU care pathways without assigning any experimental intervention.

Study population

The study included consecutive adult patients who required invasive mechanical ventilation during the study period and fulfilled the eligibility criteria. Data were recorded prospectively from initiation of mechanical ventilation until ICU discharge, hospital discharge, death, or completion of the defined outcome assessment. Mechanical ventilation was initiated according to the treating physician's clinical decision.

Sample size determination

The sample size was estimated using the single-population proportion formula, $n = Z^2p(1-p)/d^2$. Because a reliable local prevalence estimate was unavailable, p was set at 50% to provide the maximum required sample size. At a 95% confidence level ($Z = 1.96$) and an absolute precision of 10% ($d = 0.10$), the calculated sample size was $n = (1.96)^2 \times 0.50 \times 0.50/(0.10)^2 = 96.04$. The sample was rounded to 100 patients.

Eligibility criteria

Patients aged 18 years and above who required invasive mechanical ventilation through an endotracheal tube or tracheostomy were included. Patients ventilated for very short postoperative observation without ICU admission, patients with established pneumonia before intubation without subsequent ventilator-associated deterioration, patients with incomplete records, and patients whose attendants declined consent were excluded. Patients were not excluded on the basis of comorbidities because the aim was to document real-world ICU patterns.

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Data collection procedure

Data were collected using a structured proforma. Baseline variables included age, sex, comorbidities, smoking history, indication for ICU admission, and indication for mechanical ventilation. Ventilator-related variables included duration of ventilation, reintubation, tracheostomy, prolonged supine positioning, enteral feeding, prior antibiotic exposure, and sedation for more than 48 hours. Patients were evaluated daily for clinical deterioration, fever, respiratory secretions, auscultatory changes, oxygenation worsening, radiological abnormalities, and the treating team's diagnosis of pulmonary complications. Standard clinical definitions and guideline-based diagnostic principles for VAP and ventilator-associated respiratory deterioration were considered while classifying events [3,5,6].

Outcome measures

The primary outcome was the occurrence of any ventilator-associated pulmonary complication during ICU stay. The complications recorded were ventilator-associated pneumonia, atelectasis, acute respiratory distress syndrome, aspiration-related lung injury, pulmonary edema, and pneumothorax or barotrauma. Secondary outcomes included duration of mechanical ventilation, ICU length of stay, hospital length of stay, tracheostomy requirement, ICU mortality, and discharge status.

Statistical analysis

Data were entered into a spreadsheet and analysed using standard statistical methods. Continuous variables were expressed as mean ± standard deviation, and categorical variables were expressed as frequency and percentage. Pearson's chi-square test was used for categorical comparisons because all expected cell frequencies exceeded five. The independent-samples t-test was used for continuous variables. The corresponding χ^2 and t statistics with p-values are presented in Table 4. A p-value <0.05 was considered statistically significant.

Ethical considerations

Institutional Ethics Committee approval was obtained before the start of the study. Written informed consent was obtained from the patient or a legally anonymized representative. Patient identity was kept confidential, and only anonymized clinical data were used for analysis.

Results

Participant flow

A total of 118 mechanically ventilated ICU patients were examined for eligibility. Of these, 108 were considered potentially eligible after initial screening. Following a detailed eligibility assessment, 100 were confirmed eligible, included in the study, and analysed. The reasons for exclusion are shown in Figure 1.

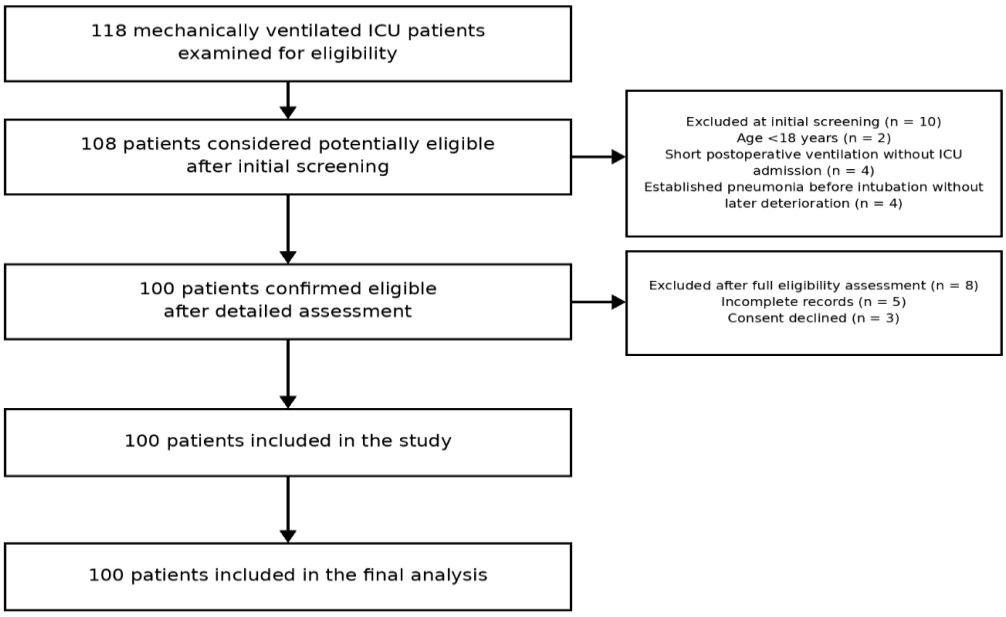

Figure 1. Participant flow diagram

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A total of 100 mechanically ventilated ICU patients were included in the study. The mean age of the study population was 56.8 ± 15.4 years. Most patients were aged above 50 years, and males constituted 62.0% of the study population. Diabetes mellitus, hypertension, chronic obstructive pulmonary disease, and smoking history were the common comorbidities and risk factors. Sepsis with respiratory failure was the most common indication for ICU admission and mechanical ventilation, followed by acute exacerbation of COPD and postoperative ventilatory support (Table 1).

Table 1: Baseline demographic profile, comorbidities, and indication for mechanical ventilation

Variable	Number of patients	Percentage
Age group		
18–30 years	10	10.0
31–50 years	24	24.0
51–65 years	36	36.0
>65 years	30	30.0
Sex		
Male	62	62.0
Female	38	38.0
Comorbidities/risk factors*		
Diabetes mellitus	38	38.0
Hypertension	34	34.0
Chronic obstructive pulmonary disease	26	26.0
Smoking history	32	32.0
Chronic kidney disease	16	16.0
Immunosuppression	8	8.0
Indication for mechanical ventilation		
Sepsis with respiratory failure	30	30.0
Acute exacerbation of COPD	18	18.0
Postoperative ventilatory support	16	16.0
Neurological illness with poor sensorium	14	14.0
Trauma-related respiratory failure	10	10.0
Acute poisoning	6	6.0
Other causes	6	6.0

**Multiple comorbidities/risk factors were present in some patients.*

The mean duration of mechanical ventilation was 6.4 ± 3.2 days. Prolonged mechanical ventilation for more than 5 days was required in 48.0% of patients. Reintubation was required in 14.0% of patients, while tracheostomy was performed in 12.0% of patients. Prior antibiotic exposure and prolonged sedation were also commonly observed among the study participants (Table 2).

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Table 2: Ventilator-related clinical characteristics

Variable	Number of patients	Percentage
Duration of ventilation ≤5 days	52	52.0
Duration of ventilation >5 days	48	48.0
Reintubation required	14	14.0
Tracheostomy performed	12	12.0
Supine position for a prolonged period	44	44.0
Enteral feeding during ventilation	72	72.0
Prior antibiotic exposure	58	58.0
Sedation for >48 hours	46	46.0

Ventilator-associated pulmonary complications were observed in 42 patients, giving an overall incidence of 42.0%.

Ventilator-associated pneumonia was the most common pulmonary complication, seen in 28.0% of patients, followed by atelectasis in 18.0%, acute respiratory distress syndrome in 12.0%, and aspiration-related lung injury in 10.0%. A few patients developed more than one pulmonary complication during ICU stay (Table 3).

Table 3: Pattern of ventilator-associated pulmonary complications

Pulmonary complication*	Number of patients	Percentage
Any ventilator-associated pulmonary complication	42	42.0
Ventilator-associated pneumonia	28	28.0
Atelectasis	18	18.0
Acute respiratory distress syndrome	12	12.0
Aspiration-related lung injury	10	10.0
Pulmonary edema	8	8.0
Pneumothorax/barotrauma	4	4.0

**Some patients had more than one pulmonary complication.*

Ventilator-associated pulmonary complications were significantly associated with age above 60 years ($\chi^2 = 5.08$, $p = .024$), COPD ($\chi^2 = 7.89$, $p = .005$), smoking history ($\chi^2 = 8.12$, $p = .004$), sepsis at admission ($\chi^2 = 5.70$, $p = .017$), mechanical ventilation for more than 5 days ($\chi^2 = 15.92$, $p < .001$), reintubation ($\chi^2 = 8.94$, $p = .003$), sedation for more than 48 hours ($\chi^2 = 9.75$, $p = .002$), and prior antibiotic exposure ($\chi^2 = 7.43$, $p = .006$). Patients with complications had longer mechanical ventilation ($t = 7.51$, $p < .001$), ICU stay ($t = 6.55$, $p < .001$), and hospital stay ($t = 5.54$, $p < .001$), as well as greater tracheostomy requirement ($\chi^2 = 9.56$, $p = .002$) and ICU mortality ($\chi^2 = 7.93$, $p = .005$) than patients without complications (Table 4).

Table 4: Risk factors and outcomes according to ventilator-associated pulmonary complication status

Variable	VAPC present n = 42	VAPC absent n = 58	Test statistic	p-value
Risk factors				
Age >60 years	24 (57.1%)	20 (34.5%)	$\chi^2 = 5.08$	.024
Male sex	28 (66.7%)	34 (58.6%)	$\chi^2 = 0.67$	.413
Diabetes mellitus	19 (45.2%)	19 (32.8%)	$\chi^2 = 1.61$	.204
COPD	17 (40.5%)	9 (15.5%)	$\chi^2 = 7.89$	.005
Smoking history	20 (47.6%)	12 (20.7%)	$\chi^2 = 8.12$	.004
Sepsis at admission	18 (42.9%)	12 (20.7%)	$\chi^2 = 5.70$	.017
Mechanical ventilation >5 days	30 (71.4%)	18 (31.0%)	$\chi^2 = 15.92$	<.001

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Variable	VAPC present n = 42	VAPC absent n = 58	Test statistic	p-value
Reintubation	11 (26.2%)	3 (5.2%)	$\chi^2 = 8.94$	.003
Sedation >48 hours	27 (64.3%)	19 (32.8%)	$\chi^2 = 9.75$	.002
Prior antibiotic exposure	31 (73.8%)	27 (46.6%)	$\chi^2 = 7.43$	.006
Clinical outcomes				
Duration of mechanical ventilation, days	8.9 ± 3.6	4.6 ± 2.1	t = 7.51	<.001
ICU stay, days	12.8 ± 5.4	7.2 ± 3.1	t = 6.55	<.001
Hospital stay, days	18.6 ± 7.8	11.4 ± 5.2	t = 5.54	<.001
Tracheostomy required	10 (23.8%)	2 (3.4%)	$\chi^2 = 9.56$	.002
ICU mortality	18 (42.9%)	10 (17.2%)	$\chi^2 = 7.93$	.005
Discharged alive	24 (57.1%)	48 (82.8%)	$\chi^2 = 7.93$	.005

Note. Categorical variables were compared using Pearson's chi-square test; continuous variables were compared using the independent-samples t-test. VAPC, ventilator-associated pulmonary complication.

Overall, ventilator-associated pulmonary complications were common among mechanically ventilated ICU patients. Their occurrence was associated with prolonged ventilation, reintubation, COPD, sepsis, longer ICU stay, greater need for tracheostomy, and increased mortality.

Discussion

The present hospital-based cross-sectional study with prospective data collection evaluated ventilator-associated pulmonary complications among 100 mechanically ventilated ICU patients. The overall incidence of any ventilator-associated pulmonary complication was 42.0%, while ventilator-associated pneumonia was documented in 28.0% of patients. This finding is clinically relevant because contemporary literature reports wide variation in VAP incidence, ranging from low single-digit rates in some surveillance systems to much higher rates in resource-limited or high-acuity ICUs [1,14]. The observed pattern supports the view that VAP is only one part of a broader group of ventilator-associated respiratory events that influence ICU recovery [5,6].

The demographic profile showed a predominance of older patients and males. Patients aged above 60 years had a significantly higher frequency of complications. Age-related decline in airway clearance, immune response, muscle strength, and physiological reserve increases vulnerability to nosocomial respiratory deterioration. Smoking history and COPD also showed significant associations with complications. These findings are consistent with earlier observations that chronic lung disease and smoking increase susceptibility to VAP and other ventilator-related pulmonary events through impaired mucociliary function, chronic airway inflammation, altered microbiome, and reduced pulmonary reserve [4,7,14].

Prolonged mechanical ventilation was the strongest risk factor in the present study. Patients ventilated for more than 5 days had a substantially higher complication rate than those ventilated for shorter durations. This relationship is biologically plausible because longer endotracheal tube exposure promotes microaspiration, biofilm formation, secretion retention, colonisation, and ventilator-induced changes in respiratory mechanics. Reintubation was also significantly associated with complications, reflecting the effects of airway trauma, aspiration during extubation failure, increased severity of illness, and repeated exposure to invasive airway devices [7,8].

Clinical outcomes were worse among patients with ventilator-associated pulmonary complications. The VAPC group had longer mechanical ventilation, ICU stay, and hospital stay, along with higher tracheostomy requirement and higher ICU mortality. These results agree with major studies showing that VAP and ventilator-associated events prolong critical care stay and increase the risk of death or delayed discharge [9-11]. The higher mortality in the present study is likely related to the combined effect of sepsis, chronic lung disease, reintubation, sedation exposure, and prolonged ventilator dependence rather than a single complication alone.

The study findings highlight the need for prevention-focused ICU practice. Strict implementation of ventilator care bundles, head-end elevation, oral care, secretion management, aspiration precautions, daily sedation interruption when clinically appropriate, spontaneous breathing trial assessment, early mobilisation, and antimicrobial stewardship are central to reducing preventable respiratory complications [3,12,13]. A multidisciplinary approach involving intensivists, anaesthesiologists, pulmonologists, nurses, physiotherapists, microbiologists, and infection-control teams is essential for improving outcomes in mechanically ventilated patients.

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Generalizability

The findings apply to similar tertiary care teaching hospitals and adult ICUs managing mixed medical, surgical, trauma, sepsis, and postoperative patients requiring invasive mechanical ventilation. Since the study reflects routine ICU practice in a government medical college setting, the results are useful for comparable resource-constrained critical care units. Extrapolation to highly specialised ICUs, paediatric units, and centres with different ventilator bundle compliance levels requires contextual interpretation.

Conclusion

Ventilator-associated pulmonary complications were frequent among mechanically ventilated ICU patients, affecting 42.0% of the study population. Ventilator-associated pneumonia was the most common complication, followed by atelectasis, acute respiratory distress syndrome, aspiration-related lung injury, pulmonary edema, and barotrauma. Older age, COPD, smoking history, sepsis, prolonged ventilation, reintubation, prolonged sedation, and prior antibiotic exposure were significantly associated with complications. Patients with complications had longer ventilation duration, longer ICU and hospital stay, greater tracheostomy requirement, and higher ICU mortality. Early identification of high-risk patients and strict adherence to preventive ICU practices are essential for improving outcomes.

Limitations

This was a single-centre cross-sectional study with prospective data collection, with a sample size of 100 patients. Microbiological confirmation and ventilator-day incidence density were not included in the dataset. Severity scores such as APACHE II and SOFA were not analysed. The study assessed associations and not causal relationships. Long-term post-discharge pulmonary outcomes were outside the scope of follow-up.

Recommendations

All mechanically ventilated patients should undergo structured daily assessment for pulmonary complications, readiness for weaning, sedation depth, secretion burden, aspiration risk, and infection markers. ICU teams should strengthen ventilator care bundle compliance, including head-end elevation, oral hygiene, closed suction practices, cuff pressure monitoring, hand hygiene, early mobilisation whenever feasible, and daily spontaneous breathing trial evaluation. Reintubation prevention through planned extubation readiness and post-extubation monitoring is important. Antibiotic use should follow local antibiogram and stewardship principles. Regular audit of ventilator-associated complications, staff training, and multidisciplinary review meetings should be implemented to improve patient safety and ICU outcomes.

Acknowledgement

The authors acknowledge the ICU staff, nursing team, respiratory therapists, microbiology personnel, and medical record staff of Government Medical College, Suryapet, for their support in patient care and data collection. The authors also thank the patients and their attendants for their cooperation during the study period.

Abbreviations

ARDS: Acute respiratory distress syndrome
COPD: Chronic obstructive pulmonary disease
ICU: Intensive care unit
MV: Mechanical ventilation
PEEP: Positive end-expiratory pressure
VAE: Ventilator-associated event
VAP: Ventilator-associated pneumonia
VAPC: Ventilator-associated pulmonary complication

Source of funding

The study had no funding.

Conflict of interest

The authors declare no conflict of interest.

Author Contributions

Dr. Mounika Vaditya contributed to the conception and design of the study, clinical data supervision, interpretation of findings, manuscript drafting, and final approval of the manuscript.
Dr. Polam Radhika contributed to study planning, data collection, literature review, analysis support, manuscript revision, and final approval of the manuscript.
Dr. Thati Nagendar contributed to clinical coordination, methodological support, data verification, interpretation of relevant clinical findings, critical review of the manuscript, and final approval of the manuscript.
Dr. Pampana Eshwaramma contributed to overall supervision, intellectual guidance, review of scientific content, manuscript editing, and final approval of the manuscript.

Data availability

Data Available on request

Author Biography

Dr. Mounika Vaditya is a qualified medical professional with an MBBS degree from Katuri Medical College (2006–2012) and an MD in Respiratory Medicine from Konaseema

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https://doi.org/10.51168/sjhrafrica.v7i2.2766
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Institute of Medical Sciences (2012–2015). She has over 7.5 years of teaching experience in the field of Respiratory Medicine, contributing actively to the academic training of undergraduate and postgraduate students. Her areas of expertise include the diagnosis and management of respiratory diseases, tuberculosis, pulmonary function testing, and bronchoscopy. She has been recognized for her dedication and excellence in the medical field with several prestigious awards, including the Vaidya Siromani Award in 2022. She continues to be committed to patient care, medical education, and advancing respiratory health through her clinical and academic contributions. **ORCID iD**: https://orcid.org/0009-0000-3474-1999

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e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/sjhrafrica.v7i2.2766
Original Article

review and meta-analysis. J Thorac Dis. 2024;16(9):5518-5528. https://doi.org/10.21037/jtd-24-150

Publisher Details:

Student's Journal of Health Research (SJHR)

(ISSN 2709-9997) Online

(ISSN 3006-1059) Print

Category: Non-Governmental & Non-profit Organization

Email: studentsjournal2020@gmail.com

WhatsApp: +256 775 434 261

Location: Scholar's Summit Nakigalala, P. O. Box 701432, Entebbe Uganda, East Africa