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Original Research Article

Respiratory Profile, Management, and Prognosis of Patients with Septic Shock and Concomitant Right Ventricular Dysfunction at the Douala General Hospital Critical Care Unit

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Abstract: ***Background*:** The interplay between right ventricular dysfunction (RVD) and respiratory failure in septic shock is a critical determinant of outcome. Data on this interaction, particularly from resource-limited settings in sub-Saharan Africa, are scarce. This study aimed to determine the respiratory profile, management strategies, and prognosis of patients with septic shock and concomitant RVD. ***Methods*:** We conducted a single-center, prospective, observational cohort study in the intensive care unit (ICU) of Douala General Hospital, Cameroon, from December 2020 to August 2021. We included patients aged ≥21 years with septic shock. Data on demographics, clinical features, respiratory parameters (respiratory rate, SpO2, PaO2/FiO2), ventilator settings, and outcomes were collected. Patients were stratified by the presence of RVD. ***Results*:** Of 75 patients screened, 53 were included (mean age 53±16 years, sex ratio 1:1). Pulmonary involvement was present in 96.7% of patients with RVD. Acute Respiratory Distress Syndrome (ARDS) was diagnosed in 30.2% of the cohort. The mean respiratory rate was 29±22 breaths/min, and the mean PaO2/FiO2 ratio was 279±181. Invasive mechanical ventilation (IMV) was required in 50% of patients with RVD, and non-invasive ventilation (NIV) in 46.6%. Mortality for patients on IMV for over two days was catastrophically high at 92.9%. In contrast, the survival rate for patients managed with spontaneous breathing was 23.3% ($p<0.005$). The most common pathogens were Klebsiella pneumoniae (17.0%) and Staphylococcus aureus (15.0%). ***Conclusion*:** In patients with septic shock and RVD in our resource-limited setting, the development of respiratory failure is nearly universal and portends a dismal prognosis. The requirement for invasive mechanical ventilation is associated with extremely high mortality. These findings highlight the lethality of this clinical syndrome and underscore the urgent need for management strategies that protect the right ventricle and avoid the harms of conventional mechanical ventilation.

Keywords: Septic Shock, Right Ventricular Dysfunction, Respiratory Failure, Douala, Sub-Saharan Africa.

1. INTRODUCTION

Septic shock, a severe manifestation of sepsis, is a life-threatening condition characterized by profound circulatory, cellular, and metabolic abnormalities that lead to multi-organ failure and high mortality [1, 2]. While much of the focus in hemodynamic management has traditionally been on the left ventricle and systemic vascular resistance, there is growing recognition of the pivotal role of the right ventricle (RV) in the pathophysiology of septic shock [3, 4].

Right ventricular dysfunction (RVD) is a frequent complication, occurring in up to 60% of septic shock patients, and is an independent predictor of mortality [5, 6]. The RV is particularly susceptible to the insults of sepsis, facing a "perfect storm" of increased

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afterload from pulmonary vasoconstriction and sepsis-induced Acute Respiratory Distress Syndrome (ARDS), decreased preload from vasodilation, and direct myocardial depression from inflammatory cytokines [7, 8]. This creates a vicious cycle where RV failure leads to reduced left ventricular filling, decreased cardiac output, and worsening systemic hypo-perfusion.

The development of respiratory failure, particularly ARDS, is a common and devastating event in sepsis. ARDS is defined by acute, diffuse, inflammatory lung injury leading to increased vascular permeability, pulmonary edema, and severe hypoxaemia [9, 10]. The management of ARDS often requires mechanical ventilation with positive end-expiratory pressure (PEEP) to improve oxygenation and recruit collapsed alveoli [11]. However, in a patient with pre-existing RVD, PEEP can further increase RV afterload, exacerbating RV failure and precipitating cardiovascular collapse [12]. This complex cardio-pulmonary interaction makes management exceptionally challenging.

In resource-limited settings (RLS) across sub-Saharan Africa, the burden of sepsis is immense, and mortality rates are substantially higher than in high-income countries [13, 14]. The challenges are magnified by limited access to advanced diagnostics, inconsistent availability of mechanical ventilators, and a shortage of trained personnel [15]. While studies from our institution have highlighted the high prevalence and prognostic importance of RVD in septic shock [5], the specific respiratory characteristics and outcomes of this high-risk subgroup remain poorly defined. Understanding this profile is critical for developing context-appropriate management strategies. Therefore, this study aimed to determine the respiratory profile, management, and prognosis of patients presenting with septic shock and concomitant RVD in a tertiary hospital in Cameroon.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

We conducted a single-center, prospective, observational cohort study in the 18-bed mixed medical-surgical Intensive Care Unit (ICU) of the Douala General Hospital in Douala, Cameroon. This facility serves as a major tertiary referral center for the region. The study was conducted over a nine-month period, from December 1, 2020, to August 31, 2021.

2.2 Study Population

All consecutive patients aged 21 years or older admitted to the ICU who met the criteria for septic shock were screened for eligibility.

Inclusion Criteria:

- Age ≥ 21 years.
- A confirmed diagnosis of septic shock according to the Sepsis-3 international consensus definitions [1].
- Informed consent obtained from the patient or their legal representative.

Exclusion Criteria:

- Known pre-existing severe cardiorespiratory disease (e.g., chronic heart failure, severe COPD, known chronic pulmonary hypertension).
- Death or transfer from the ICU before study procedures could be completed.
- Inadequate echocardiographic windows precluding the diagnosis of RVD.
- Refusal of consent.

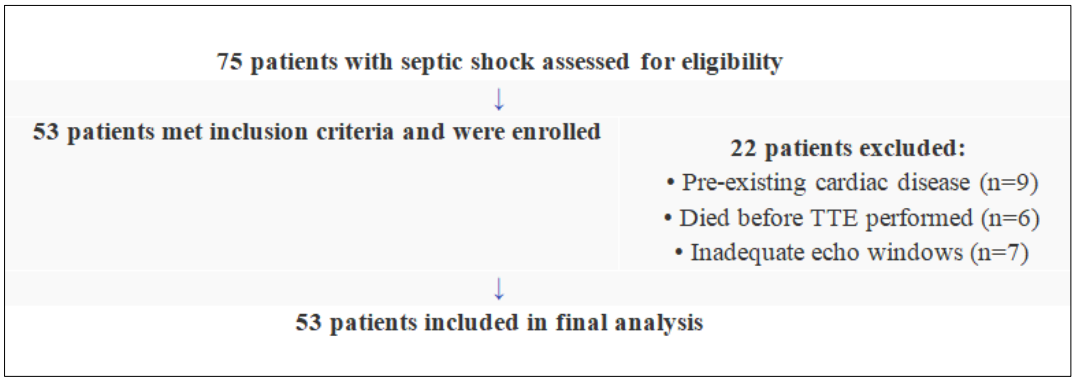

Figure 1: Patient Screening and Enrollment Flow Diagram

53 Patients Included in Final Analysis

2.3 Data Collection

A standardized data collection form was used to prospectively gather information for each enrolled patient. Data were collected on admission and throughout the ICU stay. Variables included:

- **Demographics and Clinical Data:** Age, sex, comorbidities (hypertension, diabetes, obesity), and presenting symptoms (e.g., altered general state, neurological distress).
- **Respiratory Parameters:** Respiratory rate (RR), peripheral oxygen saturation (SpO2) on ambient air and with support, and arterial blood gas (ABG) analysis for PaO2, PaCO2, and pH. The PaO2/FiO2 ratio was calculated to assess the severity of hypoxemia.

- **Respiratory Support and Ventilator Settings:** Mode of respiratory support (spontaneous breathing, non-invasive ventilation [NIV], or invasive mechanical ventilation [IMV]). For ventilated patients, we recorded the fraction of inspired oxygen (FiO2), PEEP, tidal volume (Vt), and minute ventilation (MV).
- **Infection Data:** Suspected source of infection (community-acquired pneumonia [CAP], ventilator-associated pneumonia [VAP]), and microbiological data from cultures to identify pathogens.
- **Echocardiographic Data:** A transthoracic echocardiogram was performed to diagnose RVD, defined as a Tricuspid Annular Plane Systolic Excursion (TAPSE) < 17 mm [5, 16].
- **Outcomes:** The primary outcome was in-hospital mortality. Secondary outcomes included success of weaning from mechanical ventilation, incidence of reintubation, and ICU length of stay.

2.4 Statistical Analysis

Data were entered into a Microsoft Excel 2019 spreadsheet and subsequently analyzed using Epi Info™ (Version 7.2, CDC, Atlanta, GA, USA). Descriptive statistics were used to summarize the data. Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables were presented as frequencies and percentages (%). Comparisons between groups were performed using the Student's t-test for continuous variables and the Chi-square (χ^2) test or Fisher's exact test for categorical variables. A p-value of < 0.05 was considered statistically significant.

3. RESULTS

A total of 53 patients were included in the final analysis. The cohort had a mean age of 53 ± 16 years with an equal sex ratio (1:1). The most common presenting features were a general alteration of condition and neurological distress.

3.1 Baseline Characteristics and Comorbidities

Hypertension was the most frequent comorbidity, affecting 43.4% of patients, followed by diabetes mellitus (26.4%) and obesity (24.5%). Notably, a diagnosis of ARDS was made in 16 patients (30.2%), and pulmonary embolism was suspected or confirmed in 9 patients (17.0%). In the subgroup of patients with confirmed RVD (n=30), 29 (96.7%) had evidence of pulmonary involvement. Baseline characteristics are detailed in Table 1.

Table 1: Basic characteristics of the sample size

Characteristic	Value (or Mean ± SD	Percentages(%)
Age (years)	53 ± 16	
Male Sex	27 (50.9%)	50.9
Comorbidities	-	-
Hypertension	23 (43.4%)	43.4
Diabetes Mellitus	14 (26.4%)	26.4
Obesity	13	24.5
Associated Conditions on Admission	-	-
AcuteRespiratory Distress Syndrome (ARDS)	16	30.2
Pulmonary Embolism	9	17.0

3.2 Respiratory Parameters and Blood Gas Analysis

On admission, patients exhibited significant respiratory distress. The mean respiratory rate was 29 ± 22 breaths/min, and the mean SpO2 on ambient air was 88%. Arterial blood gas analysis revealed significant hypoxemia and acidosis. The mean PaO2/FiO2 ratio for the cohort was 279 ± 181, indicating a wide range from no lung injury to moderate ARDS. These findings are summarized in Table 2.

Table 2: The respiratory profile

Parameters	Mean ± SD
Respiratory Rate (breaths/min)	29 ± 22
SpO2 on Ambient Air (%)	88% ± 12
PaO2 (mmHg)	129 ± 57
PaCO2 (mmHg)	36 ± 10
Arterial pH	7.25 ± 0.1
PaO2/FiO2 Ratio (mmHg)	279 ± 181

3.3 Infection Sources and Pathogens

The primary source of infection was community-acquired pneumonia (CAP), identified in 16 patients (28.1%). Other sources included ventilator-associated pneumonia (5.3%) and aspiration (3.6%). The most frequently isolated pathogens were Gram-negative bacteria, with *Klebsiella pneumoniae* accounting for 17.0% of cases, followed by *Pseudomonas aeruginosa*

and *Escherichia coli* (13.2% combined). *Staphylococcus aureus* was the most common Gram-positive pathogen (15.0%). SARS-CoV-2 was also identified as a pathogen in this cohort.

3.4 Respiratory Support and Ventilator Management

Among the 30 patients with RVD, 14 (46.6%) were managed with NIV, while 15 (50%) required IMV. Patients managed with spontaneous breathing had respiratory rates between 26-28 breaths/min and SpO2 levels ranging from 86-95%. For patients requiring IMV, the management strategy aimed for lung protection, although parameters varied. The mean FiO2 was 60%, with a mean PEEP of 7 ± 2 cmH2O. The PaO2/FiO2 ratio in this intubated subgroup was severely compromised, ranging from 138-154 mmHg, consistent with moderate ARDS. Ventilator settings are detailed in Table 3.

Table 3 : Mechanical ventilation parameters

Parameter	Value (Range or Mean ± SD)
Fraction of Inspired Oxygen (FiO2)	60% ± 16
Respiratory Rate (breaths/min)	15 - 19
Tidal Volume (Vt, ml)	230 - 434
Minute Ventilation (L/min)	6 ± 3
Positive End-Expiratory Pressure (PEEP, cmH2O)	7 ± 2
SpO2 (%)	92% ± 8k
PaO2/FiO2 Ratio (mmHg)	138 - 154

3.5 Clinical Outcomes

The mode of respiratory support was strongly associated with outcome. The mortality rate for patients requiring IMV for more than two days was 92.9%. In stark contrast, the survival rate for patients who could be managed on spontaneous breathing was 23.3%, with successful weaning within 72 hours ($p < 0.005$). Overall, 16 patients (67% of survivors) developed pulmonary insufficiency during their stay, and 3 patients (10% of the RVD group) required emergency reintubation. The outcomes are summarized in Table 4.

Table 4: The outcome

Outcome	InvasiveVentilation (IMV)	Spontaneous Breathing	p-value
Mortality Rate	92.9%	76.7%	<0.005
Survival Rate	7.1%	23.3%	0.006

4. DISCUSSION

This study provides a sobering look at the respiratory outcomes of patients with septic shock and RVD in a sub-Saharan African ICU. Our principal finding is that the development of respiratory failure in this cohort is nearly universal and is associated with a catastrophic prognosis. The 96.7% rate of pulmonary involvement in patients with RVD and the devastating 92.9% mortality rate for those requiring invasive mechanical ventilation for more than 48 hours highlight the extreme lethality of this cardio-pulmonary syndrome in our setting.

The mortality rates observed in our study are dramatically higher than those reported in high-income countries (HICs). While overall ARDS mortality in HICs is estimated to be around 39% [17], and mortality for septic shock ranges from 30-50% [2], our findings point to a near-fatal trajectory once invasive ventilation is initiated. This stark difference is likely multifactorial. First, patients in our setting often present late with more advanced disease, as evidenced by the profound acidosis (mean pH 7.25) and organ dysfunction on admission. Second, the management of mechanically ventilated patients in RLS is fraught with challenges, including unreliable equipment, inconsistent power and oxygen supplies, and high nurse-to-patient ratios, all of which increase the risk of iatrogenic complications and are associated with worse outcomes [15-18].

The pathophysiological interaction between RVD and mechanical ventilation is a critical factor driving these poor outcomes. The application of PEEP, a cornerstone of ARDS management, increases intrathoracic pressure and pulmonary vascular resistance, thereby increasing RV afterload [12-19]. In a patient with a healthy RV, this is usually well-tolerated. However, in a patient with pre-existing, sepsis-induced RVD, even moderate levels of PEEP (mean of 7 cmH2O in our cohort) can be sufficient to tip the fragile RV into overt failure, leading to a downward spiral of decreased cardiac output and refractory shock [8-20]. The fact that survival was significantly higher in patients who avoided intubation suggests that avoiding positive pressure ventilation was a key determinant of outcome.

Our findings underscore the critical importance of early risk stratification using bedside tools like echocardiography. As shown in a related study from our institution, identifying RVD early is crucial for prognosis [5]. The current study extends this by demonstrating that in patients with RVD, the need for respiratory support, particularly IMV, identifies a subgroup with an almost insurmountable risk of death. This implies that management strategies must be radically different for

these patients. The focus should shift from conventional ARDS management to an "RV-protective" strategy. This would involve using the lowest possible PEEP, aggressive management of hypercapnia and acidosis (which worsen pulmonary vasoconstriction), cautious fluid management to avoid RV volume overload, and potentially the early consideration of therapies that are not widely available in our setting, such as pulmonary vasodilators or inotropes [21, 22].

This study has several important limitations. As a single-center, observational study with a relatively small sample size, its findings may not be generalizable to all RLS. The diagnosis of ARDS was clinical and based on the Berlin definition criteria available, but without routine access to advanced imaging like CT scans, some misclassification is possible. Furthermore, we did not have data on fluid balance or detailed hemodynamic parameters, which would have provided a more complete picture of the cardio-pulmonary dynamics. The exclusion of patients who died before echocardiography could also introduce a selection bias, potentially underestimating the true severity of the condition.

Despite these limitations, our study has profound implications for clinical practice and future research in RLS. There is an urgent need for multicenter studies to validate these findings and to explore alternative respiratory support strategies for this high-risk population. Research into low-cost, low-pressure support modalities, such as bubble CPAP or high-flow nasal cannula, which have shown promise in pediatric populations in RLS, may be warranted for adults [23, 24]. Developing and testing RLS-specific protocols for the management of septic shock with RVD, focusing on early detection and RV-protective strategies, should be a top priority to address the unacceptably high mortality rates observed in our study.

5. CONCLUSION

In our resource-limited setting, the combination of septic shock and right ventricular dysfunction is a highly lethal syndrome. The development of respiratory failure, particularly when it necessitates invasive mechanical ventilation, is associated with a catastrophic mortality rate approaching 93%. These findings highlight the critical need to shift management paradigms towards early identification of RVD and the implementation of RV-protective strategies that prioritize avoiding or minimizing the duration and intensity of positive pressure ventilation. Such an approach is essential to improve the dismal outcomes for this vulnerable patient population in sub-Saharan Africa and similar settings.

DECLARATIONS

Ethical Approval and Consent to Participate

This study was conducted in strict adherence to the ethical principles of the Declaration of Helsinki. The study protocol received administrative approval from the Douala General Hospital and full ethical clearance from the Institutional Review Board of the Faculty of Medicine and Biomedical Sciences at the University of Yaoundé I, Cameroon. Written informed consent was obtained from all participants or their legally authorized representatives prior to enrollment in the study.

Authors' Contributions

Study Conception and Design: GNA, ZMJ. OEP, MMJ

Data Collection: GNA, MS, MMJ, RB, G, MB, OE.

Data Analysis: GNA.

Manuscript Drafting: GNA. MRS ,OEP, MMJ

Critical Revision and Final Approval of Manuscript: All authors reviewed, revised, and approved the final version of the manuscript for publication.

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Competing Interests: The authors declare that they have no competing interests.

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are not publicly available due to patient confidentiality concerns but are available from the corresponding author on reasonable request.

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