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Consequences and Solutions for the Impact of Communication Impairment on Noninvasive Ventilation Therapy for Acute Respiratory Failure: A Focused Review

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Objectives: With over 2 million cases of acute respiratory failure in the United States per year, noninvasive ventilation has become a leading treatment modality, often supplanting invasive mechanical ventilation as the initial treatment of choice. Most acute respiratory failure patients use a full face (oronasal) mask with noninvasive ventilation, which is known to impair communication, but its popularity and benefit has led many providers to accept the communication impairment. Medical staff periodically remove masks to communicate with patients, but patients are often limited to short utterances and risk lung derecruitment upon removal of positive pressure. These problems can lead to noninvasive ventilation failure, which is often linked to worse outcomes than first initiating invasive mechanical ventilation and can lead to increased hospitalization costs.

Data Sources: We searched MEDLINE and Google Scholar for “speech,” “communication,” “impairment,” “failure,” “complications,” “NIPPV,” “NIV,” and “noninvasive ventilation.”

Study Selection: We included articles with patients in acute respiratory failure. We excluded articles for patients using noninvasive ventilation therapy for obstructive sleep apnea.

Data Synthesis: Communication impairment has been associated with increasing noninvasive ventilation anxiety (odds ratio, 1.25). Of

patients using noninvasive ventilation, 48% require early discontinuation, 22% refuse noninvasive ventilation, and 9% are ultimately intubated. Improvements to communication have been shown to reduce fear and anxiety in invasive mechanical ventilation patients. Analogous communication problems exist with effective solutions in other fields, such as fighter pilot masks, that can be easily implemented to enhance noninvasive ventilation patient care, increase adherence to noninvasive ventilation treatment, and improve patient outcomes.

Conclusions: Communication impairment is an underappreciated cause of noninvasive ventilation complications and failure and requires further characterization. Analogous solutions—such as throat microphones and mask-based microphones—that can be easily implemented show potential as cost-effective methods to reduce noninvasive ventilation failure.

Key Words: acute respiratory failure; communication difficulty; communication impairment; noninvasive ventilation; patient communication

With landmark trials demonstrating the efficacy of noninvasive ventilation (NIV) in cardiogenic pulmonary edema and acute exacerbations of chronic obstructive pulmonary disease, NIV has changed the standard of care for acute respiratory failure (ARF) and reduced the amount of invasive mechanical ventilation (IMV) being used (1–4). The rate of NIV use increased from 16% in 1997 to 37% in 2011 in France (5) and around the world (6). With 2 million cases of ARF per year in the United States and rising, the number of patients receiving NIV therapy has continued to increase.

In contrast to IMV, where an endotracheal tube prevents the direct passage of air past the vocal cords, NIV allows air to flow past the vocal cords, permitting phonation. Unlike IMV, NIV interfaces can be more easily removed and replaced. For patients receiving palliative care, intermittent NIV mask removal during

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NIV treatment (7) allows more effective communication than IMV (8–11). Classically, many providers of acute care for patients in respiratory failure do precisely this. However, mask removal can result in derecruitment, which is detrimental in ARF and may lead to further lung injury. The ideal solution would be a technique that allows maintenance of continuous NIV support while substantially reducing the communication impairment (CI) inherent in the use of current full face mask technology. This may result in a dilemma between allowing the patient to communicate or potentially worsening respiratory status with mask removal. CI—where speech is insufficient to meet all communication needs—resulting from the use of a full face mask is a widely known side effect of NIV and can lead to impaired patient care (12, 13).

To our knowledge, there has yet to be a thorough review of the literature to better our understanding of the current problems surrounding the CI associated with NIV therapy for ARF. As critical care has developed into an interdisciplinary field, it is important to recognize numerous perspectives, especially those from physicians, nurses, and speech language pathologists. Although this review is directed at critical care, emergency medicine, and internal medicine physicians and providers, it is intended to educate NIV treatment providers about the underappreciated consequences of CI and potential strategies for overcoming CI caused by NIV.

We searched MEDLINE and Google Scholar for “speech,” “communication,” “impairment,” “failure,” “complications,” “NIPPV,” “NIV,” and “noninvasive ventilation.” We included articles with patients in ARF and excluded articles for patients using NIV therapy for obstructive sleep apnea. Some studies from prolonged NIV in chronic respiratory failure are used to highlight complications from NIV CI. Through the course of this review, we will define CI, explore its consequences through IMV and NIV, and demonstrate methods by which verbal communication can be restored.

COMMUNICATION IMPAIRMENT

The American Speech-Language-Hearing Association defines severe CI as an acute speech pathology condition “where speech is temporarily or permanently inadequate to meet all of the individual’s communication needs, and the inability to speak is not due primarily to a hearing impairment.” (14) In the context of this article, we focus on severe CI and will refer to it as such thereafter.

CI can be broadly grouped into several etiologies, including: language (comprehension or production), motor (e.g., dysarthria), cognitive (e.g., aphasia), and acquired (e.g., device related, such as intubation) categories (15). Of these, dysarthria has a strong body of work in characterizing CI due to poststroke patients, which can help characterize other acquired CI etiologies.

In this review, we use NIV and IMV studies to examine the effects of CI on NIV distress, claustrophobia, fear, and anxiety—all of which are factors contributing to NIV intolerance and, consequently, NIV failure (16–19). Although treatment failure endpoints may differ between NIV and IMV, many similarities exist in IMV studies that can better inform our understanding of CI consequences (20).

METHODS TO CHARACTERIZE COMMUNICATION IMPAIRMENT

Characterizing the degree of CI is fundamental in understanding not only how communication is impaired in patients using NIV, but to devise methods to improve it. Unlike IMV, where patients are completely unable to phonate due to inability to use their larynx, NIV permits natural audible speech. However, the NIV mask alters speech transmission. Speech dysarthria can be similar, in that speech is audibly generated but is altered from baseline.

One of the many causes of CI is reduced intelligibility, or “how well a speaker’s acoustic signal can be accurately recovered by a listener.” (21) Nonverbal factors contribute to comprehension, including message length, predictability, context, listener relationship, and facial cues. Intelligibility can be measured in multiple ways. Most commonly, orthographic transcription of a speech sample, with transcription accuracy can be used as the metric. Additionally, intelligibility metrics should be context independent—it is important that sentence context does not heavily influence word and sentence recognition.

We propose the use of speech dysarthria metrics, such as the Assessment of Intelligibility of Dysarthric Speech (AIDS) published by Yorkston et al (22), to evaluate the CI inflicted by full face mask NIV. The AIDS tool is commonly used in stroke induced speech dysarthria, but has also been used in characterizing communication in alternative situations. Leder et al (23) used AIDS to assess vocal CI in tracheostomy patients. Rose et al (24) also used AIDS to evaluate intelligibility of electrolarynx-generated speech in IMV patients and found that improved communication was associated with significantly reduced anxiety ($p = 0.007$) (23).

COMMUNICATION IMPAIRMENT AND IMPACT IN IMV

Numerous studies describe CI resulting from IMV and how it contributes to fear (25, 26), anxiety (27, 28), anger (26, 29, 30), and distress (31, 32). Patak et al (33) surveyed 29 critically ill patients postextubation and found that 62% of IMV patients were frustrated and distressed at the inability to communicate. These data are corroborated by many other studies, such as Khalaila et al (26) and Rotondi et al (34), whose surveys of critically ill patients postextubation found CI was the most commonly remembered (92%, 78%) experience in IMV patients. Khalaila et al (26) and Rotondi et al (34) note that 80–90% of those patients were moderately to extremely bothered by the inability to speak. Khalaila et al (26) also demonstrated positive correlations between difficulty with communication and psychologic distress, fear, and anger ($p < 0.01$). Furthermore, the study by Menzel (35) study of 48 postextubation patients found that increased CI was correlated with more intense anger resulting from the inability to talk ($p < 0.001$).

These psychologic outcomes can have a clinical impact. Chen et al (36) found in 67 intubated patients that those experiencing anxiety and psychologic distress are 50% less likely to wean from IMV. Schmidt et al (37) and Persichini et al (38) both demonstrated that anxiety and dyspnea are highly correlated in groups of 96 and 220 patients, respectively. Dyspnea may, in fact, be underreported, as Persichini et al (38) also demonstrated that dyspnea can be hard to assess in verbal CI (38).

COMMUNICATION IMPAIRMENT AND IMPACT IN NIV

CI has also been associated with adverse consequences in NIV. Schmidt et al (20) conducted the PARVENIR study with 1,063 ICU physicians and nurses and 541 patients and relatives from 32 French ICUs. In patients undergoing NIV, there was a significant association between the inability to be understood and high patient anxiety ($p < 0.0001$), and between inability to be understood and a greater chance of feeling dyspneic (16% increase; $p = 0.001$). Relatives of patients undergoing NIV who were experiencing high anxiety also reported feeling that the patient was worried about not being understood ($p < 0.0007$). Furthermore, patients were 25% more likely to be anxious when relatives observed patients being misunderstood ($p < 0.001$).

Demoule et al (39) demonstrated that, in 54 Belgian and French ICUs, moderate to severe patient anxiety during NIV treatment is associated with 4.9 times more NIV intolerance ($p < 0.001$) and 1.7 times more NIV failure ($p = 0.027$) (40). Increased patient anxiety while on NIV is correlated with physicians ($p = 0.0002$) and nurses ($p = 0.0001$) being less willing to provide NIV (20). Patients themselves also exhibit mask intolerance or refuse NIV (41). As NIV requires adherence, nonadherence, or intolerance often leads to conversion to IMV (42). Carlucci et al (43) found that of 689 patients across 42 French ICUs, 52 of 108 patients (48%) on NIV were discontinued early (i.e., discontinuation of NIV when the physician desired to continue it), 22% of which were specifically due to patient refusal. Of the 52 patients, 43 patients (77%) with early NIV discontinuation eventually required endotracheal intubation. Increasing intolerance (16/43 [59%] vs 6/65 [9%]; $p < 0.001$) was also independently associated with NIV failure. Antonelli et al (44) observed that, of 108 of 354 acute hypoxemic respiratory failure patients (30%) who failed NIV, nine intubations (9%) were specifically attributed to mask intolerance or inadequate patient cooperation.

In addition, Antonelli et al (44) (64/108 vs 13/246; $p < 0.001$) and Carlucci et al (43) show that NIV failure was significantly more associated with ICU mortality. Conversely, Carlucci et al (43) indicated that continued NIV use was independently linked to a 625% increased chance of survival ($p < 0.004$). Although survival is confounded by sickness severity, these data suggest the potential impact that NIV failure can have on mortality and complications. In particular, in the Large observational study to UNderstand the Global impact of Severe Acute respiratory FailurE (LUNG-SAFE) study, which examined 349 acute respiratory distress syndrome (ARDS) patients on NIV, NIV failure was two ($\text{Pao}_2/\text{Fio}_2$ [P/F] ratio < 150) to three (any P/F) times more associated with ICU mortality and 1.8 times more associated with hospital mortality than propensity matched patients with successful NIV (45). Notably, these findings were independent of ARDS severity (P/F < 150 , ≥ 150). Furthermore, Demoule et al (46), in a study of 524 patients in 70 French ICUs, found that NIV failure itself is independently associated with poorer outcomes in comparison to either patients directly intubated without NIV or in comparison to patients who succeeded at NIV from the outset. Consequently, outcomes may be improved if patients who would fail would be intubated first and avert failure.

COMMUNICATION IMPAIRMENT IMPAIRS CARE

CI increases rates of preventable adverse events in acute care settings (47, 48). Bartlett et al (47) found in 2,355 retrospectively reviewed admissions across 20 Quebec hospitals with 217 adverse events—63 preventable—that hospitalized patients with CI were thrice as likely to have a preventable adverse event (odds ratio, 3.00; $p = 0.004$), and more than twice as likely to have multiple adverse events (46% vs 20%; $p = 0.05$). An analogous domain is CI secondary to language barriers. Divi et al (48) found in 1,083 adverse incident reports across six hospitals that patients with language barriers were over three times as likely to experience moderate harm or worse.

STRATEGIES FOR INCREASING NIV TOLERANCE

As NIV refusal has been associated with poor outcomes, addressing patient rejection of NIV will be critical for ensuring NIV success. Some causes of NIV tolerance are easily addressable—the NIV interface may contribute to patients' tolerance of the masks. Nasal interfaces can improve tolerance, but many patients in respiratory distress breathe through their mouths, which can lead to reduced NIV efficacy (42, 49). However, approximately half of patients with hypoxemia, especially with ARDS, are not helped by face mask ventilation beyond nasal masks (50, 51). Further, Rocco et al (52) demonstrated, in a study of 38 immunocompromised patients comparing helmet NIV to oronasal NIV, that a different interface significantly decreased NIV discontinuations (1.21 vs 2.94; $p = 0.001$), and helmet NIV had a trend toward lower ICU (6/19 [31%] vs 9/19 [47%]; $p = 0.25$) and hospital (7/19 [37%] vs 10/19 [53%]; $p = 0.26$) mortality than oronasal NIV. The helmet mask is currently not approved for use in the United States.

As anxiety has been associated with NIV failure, treating NIV-induced anxiety with sedation can alleviate NIV intolerance (40). Scala (12) compiled a review of 183 patients across eight studies using NIV. A number of small studies have examined the use for sedation specifically in ARF patients with poor NIV acceptance, acutely decompensated heart failure, and severe asthma (52–57). These small studies show improved arterial blood gases and respiratory rate within sedation usage, along with possible improvement in mortality and endotracheal intubation need. As such, it is possible that treating agitation and anxiety could improve clinical outcomes.

ADAPTIVE AND ALTERNATIVE COMMUNICATION METHODS

Some studies suggest that active communication during NIV improves NIV tolerance (7). In a case series study conducted by Ando (58) among 10 patients with chronic respiratory failure from motor neuron disease using NIV, improved communication increased improved tolerance.

Adaptive and alternative communication (AAC) methods, such as communication boards and electrolarynxes have been used to ameliorate CI in IMV (59), improve patient satisfaction (60), and reduce symptoms of fear, anxiety (61), and distress (32, 59, 62). Most critical care studies currently examine IMV patients using communication boards, nurse training, and electronic devices (63). As there are many similarities between IMV and NIV CI, improvement of CI in NIV may analogously decrease fear, anxiety, and

distress, and could possibly reduce NIV intolerance while improving quality of care. We therefore propose an investigation into the consequences of using AAC methods for enhancing communication in NIV patients.

ANALOGOUS PROBLEMS AND SOLUTIONS

Analogous communication problems exist with fighter pilots, astronauts, and scuba divers—roles in which full face masks or helmets are used to facilitate breathing via positive pressure ventilation. Speech enhancement for all of these applications involve

introducing a microphone to capture a speech signal, which may be placed inside the oral cavity (64, 65), around the throat (66–68), or within the mask (69, 70). These approaches may be useful in solving this problem for NIV in modern medicine, and reducing NIV intolerance and improving NIV quality of care. Examples of these implementations are shown in **Figure 1** and categorized accordingly in **Table 1**.

Intraoral solutions, such as the Molar Mic from Sonitus Technologies (San Mateo, CA) (64, 65), are currently used in military settings. These have the distinct benefit of use without modification of any current hardware. Given its short range, the Molar Mic is generally paired with a neck-mounted short-range receiver, which then rebroadcasts over another communication method, such as Bluetooth or military radio. Primary limitations in the hospital setting are the ability to be sterilized between patients and battery-limited duration, along with constant subjection to a corrosive salivary environment. Additionally, since phonation actively leverages the mouth and lips, the spoken audio may be altered.

Throat solutions are also used in military settings, and are often classed

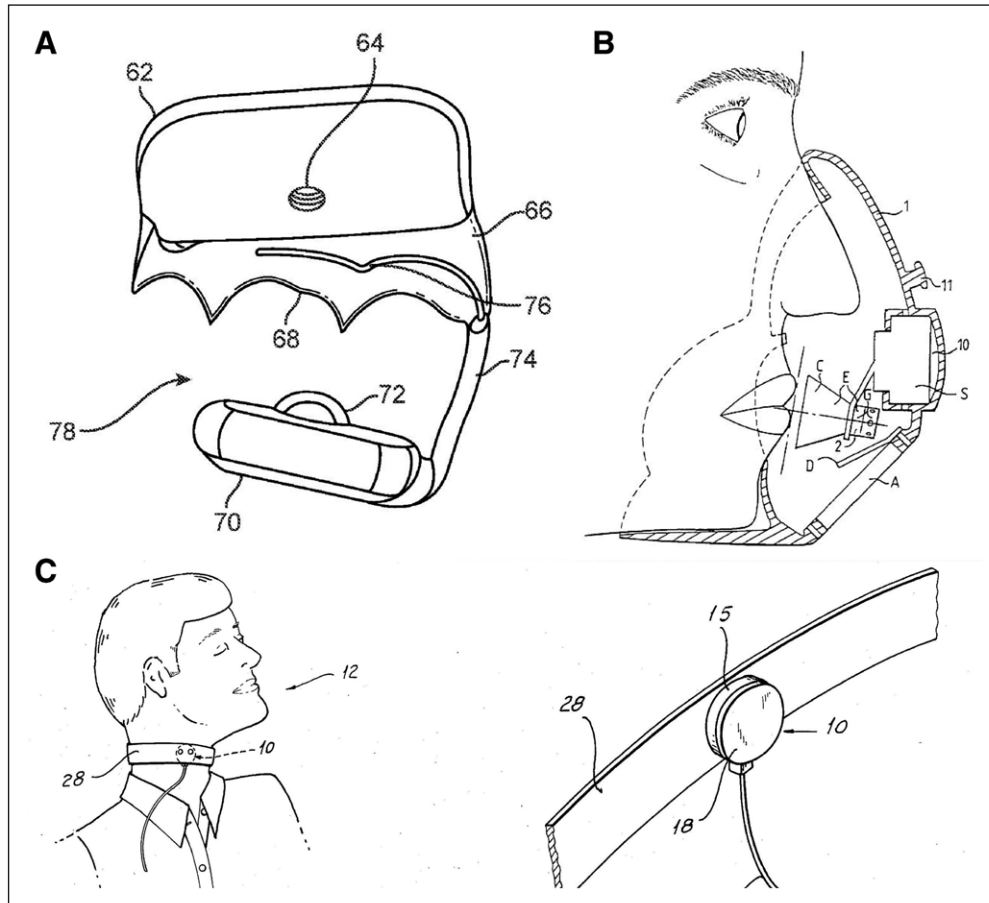


Figure 1. Examples of various analogous solutions for communicating through noninvasive ventilation masks using different modalities. **A**, Patent for intraoral microphone (Molar Mic; Sonitus Technologies, San Mateo, CA; US20190181900, public domain). **B**, Throat microphone, Ingalls (67) (Gentex Corp., Zeeland, MI; US4607383A, public domain). **C**, Intra-mask microphone (Sextant Avionique, La Défense, France; US6997178B1, public domain).

TABLE 1. Description of the Mechanism of Action of Various Possible Speech Adaptive and Alternative Communication Solutions, Analogous Solutions, and Solutions in Medicine

Category	Mechanism of Action	Analogous Solutions	Solutions in Medicine
Intraoral microphone	Recording audio waveform from inside the oral cavity	Molar Mic, Sonitus Technologies, San Mateo, CA; US20190181900A1	
Throat microphone	Measuring vibrations from the larynx	Patil and Hansen (66) Stuart (72) US2165124A Ingalls (67) US4607383A	Hamilton et al (71) US9344781B2 Hamilton et al (73) US9943712B2 Dolores One, Dolores Speech Products (Wellesley, MA)
In-mask microphone	Recording audio from inside the mask	Sextant Avionique US6997178B1 (Sextant Avionique, La Défense, France)	
On-mask contact microphone	Measuring vibrations made in the mask by patient speech		Register et al (74) US10136225B2

as silent speech interfaces since these can measure subvocalized speech. These methods leverage direct measurement of vibration from the larynx, which effectively rejects ambient noise (68). Due to alternate transmission, speech audio may be conducted differently, but still supports high quality audio. Since proper skin contact is necessary for effective vibration transmission, patient tolerance of a constrictive throat band is important. Additionally, heavier beards are problematic and will limit adequate contact (66, 68).

Current mask-based communication options are commonly used in fighter pilots and scuba divers. Most of these users chose acoustic microphones directly embedded into the mask. The U.S. military standard mask breathing unit (MBU)/12 flight masks with in-mask microphones are designed for a pressurized mask

for use at altitude (a lower pressure environment) while still permitting effective communication (69, 70). By virtue of their design at a relatively pressurized state, these most closely mimic the NIV environment. Since these microphones are exposed to the pressurized environment if applied to NIV masks, they are also subject to both ambient noise and humidity, in addition to equipment noise generated by the NIV machine.

CURRENT IMPLEMENTATIONS IN MEDICINE

Initial studies show that some of these solutions have already been designed for use in the medical environment. Examples of these implementations are shown in **Figure 2** and categorized accordingly in Table 1.

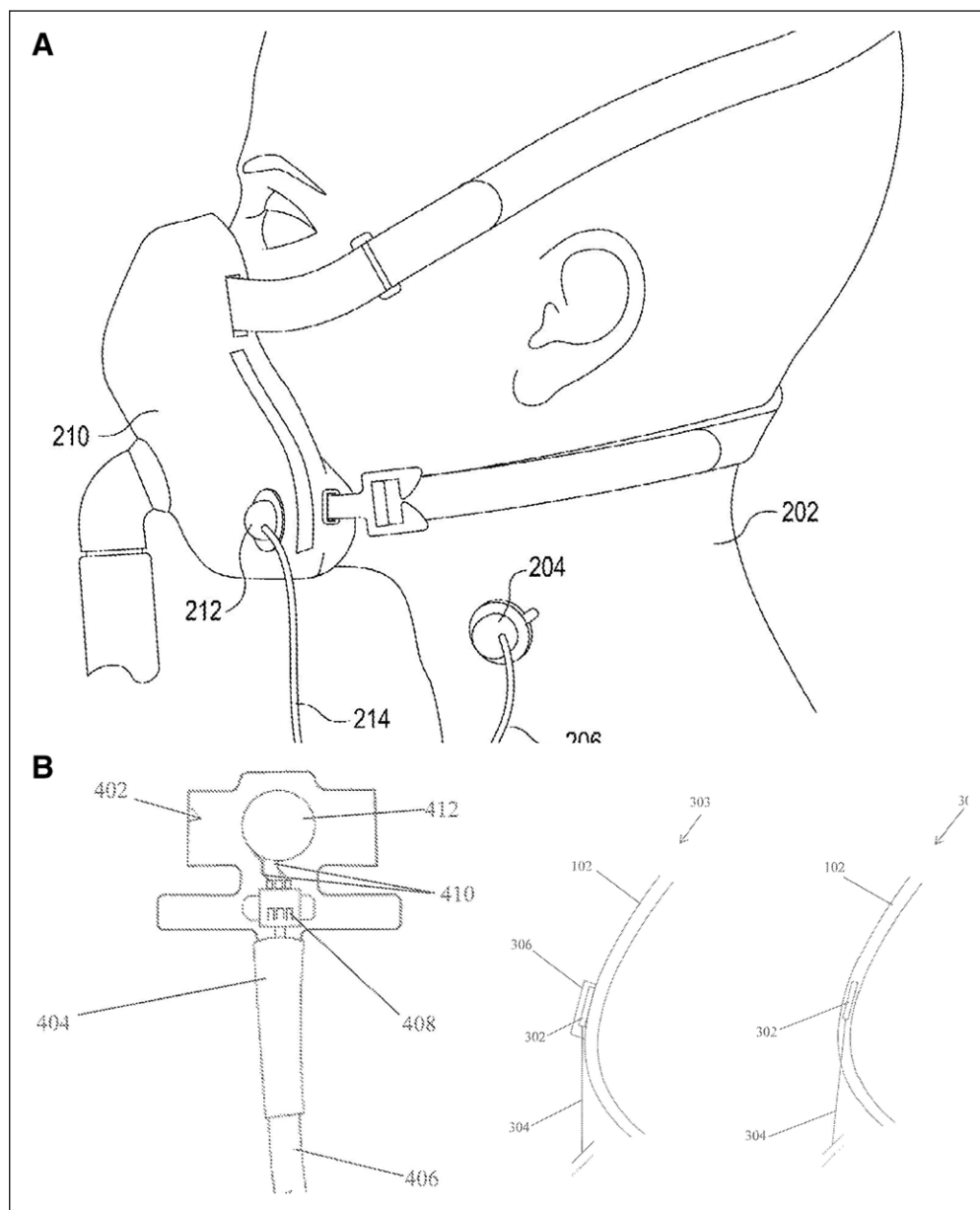


Figure 2. Patent descriptions of two speech based adaptive and alternative communication devices for noninvasive ventilation patients. **A.** Communication and speech enhancement system, Dolores Speech Products (Wellesley, MA), US9943712B2, public domain. **B.** Systems and methods for communicating through a hard plastic mask (Ataia Medical, Dallas, TX), US10136225B2, public domain.

Throat microphones are currently offered for NIV by Delores Speech Products (Wellesley, MA), with two patents (71,73,75). In a 16-patient case series, Ijssennagger et al (76) demonstrated improvement in CI in eight of 15 patients (53%) in awake critically ill patients. Two of 15 patients were on NIV and both experienced improvement in CI.

An analogous solution to the in-mask microphone is the contact microphone, which is currently offered for NIV by Ataia Medical (Dallas, TX) (74). Characterization has not yet been published.

DISCUSSION AND CONCLUSIONS

CI significantly affects care and patient management, especially for patients undergoing NIV therapy. This impairment is correlated with both physical and psychologic distress, both of which appear to contribute to NIV intolerance and may result in endotracheal intubation. Failure of initial NIV therapy is associated with worse outcomes than direct intubation, highlighting the potential benefit of reducing CI (46). Studies to investigate sedation as a method to alleviate patient anxiety have shown promise. As stated above, a significant amount of this anxiety may be a downstream effect of CI (20). Consequently, alleviating the CI may circumvent the need for chemical sedation. Several studies have revealed the impact of CI on the success of NIV/IMV and highlight the need to further pursue additional novel treatment (20, 26, 34).

This review on NIV-related CI indicates that there is a critical need for further studies in this area, as opposed to drawing indirect conclusions from IMV studies. Analogous domains, such as fighter pilot oxygen masks, provide potential methods for treating this impairment and should be explored, and some methods are already in use. Since patients can still talk while using NIV, potential exists for research into muffled speech enhancement using mask-based, throat, or intraoral microphones, which can restore efficient and natural communication. Future research is needed to measure the degree of NIV-related CI and the clinical consequences attributable to or associated with NIV. Additional research is also needed to study the degree of improvement that communications devices can achieve. Finally, explicit studies are required to establish whether remedying NIV CIs reduces the frequency of poor outcomes in acute care settings.

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