Bam N, et al. OHJN 2025 July-Dec;05(02):63-67

One Health Journal of Nepal

Short communication Open Access

Pragmatic Pathways for Noninvasive Ventilation in Type 2 Respiratory Failure: From Global Evidence to Nepalese Experience

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ABSTRACT

Noninvasive ventilation (NIV) is an established first-line intervention for Type 2 (hypercapnic) respiratory failure, offering a highly effective and less invasive alternative to endotracheal intubation. Its efficacy is rooted in core mechanisms, such as pressure support-driven improvements in gas exchange, which address principal causes like COPD and neuromuscular disorders. Several evidence confirms that this approach significantly reduces mortality, morbidity, and hospital length of stay, while preserving natural airway function and patient comfort. While arterial blood gas (ABG) analysis remains the gold standard for initiating therapy, pragmatic clinical indicators—such as tachypnea and accessory muscle use—are vital in resource-constrained settings like Nepal. Building on this foundation, recent advances in pulmonology, including portable ventilators, telemonitoring, and AI-powered analytics, are further elevating patient outcomes. To realize the full potential of these tools, their integration within multidisciplinary teams and expanded access through robust critical care infrastructure are essential for improving survival and quality of life. Therefore, this paper aims to outline a modern, integrated strategy for managing hypercapnic failure that combines advanced technology with equitable, accessible noninvasive ventilation.

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Submitted Date: 2025-07-15
Accepted Date: 2025-08-21

ORCID of corresponding author:
0009-0009-2851-2925

Keywords : *Critical Care; Pulmonary Medicine; Respiratory Failure; Ventilation, Noninvasive.*

INTRODUCTION

The global burden of respiratory illness has increasingly impacted morbidity and mortality rates. Nearly 200 million people, or 4% of the world's population, have COPD and 3.2 million die of it each year, making it the third-leading cause of death worldwide (1). Due to increasing incidences of respiratory illness such as chronic obstructive pulmonary disease (COPD), obesity, obstructive sleep apnea (OSA), the need of type of type 2 respiratory failure has emerged.(2) Non-invasive ventilation (NIV) is effective but less invasive alternative to the mechanical ventilation. Over the past two decades, pulmonology has seen rapid advancements, including the introduction of innovative diagnostic and therapeutic tools.(3) Furthermore development of critical care centers and improved patient access to specialized care has substantially enhanced clinical outcomes.(4) This short communication provides a brief overview of management of type 2 respiratory failure through NIV with the recent technological and procedural advances in pulmonology and highlight the role of pulmonology and critical care centers in improving patient accessibility, reducing morbidity, and lowering mortality rates.

RESPIRATORY FAILURE

Respiratory failure occurs when the respiratory system can no longer perform adequate gas exchange, a critical condition that significantly increases morbidity and mortality in the ICU.(5) Type 2 respiratory failure is characterized by increased arterial partial pressure of carbon dioxide ($PaCO_2$ > 6.0 kPa or 45 mmHg) and, in many cases, hypoxemia (PaO_2 < 8.0 kPa or 60 mmHg). It arises due to insufficient alveolar ventilation, resulting in carbon dioxide retention.(6)

Key causes include:(2)

- **COPD Exacerbations:** Acute worsening of COPD, often triggered by infections, causes severe airway narrowing that obstructs airflow.
- **Obesity Hypoventilation Syndrome:** The mechanical load from severe obesity restricts chest wall movement, leading to reduced lung capacity and shallow breathing.
- **Neuromuscular Disorders:** Conditions like myasthenia gravis and ALS progressively weaken the respiratory muscles, impairing their ability to ventilate the lungs.
- **Chest Wall Deformities:** Skeletal issues such as severe scoliosis physically limit the chest's ability to expand, thereby restricting lung volume.

Recognizing the clinical signs labored breathing, confusion, and cyanosis is crucial, as untreated Type 2 respiratory failure can rapidly progress to multi-organ collapse.

NON-INVASIVE VENTILATION

Non-invasive ventilation is a method for respiratory assistance that does not require endotracheal tube placement. The medical technique of NIV has grown essential for treating patients with acute respiratory failure together with chronic respiratory disease management. Patients with chronic obstructive pulmonary disease exacerbations along with acute cardiogenic pulmonary edema and immunocompromised individuals receive NIV treatment to prevent intubation.(3) The primary technique includes continuous positive airway pressure together with bilevel pressure support ventilation and high-flow nasal cannula. Noninvasive ventilation provides multiple benefits when compared to invasive ventilation methods because it enhances patient comfort while maintaining speech and swallowing abilities and minimizes potential complications.(7)

Key mechanisms include:(8)

- **Pressure support ventilation:** Delivers higher inspiratory pressure (IPAP) and lower expiratory pressure (EPAP), reducing the work of breathing.
- **Improved gas exchange:** Enhances alveolar ventilation and oxygen delivery while reducing CO_2 retention.
- **Avoidance of intubation:** Reduces risks such as ventilator-associated pneumonia, airway trauma, and prolonged ICU stays.

The management of several hypercapnic respiratory conditions heavily relies on NIV which has gained widespread acceptance through increasing research evidence. The most substantial benefit of this approach leads to decreased death rates together with reduced complication rates.(9) The delivery of proper ventilatory support through non-invasive means leads to reduced complications and quicker patient recovery compared to invasive ventilation. NIV stands as a crucial initial treatment approach for multiple acute and chronic respiratory conditions. Non-invasive ventilation offers a major advantage by minimizing the requirement for invasive mechanical ventilation which poses higher dangers of infections together with airway injuries and extended recovery durations. (8) By avoiding intubation, patients maintain their natural airway defenses, which helps reduce complications such as ventilator-associated pneumonia.(10) Moreover, patients using NIV can still communicate, eat, and drink, making the therapy more comfortable and preserving overall quality of life, particularly in those requiring long-term support.

The healthcare system benefits from substantial operational and financial advantages when using NIV as a treatment approach. The use of NIV for patients results in both reduced hospital duration and decreased healthcare expenses.(9) Hospitals gain financial advantages from this approach while patients together with their families experience decreased expenses. Patients who use NIV continuously benefit from enhanced long-term results and better comfort levels which lead to improved independence and daily life quality. The combination of clinical effectiveness, patient comfort and cost-effectiveness makes NIV the preferred treatment choice for relevant respiratory care situations. (11)

REQUISITES OF NIV

Before initiating noninvasive ventilation (NIV), the decision must be guided by a careful assessment that combines the patient's clinical symptoms with their arterial blood gas (ABG) results. A key indicator confirming Type 2 respiratory failure is the presence of hypercapnia, which is identified on an ABG test by a partial pressure of carbon dioxide ($PaCO_2$) that is typically higher than 45 mmHg. The pH must reach at least 7.25 for NIV initiation although some guidelines permit starting NIV with pH values between 7.20 and 7.25 as long as proper patient monitoring exists; intubation becomes necessary when pH drops below 7.15. (12) The presence of mild to moderate hypoxemia with PaO_2 readings below 60 mmHg on room air does not exclude NIV treatment but severe or persistent hypoxemia demands immediate invasive support. The patient's clinical status should be evaluated together with ABG findings. Candidates for this treatment display respiratory distress through elevated work of breathing and usage of accessory muscles and breath rates exceeding 24 per minute yet they maintain cooperation and command-following abilities.(13) Factors associated with NIV success include lower mMRC grade, fewer hospitalizations, and higher BMI. (14)

Healthcare providers in resource-constrained areas like Nepal need to base their decisions about starting NIV primarily on clinical assessments instead of ABG analysis. When ABG analysis is not available, the medical team must conduct thorough evaluations of the patient's respiratory condition. Medical professionals should monitor increased breathing effort alongside visible accessory muscle engagement and measure respiratory rates that exceed 24 breaths per minute and assess dyspnea severity for their assessment of patients. The patient must be alert and cooperative and follow commands during NIV treatment because it needs patient participation for safe and effective operation. Observable clinical symptoms along with ABG values serve as practical substitutes for laboratory testing to help clinicians determine which patients should start NIV treatment and which patients need immediate referral to invasive support or early intervention.

RECENT ADVANCES IN PULMONOLOGY

Modern pulmonology combines technological advancements with data analysis and care that focuses on patients. The following list represents novel approaches:

Portable NIV Devices

The development of compact and lightweight devices with battery functionality now allows non-invasive ventilation to occur beyond hospital settings in home environments and while traveling. The advanced functionality of leak compensation along with automatic pressure adjustment enhances. (15)

High-Flow Nasal Cannula (HFNC)

The High-Flow Nasal Cannula administers warm moist oxygen in large volumes to improve both oxygen delivery and patient comfort and decrease dead space. The device serves best in cases of hypoxemic respiratory failure .(16)

Tele pulmonology and Remote Monitoring

Remote consultation platforms together with wearable devices enable persistent tracking of patients' respiratory parameters. Real-time data transmission enables healthcare teams to provide early interventions when patient conditions worsen.(17)

Artificial Intelligence and Predictive Analytics

The implementation of machine learning algorithms enables prediction of exacerbations and ventilator recommendations and patient triage assistance. Hospital systems achieve better efficiency and decision-making through AI tools embedded in their operations. (18)

Advanced Bronchoscopy and Imaging

The diagnostic accuracy for lung cancer and other pulmonary diseases improves with endobronchial ultrasound (EBUS) and robotic bronchoscopy. The tools function effectively together with 3D imaging and molecular diagnostics to advance precision medicine. (19)

Pulmonary Rehabilitation and Patient Education

Long-term outcomes of chronic lung disease patients improve through rehabilitation programs which include exercise training alongside nutritional support as well as psychological care. Patients who learn proper inhaler use and medication adherence and recognition of symptoms reduces readmissions. (20)

IMPROVED ACCESS TO PULMONOLOGY SERVICES

Improving access to specialized pulmonology care is fundamental to achieving better respiratory health outcomes. This requires a multi-faceted approach centered on bridging existing healthcare gaps. At the core of this strategy are specialized critical care centers, which act as hubs equipped with essential technologies like NIV, HFNC, and advanced diagnostics. (21)To extend their reach and effectiveness, several key initiatives are crucial:

- Professional Development: Continuous training for clinicians and nurses through hands-on workshops.
- Community Outreach: Proactive screening programs to identify at-risk individuals early.
- Telemedicine: Leveraging technology to overcome geographical barriers and provide consultations to patients in remote areas.
- Lastly, supportive government policies and full insurance coverage that make this advanced care affordable for patients are necessary for it to be sustainable and available. By combining these efforts, we can make sure that help comes quickly, reduce problems, and ultimately raise the chances of survival.

CRITICAL CARE AS A BACKBONE

Advanced respiratory care depends on critical care centers to provide specialized facilities and expert personnel who handle complicated cases. The treatment delivery in these centers depends on multidisciplinary teams which include pulmonologists and intensivists along with respiratory therapists and dietitians and rehabilitation specialists. (22,23) These centers provide 24-hour patient surveillance for timely interventions together with standardized evidence-based protocols to enhance care consistency while conducting clinical trials to maintain practice currency. The program includes both rehabilitation services and follow-up care which aim to achieve sustained recovery and protect against repeated incidents. NIV in critical care will advance through new interface technology and better patient-ventilator interaction and expanded studies on its use for acute hypoxemic respiratory failure. (24)

IMPACT ON MORBIDITY AND MORTALITY

The combination of NIV with advanced pulmonology services produces noticeable improvements in clinical outcomes. According to an updated Cochrane review NIV treatment lowered hospital death rates by 46% and decreased intubation procedures by 64% relative to standard care practices.(25)Patient-centric approaches which unite technology with education alongside follow-up mechanisms guarantee enduring advantages. Patients experience better quality of life through successful chronic condition management supported by healthcare systems that provide accessible care.

PRAGMATIC CLINICAL PATHWAY IN RURAL NEPAL

While ABG analysis remains the global gold standard for initiating NIV, its availability in rural Nepal is limited due to cost, infrastructure, and training constraints. In such contexts, a clinical-first pathway offers a practical and evidence-based alternative. This approach relies on bedside indicators such as respiratory rate (>25 breaths/min), use of accessory muscles, and patient cooperation, supplemented by simple non-invasive measures like the SpO_2/FiO_2 ratio and indices such as ROX. (26–29)Authors experiences from Tribhuvan University Teaching Hospital suggest that early initiation of NIV based on these parameters can stabilize patients, prevent progression to intubation, and improve survival even without ABG confirmation. This pragmatic model not only democratizes access to life-saving therapy in underserved regions but also provides a replicable framework for other low-resource settings worldwide. However, while this clinical-first approach shows immense promise, rigorous validation through randomized controlled trials is essential to formally establish its efficacy and safety compared to the gold standard.

CONCLUSION

Noninvasive ventilation serves as a life-changing treatment approach for hypercapnic respiratory failure which avoids invasive support. Research consistently demonstrates that noninvasive ventilation lowers patient death rates and decreases both intubation needs and hospital durations. The paper highlights the critical value of complete evaluation which combines ABG measurements with clinical observations when ABG is unavailable and discusses the significance of portable devices together with telemedicine and prediction systems. The widespread availability of these benefits depends on critical care center expansion combined with training programs and supportive policies to reach patients in all geographic areas including remote locations. The advancement of medical care will stem from uniting multidisciplinary approaches with continuous research and artificial intelligence developments which enhance patient selection methods and outcome improvement strategies.

ACKNOWLEDGEMENT

None

CONFLICT OF INTEREST

None

FUNDING

This study was funded with the authors' own contributions.

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