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Role of Continuous Respiratory Monitoring In Detection of Respiratory Failure in Critically Ill Patients

Habib Rehman*
MS Scholar, Allied Health Sciences, Superior University Rawaind Road Arrain Campus Lahore, Pakistan Email: habibktk7875@gmail.com
Dr. Usra Naeem
Associat Professor, Department of Emerging Allied Technologies, Faculty of Allied health Sciences, Superior University, Rawaind Road Arrian campus Lahore, Pakistan Email: usra.naeem@superior.edu.pk
Musadiq Khan
Lecturer, Sarhad Institute of Allied Health Sciences, sarhad University of Science and Information Technology Email: musadiq.siahs@suit.edu.pk
Arshad Javaid
Lecturer, Department of Anesthesia Technology, Faculty of Allied Health Sciences, Gomal University, Dera Ismail Khan, Pakistan Email: a.javaidkhan06@gmail.com
Ahsanullah
Head of Department of Anesthesia Technology, Faculty of Allied Health Sciences, Gomal University, Dera Ismail Khan, Pakistan Email: ahsanullah@gu.edu.pk
Muhammad Arif
Lecturer, Sarhad Institute of Allied Health Sciences, sarhad University of Science and Information Technology Email: arif.siahs@suit.edu.pk
Umer Majeed
Assistant Professor, Sarhad Institute of Allied Health Sciences, Sarhad University of Science and Information Technology Email: Umer.siahs@suit.edu.pk

Author Details

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Corresponding E-mail & Author*:
Habib Rehman*
MS Scholar, Allied Health Sciences, Superior University Rawaind Road Arrain Campus Lahore, Pakistan Email: habibktk7875@gmail.com

Abstract

Background: Respiratory failure is an inability of the respiratory system to maintain adequate gas exchange, leading to hypoxemia, Hypercapnia, or both. It is a leading cause of intensive care unit (ICU) admissions and mortality. Early detection through continuous respiratory monitoring is essential for timely intervention. This study aimed to evaluate the role of constant respiratory monitoring in detecting respiratory failure in critically ill patients.

Methodology: A cross-sectional observational study was conducted at Mufti Mahmood Memorial Teaching Hospital, involving 200 critically ill adult patients admitted to the ICU over four months. The inclusion criteria comprised patients with conditions such as sepsis, pneumonia, ARDS, or post-surgical complications that required mechanical ventilation. Data were collected on demographics, respiratory parameters (SpO_2, $EtCO_2$, respiratory rate), arterial blood gases (PaO_2, $PaCO_2$, pH), and ventilator settings (tidal volume, PEEP, plateau pressure). Statistical analysis was performed using SPSS version 22, employing

descriptive statistics and chi-square tests to examine relationships between variables.
Results: The study population was predominantly male (60.5%) and aged over 60 years (33.5%). Pneumonia (23%) and COPD (21%) were the most common causes of respiratory failure. Key findings included low PaO_2 levels (<80 mmHg) in 78% of patients, abnormal $PaCO_2$ levels in 61.5%, and abnormal pH in 68.5%. The most frequent ventilator modes were SIMV (42.5%) and volume-controlled ventilation (27%). Statistical analysis revealed significant correlations between SpO_2 and FiO_2 ($p = 0.003$), PaO_2 and PEEP ($p = 0.036$), and lung compliance and plateau pressure ($p < 0.001$). Capnography effectively detected airway resistance, and $EtCO_2$ levels closely mirrored $PaCO_2$ trends ($p<0.001$).
Conclusion: it is concluded thah the patients with respiratory failure, key ventilator and clinical parameters like SpO_2-FiO_2, PaO_2-PEEP, and tidal volume-lung compliance showed significant associations, indicating the need for coordinated monitoring. Most patients were elderly males, with COPD and pneumonia as common causes. While many parameters were within normal ranges, some showed high pressures and poor lung compliance. Age, gender, and a few variables showed no significant relationships. Overall, effective management requires adjusting multiple respiratory parameters together.

INTRODUCTION:

Respiratory failure is a serious medical condition in which the respiratory system fails to adequately oxygenate the blood and/or remove carbon dioxide. This failure is formally diagnosed by measuring the levels of oxygen and carbon dioxide in the arterial blood. It occurs when one or both of the following are present: Low Oxygen Level (Hypoxemia), Partial pressure of arterial oxygen (PaO_2) is ≤ 60 mmHg (normal is 80-100 mmHg). High Carbon Dioxide Level (Hypercapnia) The Partial pressure of arterial carbon dioxide ($PaCO_2$) is ≥ 50 mmHg (normal is 35-45 mmHg). Respiratory failure caused by lung disorders such as pneumonia has the power to send patients to the critical care unit (CCU); in many other cases, respiratory failure is caused by sepsis, heart failure, or brain issues. A variety of diseases are associated with respiratory distress(1).

Gaseous exchange is a vital process performed by the respiratory system.. After passing through the upper airways, Oxygen enters the capillary via diffusion through the alveolocapillary membrane—Bloodstream in the alveoli. After joining hemoglobin there, it is carried to the tissues by arterial blood. Adenosine triphosphate, which is necessary for all metabolic functions, is produced in the tissues using oxygen.(2) A significant amount of CO2, the primary consequence of cellular metabolism, is hydrated as carbonic acid in the capillary blood after diffusing from the tissues. The venous blood then carries the carbonic acid to the lungs. It diffuses from the pulmonary blood into the lungs' alveoli before being released into the environment (Expiration)(3). Maintaining homeostasis, or the internal environment of the organism, requires gas exchange that is suitable for metabolic demands. An elaborate system of structures performs and controls respiration. (4).

Classification of respiratory Failure:

By measuring arterial blood gas, three types of respiratory failure can be identified... Type I denotes an oxygenation failure, Type II a ventilation failure, and Type III a combination of the two(5).

Respiratory Failure Type I (Arterial Hypoxemia; Failure of Oxygenation).

The arterial blood's partial oxygen pressure is influenced by the factors such as alveolar membrane's diffusion(6), Minute airflow(7), amount of blood flowing through the lungs capillaries(8), O2 saturation of hemoglobin within the blood moving through the pulmonary capillaries as a consequence of cardiac output and tissue metabolism(9), Ventilation-perfusion matching and Oxygen partial pressure in inspiratory gas.(10)

Type I failure is distinguished by an abnormally low arterial circulation partial pressure of oxygen. It is characterized by low arterial blood oxygen partial pressure (PaO2 < 60 mm Hg when breathing room air), venous admixture, increased PaO2-difference, and Vd/VT. The etiology may be any condition that results in a right-to-left intrapulmonary shunt or regions of inadequate ventilation-perfusion(11).

Pathophysiological mechanisms of arterial Hypoxemia

A reduction in the oxygen partial pressure in the alveoli

A lack of oxygen

A reduction in the inspired air's O2 partial pressure in regions of limited ventilation perfusion, or beneath ventilated alveoli(12)

Areas of zero ventilation-perfusion, or intrapulmonary shunts

Reduced O2 content in the mixed veins (low hemoglobin saturation)

A higher rate of metabolism

A reduction in cardiac output

Reduced oxygen concentration in the arteries(13)

Reasons for respiratory failure of Type I (Oxygenation)

Acute lung injury

Out of breath

Edema in the lung Type II failure is defined as the partial pressure of oxygen in arterial blood and the partial pressure of oxygen in alveoli.

Fourth, COPD

Pneumonia

The pneumothorax

An embolism in the lungs

Hypertension in the lungs(14)

Arterial Hypercapnia (Ventilator Failure) is a type II respiratory failure. The effectiveness of the ventilator system that removes (washes away) CO2 generated during tissue metabolism is reflected in the arterial blood's CO2 partial pressure. Any condition that reduces central respiratory drive, disrupts the central nervous system's signal transmission, or limits the muscle of respiration capacity can cause inflation. The chest wall and lungs can result in an error of the second kind. The PAO2 difference stays constant because an extreme increase in the arterial circulation's partial pressure of CO2 (CO2 partial pressure in arterial blood greater than 46 mm Hg) is coupled with a corresponding drop. Type II failure is defined as the partial pressure of oxygen in arterial blood and the partial pressure of oxygen in alveoli.(15)

METHODOLOGY

This study used a cross-sectional observational design to determine the role of continuous respiratory monitoring in detection of respiratory failure in critically ill patients Data were collected over four months from the ICU at Mufti Mahmood Memorial Teaching Hospital in Dera Ismail Khan.. A total of 200 patients with a prevalence of 15% were enrolled in the study.After confirming consent, the researcher used data gathering methods to gather data through a Survey, and will be collected according to the variable of the data sheet.

A non-probability convenience sampling technique was used, selecting students who met the inclusion and exclusion criteria. Inclusion criteria included ICU patients who are very sick, Individuals who may have respiratory failure due to conditions like sepsis, pneumonia, ARDS, or post-surgical complications,Patients who need continuous breathing monitoring,Adults (18+ years old) and Patients or their family members agree to participate.Exclusion criteria included Patient not requiring intensive care or mechanical ventilation,Patients with muscle diseases that affect breathing,Pregnant patients,Patients with missing medical data,Patients were already on long-term ventilators before ICU stay.

After confirming consent, the researcher used data gathering methods to gather data through a Survey, and will be collected according to the variable of the data sheet.. Data were analyzed using SPSS version 22, the outcomes were shaped using descriptive statistics and the study's findings have been displayed as text, and tables.

RESULTS

Demographic characteristics of patients:

The study included 200 payients recruited from Mufti Mahmood Memorial Teaching Hospital in Dera Ismail Khan with an age range of , 67 individuals (33.5%), were over 60 years of age. This was followed by the 18–40 age group, which accounted for 57 participants (28.5%). The 40–60 age group comprised 43 participants (21.5%), while the smallest proportion of participants, 33 individuals (16.5%), were aged between 0 and 18 years. This distribution indicates that older individuals, particularly those above 60, made up the largest segment of the study population,

with 121 participants (60.5%)**,** while females accounted for 79 participants (39.5%)**.**(TABLE 1)**.**

Table 1 The statistics of age and gender

Statistics					
		Gender		Age	
N	Valid	200		200	
	Missing	0		0	
		Male	121	0-18 year	33
				18-40year	57
		Female	79	40-60 year	43
				>60 year	67

Among 200 patients, the most common condition was pneumonia, observed in 46 participants (23.0%). This was followed by chronic obstructive pulmonary disease (COPD), affecting 42 individuals (21.0%), and other causes observed less common. (Table 2). Overall, the findings show that a sizable majority of the subjects (78%) experienced some degree of hypoxemia, with mild hypoxemia being the most common finding (Table 3). In this study, the distribution of current ventilator modes was analyzed in 200 patients. The findings indicated that the most commonly used mode was Synchronized Intermittent Mandatory Ventilation (SIMV), which was observed in 42.5% (85 cases) of the patients. This was followed by Volume-Controlled Ventilation (VCV) in 27% (54 cases), and Pressure Support Ventilation (PSV) in 25% (50 cases). The least frequently used mode was Pressure-Controlled Ventilation (PCV), noted in only 5.5% (11 cases).(Table 4). The analysis revealed that 27.5% (55 cases) displayed a normal capnography waveform. Hypoventilation was observed in 29% (58 cases), while 28% (56 cases) demonstrated hyperventilation patterns. Additionally, 15.5% (31 cases) showed waveforms indicative of airway obstruction(Table 5)

Table 2 Frequency of Respiratory Failure Causes

Causes		Frequency	Percent
Valid	ARDS	28	14.0
	Pneumonia	46	23.0
	COPD	42	21.0
	Neuromuscular disorder	25	12.5
	PORD	19	9.5
	Other	40	20.0
	Total	200	100.0

Table 3 PAO2 in ABG Frequency

PAO2 in ABG					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	>80 mmHg	44	22.0	22.0	22.0
	60-80 mmHg	66	33.0	33.0	55.0
	40-60mmHg	61	30.5	30.5	85.5
	<40mmHg	29	14.5	14.5	100.0
	Total	200	100.0	100.0	

Table 0 Frequency of current ventilator mode

Current ventilator mode					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	VCV	54	27.0	27.0	27.0
	PCV	11	5.5	5.5	32.5
	PSV	50	25.0	25.0	57.5
	SIMV	85	42.5	42.5	100.0
	Total	200	100.0	100.0	

Table 5 frequency of ETCO2 level on capnography

EtCO2 Level on capnography					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	35-45mmHg	58	29.0	29.0	29.0
	<35mmHg	67	33.5	33.5	62.5
	>45mmHg	74	37.0	37.0	99.5
	4	1	.5	.5	100.0
	Total	200	100.0	100.0	

DISCUSSION:

This study assessed the role of continuous respiratory monitoring in detecting respiratory failure among critically ill patients admitted to the ICU at Mufti Mahmood Memorial Teaching Hospital. The findings highlight important clinical insights into demographic characteristics, causes of respiratory failure, abnormalities in gas exchange, ventilatory parameters, and their interrelationships.The demographic profile showed that the majority of patients were male (60.5%) and over the age of 60 years (33.5%). This aligns with global trends indicating higher prevalence of respiratory failure in older populations due to weakened pulmonary reserve, age-related comorbidities, and delayed physiological compensation. The male predominance may be explained by higher exposure to smoking, occupational hazards, and chronic respiratory diseases such as COPD in this group(16).The primary causes of respiratory failure observed in this study were pneumonia (23%) and COPD (21%), consistent with earlier reports that identify infectious and obstructive pulmonary diseases as leading contributors to ICU admissions. ARDS, neuromuscular disorders, and postoperative complications also accounted for a considerable portion of cases, underlining the multifactorial etiology of respiratory failure(17).The study revealed that 78% of patients had PaO_2 levels below 80 mmHg, with hypoxemia being the most common finding. Similarly, 61.5% had abnormal $PaCO_2$ levels, and 68.5% had pH disturbances, reflecting poor gas exchange and impaired homeostasis. These findings underscore the importance of continuous monitoring of oxygenation and ventilation indices in critically ill patients, as intermittent measurements may miss early signs of deterioration(18).Analysis of ventilator parameters showed that SIMV (42.5%) and VCV (27%) were the most commonly employed ventilator modes, indicating a preference for modes that combine mandatory and spontaneous breaths. The majority of patients received tidal volumes within the lung-protective range of 6–8 ml/kg IBW, while elevated plateau pressures (>30 cmH_2O) and reduced lung compliance (<30 ml/cmH_2O) were seen in a subset of patients, suggesting risk of ventilator-induced lung injury. This supports evidence that continuous evaluation of compliance, pressures, and volumes is critical for optimizing ventilation strategies(19).Capnography findings revealed strong correlations between $EtCO_2$ and $PaCO_2$, demonstrating its reliability in detecting hypercapnia or hypocapnia in real time. Moreover, abnormal capnography waveforms were observed in 72.5% of patients, with hypoventilation and hyperventilation being common patterns. These findings reinforce capnography's role as an effective tool in early detection of airway resistance and ventilatory failure.Significant correlations were identified between SpO_2 and FiO_2 ($p=0.003$), PaO_2 and PEEP ($p=0.036$), and lung compliance with plateau pressure ($p<0.001$)(20). This interdependence of parameters emphasizes the need for integrated monitoring rather than isolated observation. For instance, titration of FiO_2 must be accompanied by SpO_2 surveillance, while PEEP adjustments should be guided by PaO_2 levels and lung mechanics.Interestingly, gender, age, and auto-PEEP showed no significant associations with outcomes, suggesting that physiological responses and ventilatory parameters outweigh demographic factors in determining respiratory failure progression.

Overall, the results of this study affirm that continuous respiratory monitoring allows timely recognition of abnormalities, supports evidence-based ventilatory adjustments, and reduces the risk of complications. These findings align with global literature advocating for advanced monitoring systems in ICU practice to improve survival and reduce length of stay.

Conclusion:

This study conclude that among 200 patients with respiratory failure participated in this study, which used the chi-square test and cross tabulation to evaluate a number of clinical and ventilator data. The majority of patients, according to the results, were men over 60. COPD and pneumonia were the most frequent causes of respiratory failure. A portion of patients had abnormal oxygen and carbon dioxide levels as well as a change in PH, indicating poor gas exchange. Most participants were on mechanical ventilation, and common ventilator modes include SIMV and VCV.Fio2, PEEP, PIP, and Tidal volume were mostly within the recommended clinical range. However, some patients had high pressure and poor lung compliance, indicating difficulty in breathing. Statistical analysis showed that many variables, such as SPO2 and FIO2, PAO2 and PEEP, and tidal volume and lung compliance, were significantly related. This means they affect each other and must be monitored closely together. On the other hand, gender and age, pCO2 and respiratory rate, and auto-PEEP and airway resistance showed no significant relationship, meaning they were independent of each other. Overall, the study highlights the importance of evaluating and adjusting multiple respiratory and ventilator parameters together to effectively treat patients suffering from respiratory failure.

Recommendations

It is recommended that continuous respiratory monitoring be established as a standard of care in ICUs for early detection of hypoxemia, hypercapnia, and ventilatory failure. Capnography should be routinely combined with pulse oximetry for comprehensive assessment, and ventilator settings should be individualized with careful attention to plateau pressures, tidal volumes, and lung compliance to prevent lung injury. Hospitals are advised to allocate resources for advanced monitoring equipment, ensure regular maintenance, and provide ongoing training for ICU staff under standardized protocols and guidelines. Furthermore, future research should focus on multicenter validation studies, comparisons between continuous and intermittent monitoring, the role of artificial intelligence in predicting deterioration, and long-term follow-up of patients after ICU discharge.

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