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Noninvasive Ventilation in respiratory therapy

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Abstract
Noninvasive ventilation (NIV) has become a cornerstone in respiratory therapy, providing ventilatory support without the need for invasive procedures. Initially developed to address chronic respiratory conditions such as neuromuscular disorders and obesity hypoventilation syndrome, NIV has evolved into a critical intervention for both chronic and acute respiratory insufficiencies. Its applications in managing conditions like chronic obstructive pulmonary disease (COPD), acute respiratory failure, and severe hypoxemia have yielded significant clinical benefits, including enhanced oxygenation, reduced hospital admissions, and improved quality of life. Technological advancements, such as adaptive algorithms and patient-friendly interfaces like nasal masks, face masks, helmet systems, and total face masks, have expanded its utility in both hospital and home settings. However, challenges persist, including patient adherence, mask discomfort, and the need for standardized guidelines and training. This review explores the applications, benefits, limitations, and innovations in NIV, highlighting its transformative role in modern respiratory care and its potential to further enhance patient outcomes through ongoing research and technological development.
Keywords: Noninvasive ventilation, chronic respiratory insufficiency, acute respiratory failure, positive airway pressure, respiratory therapy, COPD, mechanical ventilation, NIV interfaces, helmet system, total face mask, chronic hypoxemia.

1. Introduction

Mechanical ventilation is a fundamental component of modern respiratory care, providing essential support to patients with compromised breathing function. Noninvasive ventilation (NIV) represents a significant advancement within this field, offering effective ventilatory assistance without the need for invasive procedures such as endotracheal intubation or tracheostomy. This approach enhances patient comfort, reduces the risk of complications associated with invasive methods, and allows for broader applications in managing respiratory conditions.

Historically, NIV was initially utilized in the treatment of neuromuscular disorders, tuberculosis sequelae, and obesity hypoventilation syndrome. Its evolution has been shaped by advancements in technology, particularly the introduction of continuous positive airway pressure (CPAP) systems and bi-level positive airway pressure (BiPAP) devices. These innovations have paved the way for the widespread adoption of NIV in both acute and chronic respiratory insufficiency.

In chronic settings, NIV has demonstrated efficacy in improving gas exchange, reducing symptoms, and enhancing quality of life for patients with conditions such as chronic obstructive pulmonary disease (COPD) and neuromuscular disorders. In acute scenarios, such as exacerbations of COPD or hypoxemic respiratory failure, NIV has proven instrumental in reducing hospital mortality rates and the need for invasive ventilation.

This paper aims to explore the applications, benefits, and challenges of NIV in respiratory therapy. By examining its role in chronic and acute care, the development of various interfaces, and the integration of advanced technologies, this review highlights the transformative impact of NIV on respiratory medicine and its potential for further innovation in improving patient outcomes.

2. NIV in Chronic Respiratory Insufficiency

Noninvasive ventilation (NIV) plays a crucial role in managing chronic respiratory insufficiency, particularly in conditions like chronic obstructive pulmonary disease (COPD), obesity hypoventilation syndrome (OHS), and neuromuscular disorders. It addresses chronic hypercapnic respiratory failure (CHRF) by reducing elevated arterial carbon dioxide levels ($PaCO_2$) and improving oxygenation during sleep. This leads to better symptom control, reduced exacerbation frequency, and a significant decrease in hospital admissions, thereby improving patient survival and quality of life(5).

In COPD, NIV enhances breathing mechanics, reduces the work of breathing, and minimizes hypercapnia. High-intensity NIV targeting normocapnia has been shown to outperform traditional low-intensity modes in improving clinical outcomes. In OHS, it helps correct chronic alveolar hypoventilation, reducing risks of cardiovascular complications such as pulmonary hypertension. For neuromuscular disorders like ALS or Duchenne muscular dystrophy, NIV supports respiratory function and prolongs survival while delaying the need for invasive interventions(6).

Technological advancements in NIV, including adaptive algorithms and portable ventilators, have facilitated its use in home settings. Integration with telemonitoring allows real-time adjustments, enhancing patient safety and compliance. Despite its benefits, challenges like mask discomfort and patient adherence persist. Innovations such as improved mask designs and humidification systems have made significant strides in addressing these issues. Ultimately, NIV not only stabilizes respiratory function but also improves sleep quality and psychological well-being, highlighting its holistic impact on chronic respiratory insufficiency management(7).

3. NIV in Acute Respiratory Insufficiency

Noninvasive ventilation (NIV) is an essential intervention in managing acute respiratory insufficiency, particularly in conditions like chronic obstructive pulmonary disease (COPD) exacerbations, acute cardiogenic pulmonary edema, and severe hypoxemic respiratory failure. Its role is to provide ventilatory support without the need for endotracheal intubation, reducing complications such as ventilator-associated pneumonia and improving patient outcomes(8).

In cases of acute hypercapnic respiratory failure, particularly in COPD exacerbations, NIV has demonstrated significant effectiveness. It improves gas exchange, reduces work of breathing, and decreases mortality. Studies show that NIV initiation in hypercapnic patients often leads to rapid correction of arterial pH and partial pressure of carbon dioxide ($PaCO_2$) levels. Adherence to NIV guidelines correlates with better clinical outcomes, including lower hospital mortality rates and reduced need for invasive ventilation interventions(9).

For acute hypoxemic respiratory failure, such as in severe COVID-19 pneumonia, NIV has been employed as an alternative or bridge to intubation. Research indicates that using NIV can reduce ICU admissions and mortality rates in patients with a PaO_2/FiO_2 ratio indicative of severe hypoxemia. However, patient selection and careful monitoring are critical to preventing NIV failure, which can delay intubation and worsen outcomes(10).

Optimal use of NIV requires proper patient selection, device settings, and monitoring. Indications include severe respiratory distress with preserved consciousness, hemodynamic stability, and the ability to protect the airway. Common settings involve applying bi-level positive airway pressure (BiPAP) to support ventilation. Close observation is necessary to assess treatment success and avoid complications such as aspiration or skin injury from masks (11).

Despite its benefits, the success of NIV is influenced by patient factors, healthcare provider expertise, and adherence to guidelines. Challenges include identifying predictors of NIV success or failure, managing resource constraints, and ensuring standardized training across healthcare centers. Future research should explore advanced technologies, such as real-time monitoring tools and machine learning algorithms, to improve NIV application and outcomes.By effectively managing acute respiratory insufficiency through timely and appropriate NIV application, healthcare providers can significantly enhance patient recovery and reduce healthcare burdens(12).

4. NIV Interfaces and Respirators

Noninvasive ventilation (NIV) interfaces serve as the connection between the ventilator and the patient, ensuring effective delivery of air or oxygen. The choice of interface significantly impacts the success of NIV therapy, affecting patient comfort, gas exchange, and overall compliance. Commonly used interfaces include nasal masks, face masks, total face masks, and helmet systems. Each has unique mechanisms, ideal applications, advantages, and disadvantages.

NIV Interfaces

Nasal masks are compact devices designed to cover the nose, delivering pressurized air or oxygen directly through the nostrils. These masks create a seal around the nose, allowing air to flow into the upper respiratory tract, which helps alleviate respiratory distress by improving oxygenation and ventilation. The device relies on the patient's ability to keep their mouth closed to prevent air leaks, making it ideal for cooperative patients who primarily breathe through their noses(13).

Nasal masks are commonly employed in conditions requiring low-to-moderate positive airway pressure, such as obstructive sleep apnea or mild chronic respiratory insufficiency. Proper fitting is crucial to ensure an airtight seal without causing discomfort or skin irritation. Flow and pressure settings should be adjusted to meet the patient's specific requirements while minimizing potential complications like air leaks or dryness(14).

One of the primary advantages of nasal masks is their comfort and reduced bulkiness compared to other interfaces. Their minimal design alleviates feelings of claustrophobia, making them more tolerable for patients during prolonged therapy sessions. Additionally, nasal masks allow for natural speaking, eating, and drinking, which enhances patient compliance and quality of life. They are particularly effective in managing conditions like sleep apnea or mild respiratory insufficiency, where less aggressive ventilation is sufficient(15).

However, nasal masks have limitations. The reliance on the patient maintaining a closed mouth can lead to air leaks, reducing the effectiveness of the therapy. Patients who habitually breathe through their mouths may require additional measures, such as a chin strap, to optimize therapy. Prolonged use can cause nasal dryness or irritation, which may necessitate the use of humidifiers or nasal saline sprays. Nasal masks are also less effective in severe respiratory failure where higher pressures and greater mask stability are needed(16).

Nasal masks represent a cornerstone in noninvasive ventilation therapy for patients requiring low-to-moderate respiratory support. Their comfort and convenience make them an excellent choice for specific clinical scenarios, but their effectiveness is contingent on proper patient selection and mask fitting. Regular assessment and adjustments ensure optimal therapeutic outcomes.

Nasal Mask

Face masks are one of the most widely used interfaces in noninvasive ventilation (NIV). They are designed to cover both the nose and mouth, forming a sealed interface that ensures pressurized air is effectively delivered into the upper respiratory tract. This type of mask is particularly suitable for patients who are unable to maintain nasal breathing or tend to breathe through their mouths. The secure seal provided by face masks minimizes air leaks, which is critical for maintaining consistent ventilation pressure(17).

Face masks are commonly used in patients experiencing moderate-to-severe respiratory insufficiency, such as acute exacerbations of chronic obstructive pulmonary disease (COPD), cardiogenic pulmonary edema, or hypoxemic respiratory failure. The ideal parameters for using face masks include pressure settings tailored to the patient's needs, typically ranging from 10–20 cm H_2O for bilevel positive airway pressure (BiPAP). Proper fitting and positioning of the mask are essential to optimize performance and minimize air leaks or skin irritation. High-flow oxygen or pressure support can also be delivered through face masks, depending on the patient's requirements(18).

One of the key benefits of face masks is their versatility in managing a wide range of respiratory conditions. By covering both the nose and mouth, these masks are effective in preventing air leaks, especially in patients who breathe predominantly through their mouths. This feature makes them ideal for delivering higher pressures needed for severe respiratory distress. Face masks are also more stable than nasal masks in cases where higher pressures are required, as the dual-coverage design ensures consistent pressure delivery. They are readily available in various sizes, enabling customization to suit individual patient anatomy(19).

Despite their effectiveness, face masks have notable drawbacks. Their larger size and coverage can make them uncomfortable for some patients, especially during prolonged use. The mask's tight fit, required to maintain a proper seal, may lead to pressure sores, facial irritation, or skin breakdown over time. Additionally, the full-face design can increase feelings of claustrophobia, particularly in anxious patients. Communication, eating, and drinking are also hindered, as patients must remove the mask for these activities. Furthermore, poorly fitted masks may result in air leaks, compromising therapy effectiveness and increasing the risk of ventilator asynchrony(20).

Face masks play a critical role in noninvasive ventilation, particularly for patients requiring moderate to high ventilatory support. Their effectiveness in preventing air leaks and delivering higher pressures makes them a preferred option for acute respiratory conditions. However, careful selection, fitting, and monitoring are crucial to address the potential discomfort and complications associated with their use. Balancing these factors can ensure optimal therapeutic outcomes while maintaining patient comfort and adherence to treatment.

Face Mask

Face masks are a primary interface used in noninvasive ventilation (NIV), covering both the nose and mouth to deliver pressurized air or oxygen. Their design creates a secure seal over the mid-face region, ensuring consistent airflow and effective ventilatory support. This interface is particularly suited for patients who are unable to maintain exclusive nasal breathing, such as those with nasal obstruction or mouth-breathing tendencies. The mask allows positive airway pressure (PAP) to improve ventilation and oxygenation while reducing the effort required for breathing(21).

Face masks are commonly employed in conditions requiring moderate to high ventilatory support, such as acute exacerbations of chronic obstructive pulmonary disease (COPD), acute cardiogenic pulmonary edema, or hypoxemic respiratory failure. Pressure settings typically range from 10–25 cm H_2O for bilevel positive airway pressure (BiPAP) to maintain effective ventilation. Oxygen supplementation can be adjusted based on the patient's arterial oxygen saturation (SpO_2) or partial pressure of oxygen (PaO_2) levels. Proper mask fitting is critical to minimize air leaks and ensure the efficacy of the therapy. Masks are available in various sizes to accommodate different facial anatomies, and adjustable straps aid in achieving a secure yet comfortable fit(22).

The dual-coverage design of face masks provides several benefits, particularly in preventing air leaks that are more common with nasal masks. This makes face masks an excellent choice for patients who breathe through their mouths or require higher pressure settings. Their versatility allows their use in a variety of respiratory conditions, ranging from acute hypercapnic to hypoxemic failure. Studies have shown that the use of face masks in acute COPD exacerbations significantly reduces the need for invasive mechanical ventilation, lowers hospital mortality, and shortens ICU stays (European Respiratory Journal, 2023). Additionally, they are easily available and adaptable for use in home or hospital settings, making them a practical choice for both acute and chronic management(23).

Despite their efficacy, face masks are associated with certain challenges. Their larger coverage area can cause discomfort, particularly during prolonged use. Patients may experience pressure-related skin injuries, such as sores or irritation, especially around the nasal bridge or cheeks. The tight seal required for effective therapy can also increase feelings of claustrophobia, particularly in anxious individuals. Moreover, face masks interfere with oral intake, requiring the mask to be removed for eating, drinking, or taking oral medications, which may disrupt ventilation. Air leaks, though less common than with nasal masks, can still occur if the mask is improperly fitted, leading to decreased therapeutic effectiveness and increased risk of ventilator asynchrony(24).

Face masks remain a cornerstone in noninvasive ventilation due to their effectiveness in delivering higher pressures and preventing air leaks. Their ability to address both hypercapnic and hypoxemic respiratory failure makes them a versatile option in acute care. However, their success depends heavily on proper fitting, regular monitoring, and addressing patient comfort issues. With advancements in mask design and material, many of the associated challenges can be mitigated, ensuring a more positive experience for patients and improved clinical outcomes.

Total Face Mask

Total face masks are specialized interfaces designed to cover the entire face, including the eyes, nose, and mouth. Unlike nasal or traditional face masks, which target specific regions, total face masks provide a comprehensive seal around the perimeter of the face. This design minimizes air leaks and ensures consistent delivery of positive airway pressure (PAP). The mask's larger surface area helps distribute pressure evenly, reducing localized pressure points that can lead to skin breakdown. These masks are particularly beneficial for patients experiencing severe respiratory insufficiency or those who struggle with traditional interfaces due to facial anatomical challenges or discomfort(25).

Total face masks are used in a range of clinical scenarios, often in cases of acute respiratory failure requiring noninvasive positive pressure ventilation (NPPV). Pressure settings typically depend on the patient's condition, with common bilevel positive airway pressure (BiPAP) parameters ranging between 10–25 cm H_2O. Humidification is often integrated to counteract dryness caused by prolonged use. The mask must be fitted correctly to ensure a secure seal without causing discomfort, as poor fitting can lead to air leaks or suboptimal ventilation. Its transparent design allows healthcare providers to monitor for skin discoloration or other signs of distress(26).

One of the key benefits of total face masks is their ability to eliminate pressure points around the nose and mouth, making them ideal for patients who develop skin ulcers with smaller interfaces. Their comprehensive coverage reduces the risk of air leaks, even at higher pressure settings, ensuring effective ventilation. Additionally, they are highly effective for patients with unique facial structures, such as those with facial deformities, facial hair, or dental irregularities, which can interfere with the seal of traditional masks. The transparent design allows for better patient monitoring and communication, which can help reduce feelings of claustrophobia or isolation(27).

Despite their advantages, total face masks come with limitations. The larger size and coverage can make them less comfortable, particularly during prolonged use. They may cause fogging, which can obscure the patient's vision and increase discomfort. Furthermore, the mask can interfere with essential activities like eating, drinking, or verbal communication, necessitating frequent removal that may disrupt ventilation. There is also an increased risk of conjunctival irritation due to airflow exposure near the eyes, although this can be mitigated with proper humidification and fitting. Additionally, total face masks are less portable and may require more training for proper application compared to simpler designs(28).

Total face masks are a valuable tool in noninvasive ventilation, offering a solution for patients who cannot tolerate or benefit from smaller interfaces. Their ability to deliver effective ventilation while minimizing air leaks makes them a critical option in cases of severe respiratory distress or complex anatomical challenges. However, their use requires careful fitting, monitoring, and patient education to ensure optimal comfort and therapeutic outcomes. As designs continue to improve, total face masks are likely to become even more effective and patient-friendly.

The Helmet System

The helmet system is an alternative noninvasive interface used in respiratory therapy, designed to cover the entire head, similar to a full-face mask, but with a greater emphasis on providing a sealed environment for positive pressure ventilation. Unlike traditional face masks or total face masks, the helmet is a larger, more enclosed structure that creates a tight seal around the neck and shoulders, with the head remaining inside(11). This system works by delivering positive pressure airflow into the helmet, which is then distributed throughout the head and upper airways. It is typically used to treat patients with acute respiratory failure, such as those suffering from chronic obstructive pulmonary disease (COPD) exacerbations, acute respiratory distress syndrome (ARDS), or hypoxemic respiratory failure. The helmet provides continuous positive airway pressure (CPAP) or bilevel positive airway pressure (BiPAP), allowing the patient to breathe more easily while avoiding the need for invasive mechanical ventilation(29).

The helmet system is generally utilized in patients who require high levels of respiratory support but need to avoid invasive ventilation. Pressure settings vary depending on the severity of the condition, typically ranging from 8–20 cm H_2O for CPAP and up to 25 cm H_2O for BiPAP. The settings are adjusted based on the patient's clinical condition, with the goal of improving oxygenation and reducing the work of breathing. The helmet system has the advantage of offering full-face coverage without the discomfort of traditional face masks, and it provides a constant seal, which minimizes air leaks. In terms of ventilation parameters, respiratory rates, and inspiratory pressures can be adjusted to match the patient's specific requirements, ensuring that the therapeutic goals are met effectively(30).

The helmet system offers several significant advantages over other noninvasive interfaces. One of its primary benefits is that it reduces the risk of skin breakdown and discomfort, which can occur with nasal or face masks. Since the helmet does not apply pressure to the facial skin, it is less likely to cause pressure sores around the nose, chin, or cheeks, making it a more comfortable option for long-term use. Additionally, the helmet system can provide consistent ventilation even during higher levels of pressure support, which is crucial for patients with severe respiratory insufficiency. The helmet's design also allows patients to communicate and even eat or drink without needing to remove the device, as it does not obstruct the mouth or nose in the same way that full-face masks do. Furthermore, the helmet system is effective in preventing the discomfort associated with claustrophobia, which may be a concern for some patients using traditional masks(31).

While the helmet system offers significant benefits, it also has its limitations. One challenge is the potential for discomfort due to the device's large size and the need to ensure a secure, airtight seal. Poor fitting of the helmet can lead to leaks, which diminish its effectiveness and increase the risk of respiratory complications. The system also requires more space than other noninvasive interfaces, which may make it cumbersome for use in certain settings, particularly in smaller hospital rooms or during transport. Additionally, the helmet can create a humidified environment that may lead to discomfort, moisture buildup, or even increased work of breathing if not properly managed. Despite its advantages, the helmet is often seen as more complicated and less user-friendly compared to simpler interfaces like nasal or face masks(32).

The helmet system is an innovative and valuable tool in noninvasive ventilation, offering a more comfortable and effective option for patients requiring high levels of ventilatory support. Its ability to reduce facial discomfort and skin breakdown makes it particularly beneficial for patients who are intolerant to traditional masks. However, its larger size and the potential for issues with sealing and humidity management require careful consideration and monitoring. As advances in helmet design continue, this system is likely to become an increasingly important option for managing acute respiratory failure and minimizing the need for invasive mechanical ventilation. Regular patient assessment and fitting adjustments are essential to ensure optimal performance and therapeutic outcomes.

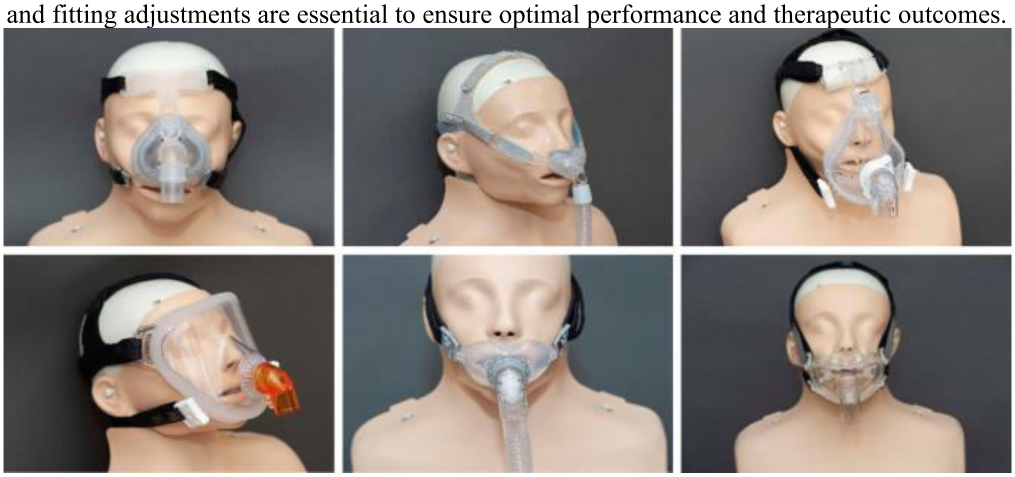

Figure 1: Interfaces for noninvasive ventilation. Top (left to right): nasal mask, nasal pillows, oronasal mask. Bottom (left to right): total face mask, oral mask, hybrid mask (33).

5. Conclusion

Noninvasive ventilation (NIV) has emerged as a cornerstone in modern respiratory care, offering a less invasive and more patient-friendly approach to ventilatory support. Its application in both chronic and acute respiratory insufficiency has significantly improved patient outcomes, reducing mortality, morbidity, and the need for invasive mechanical ventilation.

The versatility of NIV, coupled with advancements in technology and interface design, has broadened its therapeutic range. Nasal masks, face masks, total face masks, and helmet systems provide tailored solutions for various patient needs, enhancing comfort and compliance. However, challenges such as mask-related discomfort, patient adherence, and proper application remain critical areas for optimization.

Future research should focus on developing innovative interfaces, refining patient selection criteria, and exploring new strategies to improve adherence. By addressing these challenges and continuing to expand its applications, NIV has the potential to revolutionize respiratory care, transforming patient outcomes and enhancing quality of life.

References

(1) Navarra SM, Congedo MT, Pennisi MA. Indications for non-invasive ventilation in respiratory failure. Reviews on recent clinical trials. 2020 Dec 1;15(4):251-7.

(2) Popowicz P, Leonard K. Noninvasive ventilation and oxygenation strategies. The Surgical Clinics of North America. 2021 Nov 18;102(1):149.

(3) Windisch W, Weber-Carstens S, Kluge S, Rossaint R, Welte T, Karagiannidis C. Invasive and non-invasive ventilation in patients with COVID-19. DeutschesÄrzteblatt International. 2020 Aug;117(31-32):528.

(4) Chawla R, Dixit SB, Zirpe KG, Chaudhry D, Khilnani GC, Mehta Y, Khatib KI, Jagiasi BG, Chanchalani G, Mishra RC, Samavedam S. ISCCM guidelines for the use of non-invasive ventilation in acute respiratory failure in adult ICUs. Indian journal of critical care medicine: peer-reviewed, official publication of Indian Society of Critical Care Medicine. 2020 Jan;24(Suppl 1):S61.

(5) Yüksel A, Çiftçi F, Çiledağ A, Kaya A. The effects of home noninvasive ventilation on the quality of life and physiological parameters of patients with chronic respiratory failure. The Clinical Respiratory Journal. 2020 Sep;14(9):880-8.

(6) Duiverman ML, Vonk JM, Bladder G, van Melle JP, Nieuwenhuis J, Hazenberg A, Kerstjens HA, van Boven JF, Wijkstra PJ. Home initiation of chronic non-invasive ventilation in COPD patients with chronic hypercapnic respiratory failure: a randomised controlled trial. Thorax. 2020 Mar 1;75(3):244-52.

(7) Coleman JM, Gates KL, Kalhan R. Home noninvasive ventilation for patients with chronic obstructive pulmonary disease and chronic respiratory failure. JAMA. 2020 Feb 4;323(5):421-2.

(8) Lima CT, dos Santos Vasconcelos R, Pontes SM, Junior AA, Magalhã R. Noninvasive Ventilation Interfaces in the Treatment of Acute Respiratory Insufficiency: A Critical Review. Open Journal of Emergency Medicine. 2024 Jul 30;12(3):95-103.

(9) Nogueira AN, Lima CT, dos Santos Vasconcelos R, Pontes SM, Junior AA, Junior RM. Noninvasive Ventilation Interfaces in the Treatment of Acute Respiratory Insufficiency: A Critical Review.

(10) Jacinto MA, Reis C, Leite T, Fonseca C. Respiratory Rehabilitation Gains in People With Respiratory Insufficiency Submitted to Noninvasive Ventilation: Systematic Review of Literature. Noninvasive Ventilation Technologies and Healthcare for Geriatric Patients. 2020:1-9.

(11) Rosà T, Menga LS, Tejpal A, Cesarano M, Michi T, Sklar MC, Grieco DL. Non-invasive ventilation for acute hypoxemic respiratory failure, including COVID-19. Journal of Intensive Medicine. 2023 Jan 25;3(01):11-9.

(12) Chen TH, Hsu JH. Noninvasive ventilation and mechanical insufflator-exsufflator for acute respiratory failure in children with neuromuscular disorders. Frontiers in Pediatrics. 2020 Oct 30;8:593282.

(13) Pierucci P, Portacci A, Carpagnano GE, Banfi P, Crimi C, Misseri G, Gregoretti C. The right interface for the right patient in noninvasive ventilation: A systematic review. Expert Review of Respiratory Medicine. 2022 Aug 3;16(8):931-44.

(14) Scala R, Accurso G, Ippolito M, Cortegiani A, Iozzo P, Vitale F, Guidelli L, Gregoretti C. Material and technology: back to the future for the choice of interface for non-invasive ventilation–a concise review. Respiration. 2020 Dec 8;99(9):800-17.

(15) Léotard A, Lebret M, Daabek N, Prigent H, Destors M, Saint-Raymond C, Sagniez A, Leroux K, Tamisier R, Lofaso F, Pépin JL. Impact of interface type on noninvasive ventilation efficacy in patients with neuromuscular disease: a randomized cross-over trial. Archivos de Bronconeumología. 2021 Apr 1;57(4):273-80.

(16) Alhamad BR. The Mask Interface Designs. InUpper Airway Disorders and Noninvasive Mechanical Ventilation: Rationale and Approaches 2023 Aug 26 (pp. 83-95). Cham: Springer International Publishing.

(17) Majorski DS, Callegari JC, Schwarz SB, Magnet FS, Majorski R, Storre JH, Schmoor C, Windisch W. Oronasal versus nasal masks for non-invasive ventilation in COPD: a randomized crossover trial. International Journal of Chronic Obstructive Pulmonary Disease. 2021 Mar 26:771-81.
(18) Khirani S, Ducrot V. Mask interfaces and devices for home noninvasive ventilation in children. Pediatric Pulmonology. 2024 Mar 28.
(19) Li LL, Dai B, Lu J, Li XY. Effect of different interfaces on FIO2 and CO2 rebreathing during noninvasive ventilation. Respiratory Care. 2021 Jan 1;66(1):25-32.
(20) Todur P, Nileshwar A. NIV in High-Risk Infections, Mass Casualty, and Pandemics: What Interface?.InNoninvasive Mechanical Ventilation in High Risk Infections, Mass Casualty and Pandemics 2023 Jul 5 (pp. 109-117). Cham: Springer International Publishing.
(21) Vasconcelos RS, Nogueira AN, Montenegro Junior RM, Peixoto Junior AA, Ferreira LA, Sousa CE, Ricca DE, da Silveira JA, Ribeiro FC, Cavalcanti FR, Lobo Filho JG. A New Full-Face Mask for Multifunctional Non-Invasive Ventilation. Medicina. 2023 Aug 2;59(8):1410.
(22)Gupta PP. Choosing Appropriate Interface for Non-Invasive Ventilators. United Academy of Pulmonary Medicine Journal of Respiratory Diseases and Allied Sciences. 2021 Aug 30;1(02):95-.
(23)Tatham KC, Ko M, Palozzi L, Lapinsky SE, Brochard LJ, Goligher EC. Helmet interface increases lung volumes at equivalent ventilator pressures compared to the face mask interface during non-invasive ventilation. Critical Care. 2020 Dec;24:1-3.
(24)Cui X, Jung H, Lee W, Kim SH, Yun RY, Kim SY, You H, Huh S. Ergonomics and personalization of noninvasive ventilation masks. Respiratory Care. 2022 Jan 1;67(1):87-101.
(25) Ferrone G, Spinazzola G, Costa R, Piastra M, Maresca G, Antonelli M, Conti G. Influence of total face masks design and circuit on synchrony and performance during pressure support ventilation: a bench study. Respiratory Medicine and Research. 2022 Nov 1;82:100963.
(26) Minami T, Kai S, Tanaka T, Ito I, Kato G, Nagao M, Date H, Hirai T, Ohtsuru S, Chin K. Non-invasive ventilation using a novel ventilator and non-vented full-face mask for patients with respiratory failure during the COVID-19 pandemic: report of three cases. Respiratory Investigation. 2022 Jul 1;60(4):607-11.
(27) Cousin VL, Corbisier T, Rimensberger PC, Polito A, Bordessoule A. Total face mask with neurally adjusted ventilatory assist as a rescue therapy in infants with severe bronchiolitis. European Journal of Pediatrics. 2024 Apr 6:1-5.
(28) Lemyze M, Mallat J, Vangrunderbeek N, Granier M. Under-The-Nose Versus Over-The-Nose Face Mask to Prevent Facial Pressure Sores During Face Mask-Delivered Noninvasive Ventilation for Acute Hypercapnic Respiratory Failure: A Randomized Controlled Trial. Critical Care Medicine. 2023 Sep 1;51(9):1177-84.
(29) Bongiovanni F, Grieco DL, Anzellotti GM, Menga LS, Michi T, Cesarano M, Raggi V, De Bartolomeo C, Mura B, Mercurio G, D'Arrigo S. Gas conditioning during helmet noninvasive ventilation: effect on comfort, gas exchange, inspiratory effort, transpulmonary pressure and patient–ventilator interaction. Annals of Intensive Care. 2021 Dec 24;11(1):184.
(30) Grieco DL, Patel BK, Antonelli M. Helmet noninvasive support in hypoxemic respiratory failure. Intensive Care Medicine. 2022 Aug;48(8):1072-5.
(31) Menga LS, DelleCese L, Rosà T, Cesarano M, Scarascia R, Michi T, Biasucci DG, Ruggiero E, Dell'Anna AM, Cutuli SL, Tanzarella ES. Respective effects of helmet pressure support, continuous positive airway pressure, and nasal high-flow in hypoxemic respiratory failure: a randomized crossover clinical trial. American Journal of Respiratory and Critical Care Medicine. 2023 May 15;207(10):1310-23.
(32) Gil A, Martínez M, Quintero P, Medina A. Computational evaluation of rebreathing and effective dead space on a helmet-like interface during the COVID-19 pandemic. Journal of Biomechanics. 2021 Mar 30;118:110302.
(33) Obi J, Pastores SM. Discomfort and Adaptation. Mask Interface Problems. In: Springer eBooks [Internet]. 2022. p. 35–45. Available from: https://doi.org/10.1007/978-3-030-71298-3_5