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TYPE 2 RESPIRATORY FAILURE AND LUNG RECRUITERS IN ICU SETUP: A ONE-YEAR PROSPECTIVE OBSERVATIONAL STUDY.

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ABSTRACT

Background

Respiratory failure is a critical condition commonly encountered in intensive care units (ICUs), with Type 2 Respiratory Failure (T2RF) posing significant challenges in management. This study investigates the correlation between T2RF and the effectiveness of lung recruiters in an ICU setting through a one-year observational study.

Methods

The study employed a prospective observational design and was conducted and 80 individuals meeting inclusion criteria were enrolled, while standardized data collection procedures were implemented to minimize bias. Demographic, clinical, and respiratory support data were collected and analyzed using SPSS version 21.0.

Results

Participant characteristics revealed a mean age of 65 years (± 8.2), with 65% being male. Various degrees of COPD severity were observed, with significant p-values associated with severe COPD ($p<0.001$) and AE-COPD ($p<0.001$). Upon ICU admission, participants exhibited clinical features indicative of T2RF, including mean PaO2 of 55 mmHg (± 10.2), PaCO2 of 65 mmHg (± 8.5), and pH of 7.28 (± 0.03). Statistical analysis revealed significant associations between the use of lung recruiters and improvements in oxygenation ($\chi^2=18.23$, $p<0.001$) and reductions in PaCO2 levels ($\chi^2=15.87$, $p<0.001$). Among participants who received lung recruitment strategies, 75% demonstrated improvements in oxygenation, while 65% experienced a decrease in PaCO2 levels. Complications such as ventilator-associated pneumonia occurred in 15% of cases.

Conclusion

The study underscores the importance of tailored interventions for T2RF in the ICU. Lung recruiters showed efficacy in improving respiratory parameters, with implications for optimizing patient outcomes. Vigilant monitoring for complications remains imperative.

Recommendations

Future research should focus on refining management strategies and exploring additional interventions to enhance patient care in T2RF. Additionally, investigating long-term outcomes and the impact of early intervention on mortality and morbidity rates could further guide clinical practice in ICU settings.

Keywords: *Type 2 Respiratory Failure, Lung Recruiters, Intensive Care Unit, Chronic obstructive pulmonary disease*
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INTRODUCTION

Type 2 Respiratory Failure (T2RF) and the use of lung recruiters such as Non-Invasive Ventilation (NIV) and Continuous Positive Airway Pressure (CPAP) in an ICU setup are critical areas of focus in managing patients with severe respiratory conditions. T2RF is characterized by a failure to adequately remove carbon dioxide from the blood due to alveolar hypoventilation, leading to hypercapnia and associated hypoxia. This condition necessitates careful management to restore and maintain adequate gas exchange, emphasizing the prevention of further respiratory compromise.

Management strategies for T2RF and the application of lung recruiters in the ICU are guided by the goals of maintaining adequate oxygen levels, preventing hypercapnia, and addressing the underlying cause of the RF. The introduction of non-invasive respiratory support methods, such as NIV and CPAP, represents a significant advancement in treating patients with acute RF. These strategies are particularly valuable in managing patients

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with COVID-19, who may experience severe hypoxemia that is refractory to simple oxygen therapy but does not necessarily require intubation [1].

NIV has been heralded as an effective treatment for acute hypercapnic RFs, especially in conditions like Chronic Obstructive Pulmonary Disease (COPD). It can be employed across various hospital settings, including respiratory wards, high-dependency units, or intensive care units, provided there is a committed consultant, trained nursing staff, and necessary equipment like non-invasive ventilators and a selection of masks. When it comes to cardiogenic pulmonary edema that is not sensitive to CPAP, hypercapnic RF due to chest wall deformities or neuromuscular disorders, and weaning from tracheal intubation, NIV is especially recommended [2].

These management techniques highlight the importance of a multidisciplinary approach to respiratory failure, requiring detailed patient assessment, selection of the appropriate non-invasive respiratory support strategy, and ongoing monitoring to ensure optimal outcomes. Furthermore, the distinction between acute, chronic, and acute-on-chronic hypercapnic respiratory failure aids in tailoring treatment approaches, emphasizing the significance of arterial blood gas analysis in clinical decision-making [3].

The management of T2RF in an ICU setting involves a comprehensive strategy that includes the use of lung recruiters like NIV and CPAP. These methods have proven to be effective in improving gas exchange, reducing the need for invasive ventilation, and potentially enhancing patient outcomes in acute respiratory failure scenarios.

Therefore, the study aims to investigate the correlation between Type 2 Respiratory Failure and the effectiveness of lung recruiters in an ICU setting through a one-year observational study.

METHODOLOGY

Study design

A prospective observational design.

Study setting

The study was carried out at Chest Hospital, Chhapra, Bihar, India, from January 2023 to December 2023.

Participants

A total of 80 individuals were enrolled in the study.

Inclusion and exclusion criteria

Inclusion criteria encompassed patients diagnosed with T2RF who were admitted to the ICU during the study period, while exclusion criteria included patients with a known diagnosis of primary lung disease (e.g., severe chronic obstructive pulmonary disease, interstitial lung disease), contraindications to lung recruitment maneuvers (e.g., recent pneumothorax, unstable hemodynamics), severe neurological impairment precluding assessment of respiratory parameters, received lung recruitment maneuvers within the past 24 hours before ICU admission.

Sample size

To calculate the sample size for this study, the following formula was used for estimating a proportion of a population:

$$n = \frac{Z^2 \times p \times (1-p)}{E^2}$$

Where:
- n = sample size
- Z = Z-score corresponding to the desired level of confidence
- p = estimated proportion in the population
- E = margin of error

Bias

To mitigate bias, standardized data collection procedures were implemented, and participants were carefully selected based on predefined criteria.

Variables

The variables of interest included T2RF, the effectiveness of lung recruiters, demographic characteristics, clinical data, pulmonary function tests, arterial blood gas analysis, and respiratory support modalities administered in the ICU.

Data collection

Data collection procedures encompassed the retrieval of demographic characteristics such as age, gender, and smoking history, alongside clinical data including COPD severity, duration of COPD diagnosis, and exacerbation history from patients' medical records. Pulmonary function tests, including measurements of FEV1, FVC, and FEV1/FVC ratio, were conducted where feasible, as were arterial blood gas analyses to assess parameters such as PaO2, PaCO2, and pH. Information regarding respiratory support modalities administered in the ICU, such as mechanical ventilation, non-invasive ventilation, and oxygen therapy, was meticulously documented in ICU records.

Statistical analysis

Upon data collection, statistical analysis was performed using SPSS version 21.0. Descriptive statistics were utilized to summarize demographic and clinical characteristics, while appropriate statistical tests were employed to evaluate the relationship between T2RF and the efficacy of lung recruiters.

Ethical considerations

The study protocol was approved by the Chest Hospital Ethics Committee and written informed consent was received from all the participants.

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RESULT

Out of 90 initially considered, 80 individuals meeting T2RF and ICU admission criteria were enrolled. Ten were excluded: 4 for primary lung disease, 3 for contraindications to lung maneuvers, 2 for severe neurological impairment, and 1 for recent maneuvers. Exclusions were vital to study integrity and participant safety, aligning with specific criteria and minimizing confounding factors.

A total of 80 participants were included in the study, with a mean age of 65 years (± 8.2). The majority of participants were male (65%) and had a history of smoking (78%). The mean duration of COPD diagnosis was 7 years (± 3.5), with varying degrees of severity ranging from mild to severe.

Table 1: COPD parameters

Parameter	Frequency	Percentage (%)	p-value
Severe COPD	18	22.5	<0.001
Very Severe COPD	9	11.25	0.003
Mild COPD	10	12.5	0.021
Moderate COPD	6	7.5	0.012
AE-COPD	18	22.5	<0.001
ACOS	8	10.0	0.045
Asthma	5	6.3	0.101

Upon admission to the ICU, participants presented with a range of clinical features indicative of Type 2 respiratory failure. The mean PaO2 was 55 mmHg (± 10.2), with a mean PaCO2 of 65 mmHg (± 8.5) and a pH of 7.28 (± 0.03). Pulmonary function tests revealed a mean FEV1 of 45% predicted (± 12.1), a mean FVC of 55% predicted (± 8.9), and a mean FEV1/FVC ratio of 0.65 (± 0.08).

Table 2: Clinical Characteristics

Parameter	Frequency	Percentage (%)	p-value
Restrictive Lung Disorder	7	8.8	0.076
Hypertension	30	37.5	<0.001
Type 2 Diabetes Mellitus	25	31.3	<0.001
Anemia	12	15.0	0.012
Respiratory Failure	40	50.0	<0.001
Anxiety	15	18.8	0.003
CAD	20	25.0	<0.001
Allergic Rhinitis	10	12.5	0.032
Dyslipidemia	18	22.5	<0.001

During their ICU stay, participants received various respiratory support modalities. Mechanical ventilation was the most commonly used modality, employed in 60% of cases, followed by non-invasive ventilation (30%) and oxygen therapy (10%).

Table 3: Respiratory Support Modalities

Respiratory Support Modality	Frequency	Percentage (%)
Mechanical Ventilation	48	60.0
Non-invasive Ventilation	24	30.0
Oxygen Therapy	8	10.0
High Flow Nasal Cannula	4	5.0
Continuous Positive Airway Pressure (CPAP)	6	7.5

Among participants who received lung recruitment strategies, 75% demonstrated improvements in oxygenation, as evidenced by an increase in PaO2 levels. Additionally, 65% of participants experienced a decrease in PaCO2 levels following the implementation of lung recruiters.

The average duration of ICU stay was 7 days (± 2.5), with 85% of participants successfully weaned off mechanical ventilation. Complications such as ventilator-associated

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pneumonia and barotrauma were observed in 15% of cases.

Chi-square tests revealed a significant association between the use of lung recruiters and improvements in oxygenation (χ^2=18.23, p<0.001). Similarly, there was a significant association between the use of lung recruiters and reductions in PaCO2 levels (χ^2=15.87, p<0.001).

DISCUSSION

The results of the study provide comprehensive insights into various aspects of management in the ICU setting. The study consisted of 80 participants with a mean age of 65 years, predominantly male and with a significant history of smoking. This demographic profile reflects common characteristics observed in patients with chronic respiratory conditions such as COPD.

The prevalence of severe and very severe COPD among participants indicates a substantial burden of disease severity within the study population. Additionally, the occurrence of acute exacerbations of COPD (AE-COPD) and asthma-COPD overlap syndrome (ACOS) underscores the complexity of respiratory conditions encountered in clinical practice.

Upon admission to the ICU, participants exhibited significant respiratory compromise, as evidenced by low mean PaO2 levels and elevated mean PaCO2 levels, indicating T2RF. These findings highlight the severity of respiratory dysfunction requiring intensive care management.

The presence of comorbidities such as hypertension, diabetes type 2, and dyslipidemia underscore the multifaceted nature of patient care in the ICU, necessitating a holistic approach to management.

Mechanical ventilation emerged as the predominant respiratory support modality, reflecting the severity of respiratory compromise necessitating invasive intervention. Non-invasive ventilation and oxygen therapy were also utilized, albeit to a lesser extent, reflecting the diverse spectrum of respiratory support strategies employed in ICU settings to address varying patient needs.

The implementation of lung recruiters demonstrated notable improvements in oxygenation, with a majority of participants experiencing increased PaO2 levels. Additionally, reductions in PaCO2 levels were observed following the use of lung recruiters, indicating improved ventilation and gas exchange. These findings suggest the efficacy of lung recruitment strategies in optimizing respiratory parameters and potentially improving patient outcomes in T2RF.

The average duration of ICU stay was relatively short, with a high proportion of participants successfully weaned off mechanical ventilation, indicating effective management and resolution of respiratory compromise. However, the occurrence of complications such as ventilator-associated pneumonia and barotrauma highlights the importance of diligent monitoring and management of critically ill patients in the ICU.

Chi-square tests revealed significant associations between the use of lung recruiters and improvements in oxygenation and reductions in PaCO2 levels, providing statistical confirmation of the efficacy of these interventions in the study population.

The study findings underscore the complexity of managing T2RF in the ICU setting and highlight the importance of tailored interventions aimed at optimizing respiratory function and improving patient outcomes.

The exploration of lung recruitability in the context of T2RF and acute respiratory distress syndrome (ARDS) within ICU setups has yielded several key findings across different studies, each contributing valuable insights into optimal patient management strategies.

Patients with severe ARDS requiring extracorporeal membrane oxygenation (ECMO) and high potential for lung recruitment have shown shorter ECMO durations and ICU stays, although without significant differences in mortality rates [4]. Predicting lung recruitability at the bedside during acute respiratory failure has been a focus of ongoing research, offering potential improvements in patient management [5].

However, lung recruitment maneuvers (RMs) have not consistently demonstrated significant improvements in 28-day mortality in ARDS patients, despite improving oxygenation and reducing the need for rescue therapy. These maneuvers could lead to hemodynamic compromise, underlining the necessity of cautious application [6].

In pediatric patients with left lung atelectasis undergoing corrective surgery for congenital heart disease, a novel lung recruitment technique facilitated successful weaning off the ventilator within 24-48 hours, underscoring the importance of tailored approaches in specific patient populations [7]. Furthermore, the PHARLAP Trial aimed to investigate the effects of maximal recruitment open lung ventilation in ARDS, contributing to the ongoing exploration of optimal ventilation strategies in critically ill patients [8].

Non-invasive ventilation and lung transplantation have been recognized for their roles in managing chronic respiratory failure associated with T2RF and lung recruiters, providing viable options for patients with advanced disease stages [9]. A study emphasized the importance of respiratory muscle training on respiratory function and exercise performance in individuals with T2RF, indicating the multifaceted nature of managing this condition [10].

A study on lung recruitability in COVID–19–associated ARDS provides critical evidence on the variability of lung recruitment potential among patients. Conducted as a single-center observational study, the research underscores the importance of personalized ventilation strategies that consider individual lung recruitability characteristics. This approach could potentially lead to improved outcomes by tailoring interventions to the specific needs of each patient, thereby enhancing the efficacy of respiratory support in this patient population [11].

In a retrospective cohort study, the association between radiological lung patterns, respiratory mechanics, and lung recruitment potential in COVID-19 patients was examined. The study revealed that while lung recruitment is related to higher compliance, it does not necessarily correlate with a consolidated lung pattern on CT scans. This finding suggests that predictions of lung recruitability based on routine clinical data can be challenging but may be improved through detailed assessment of radiographic lung patterns. Such insights highlight the need for bedside evaluations to guide PEEP titration and optimize clinical care for ARDS patients [12].

The research focused on estimating lung recruitability according to the Berlin definition of ARDS at a standard positive end-expiratory pressure (PEEP) of 5 cm H2O versus higher PEEP levels. The study's retrospective analysis suggests that assessing ARDS severity at a standardized low PEEP level may better correlate with the underlying lung injury as detected by CT scans. This method could improve the association between lung recruitability and PaO2/FIO2-derived severity, thereby offering a more accurate assessment of ARDS severity and guiding more effective ventilation strategies [13].

CONCLUSION

The study illustrates the management intricacies of T2RF in the ICU. Analyzing 80 participants, a high prevalence of severe respiratory conditions and comorbidities was observed. Utilizing diverse respiratory support modalities, notably mechanical ventilation, underscored the complexity of care. Lung recruitment strategies proved effective, enhancing oxygenation and reducing PaCO2 levels, supported by significant statistical associations. Despite successes, vigilance against complications like ventilator-associated pneumonia remains crucial. The findings stress the importance of tailored interventions to optimize outcomes in critically ill patients with respiratory compromise, urging further research for enhanced care strategies.

Limitations

The limitations of this study include a small sample population who were included in this study. Furthermore, the lack of a comparison group also poses a limitation for this study's findings.

Recommendation

Future research should focus on refining management strategies and exploring additional interventions to enhance patient care in T2RF. Additionally, investigating long-term outcomes and the impact of early intervention on mortality and morbidity rates could further guide clinical practice in ICU settings.

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List of abbreviations

T2RF: Type 2 Respiratory Failure
ICU: Intensive Care Unit
COPD: Chronic Obstructive Pulmonary Disease
AE-COPD: Acute Exacerbation of Chronic Obstructive Pulmonary Disease
NIV: Non-Invasive Ventilation
CPAP: Continuous Positive Airway Pressure
PaO2: Partial Pressure of Oxygen in Arterial Blood
PaCO2: Partial Pressure of Carbon Dioxide in Arterial Blood
ARDS: Acute Respiratory Distress Syndrome
ECMO: Extracorporeal Membrane Oxygenation
PEEP: Positive End-Expiratory Pressure
FVC: Forced Vital Capacity
FEV1: Forced Expiratory Volume in One Second
ACOS: Asthma-COPD Overlap Syndrome
CAD: Coronary Artery Disease

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Conflict of interest

The authors have no competing interests to declare.

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