

Expanding the Use of Noninvasive Ventilation During an Epidemic

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ABSTRACT

Noninvasive ventilation (NIV) is a proved and effective therapeutic option for some patients with respiratory failure. During an epidemic, NIV can free up respirators and other intensive care unit equipment for patients with respiratory insufficiency whose survival depends exclusively on invasive ventilation. Some guidelines have indicated that NIV is potentially hazardous and should not be recommended for use during epidemics, given the perceived potential risk of transmission from aerosolized pathogen dispersion to other patients or medical staff. Conversely, some reports of previous epidemics describe NIV as a very efficient and safe modality of respiratory support, if strict infection control measures are implemented.

We discuss NIV use during epidemics and indicate the need for prospective randomized clinical studies on the efficacy of NIV in epidemic conditions to provide important information to the current body of literature. Meanwhile, the use of NIV under strict infection control guidelines should be incorporated into epidemic preparedness planning. (*Disaster Med Public Health Preparedness*. 2014;8:310-314)

Key Words: intensive care, infection control, epidemics, respiratory insufficiency, noninvasive ventilation

Noninvasive ventilation (NIV) provides ventilatory support through a patient's upper airway using a facial mask or similar device connected to a respirator, in contrast to invasive ventilation, which requires the placement of an invasive airway such as an endotracheal or tracheostomy tube. First developed in the 1940s as an intermittent positive pressure breathing device for use in high-altitude aviation, NIVs were subsequently used by Motley and colleagues at Bellevue Hospital to treat acute respiratory failure in patients with pneumonia, pulmonary edema, near-drowning, acute severe asthma, and Guillain-Barré syndrome.¹ The application of NIV in clinical settings became widespread in the 1980s. In 1989, Meduri and colleagues successfully applied NIV via full-face mask in patients with respiratory insufficiency and chronic obstructive pulmonary disease (COPD), congestive heart failure, or pneumonia.²

Thereafter, NIV has become increasingly adopted by critical care clinicians for the treatment of acute respiratory failure in both emergency and critical care settings.³ The medical conditions for which critical care clinicians have recognized the importance of NIV have also rapidly increased during this period.⁴ When appropriately indicated and promptly administered, NIV offers an alternative to tracheal intubation,

sedation, risk of infection, and myriad complications associated with invasive ventilation, and it can promote rapid respiratory recovery, and reduce a patient's dependence on critical care facilities.

NONEPIDEMIC USE OF NIV

In addition to strongly proved benefits in patients with acute hypercapnic respiratory failure due to acute exacerbation of COPD and pulmonary edema resulting from heart failure,⁵ NIV has become a useful therapeutic option for respiratory failure in patients who are immunosuppressed⁶ and in patients with chest trauma.⁷ Successful use of NIV has also been seen in patients with chronic respiratory failure due to neurological and neuromuscular diseases such as multiple sclerosis, amyotrophic lateral sclerosis, and muscular dystrophies⁸ and during the respirator-weaning process.⁹ In contrast, the utility of NIV in hypoxic respiratory failure due to pneumonia is still doubtful.¹⁰

In spite of very well-known indications, the use of NIV in clinical practice is far from uniform. In a study of NIV use in 82 US hospitals, the average NIV rate of use was 20% of ventilator starts. The rate of use of NIV differed from 0 to more than 50% of ventilator starts within the same region. Lack of knowledge,

insufficient training, and inadequate equipment were perceived as the most common reasons for the underuse of NIV. A very important finding of this study was that most clinicians who had used NIV as a regular clinical routine considered their experience with NIV as good to excellent.¹¹ In a European study of 42 French hospitals, the NIV rate of use was 16% of ventilator starts, but even in 20% of the reported hospitals NIV had never been used.¹²

BENEFITS VERSUS RISKS OF USING NIV DURING AN EPIDEMIC

One of the important issues of preparedness planning for an epidemic caused by a respiratory pathogen is to reevaluate the use of NIV in the treatment of respiratory failure,¹³ especially when shortages of respirators present a real concern. During the past 20 years, 2 epidemics have emerged, severe acute respiratory syndrome (SARS) in 2003 and H1N1virus in 2009. Both outbreaks resulted in a significant number of patients developing serious disease and acute respiratory failure, the recovery from which depended on the availability of intensive care resources, especially respirators.

During the 2003 SARS epidemic, 14% to 25% of patients progressed to acute respiratory failure, requiring mechanical ventilation.¹⁴ During the 2009 H1N1 epidemic, approximately 10% to 30% of the hospitalized patients were admitted to an intensive care unit (ICU), most of them due to respiratory failure.¹⁵ In both events, the medical community faced the difficult task of making the ICU facility during an epidemic available to all critically ill patients, in addition to providing the required number of respirators and other necessary respiratory equipment.

The use of NIV in patients with H1N1 influenza has been reported with varying rates of success. Rello et al described NIV use at ICU admission in 1 of 3 patients with H1N1 virus and respiratory failure, but 75% of them had an unfavorable clinical course and required tracheal intubation and invasive mechanical ventilation.¹⁶ The study of 337 patients with H1N1 admitted to ICUs in Argentina reported that NIV was used in 64 (19%) patients, with favorable outcomes in 43 patients who survived (67%).¹⁷ Masclans et al reported 685 patients with confirmed H1N1 viral pneumonia who were admitted to Spanish ICUs, 489 of whom required mechanical

ventilation.¹⁸ NIV was used in 177 patients, and successful outcomes were seen in 72 patients (40.7%), while the other patients required invasive ventilation (Table 1). Patients in whom NIV was successful had shorter hospital stays and lower mortality rates, similar to those of the nonventilated patients. The mortality of patients in whom NIV failed was similar to that of the patients requiring intubation from the start.¹⁸

Another critical preparedness task was to ensure a safe hospital environment for other patients and for health care workers (HCWs) during an epidemic. In the course of the 2003 SARS epidemic in Vietnam, 57% of SARS patients were HCWs; in Canada, 43% were HCWs; and in Singapore, 41% were HCWs. Worldwide, about 21% of SARS patients were HCWs²⁰ (Table 2).

Recognizing the occurrence and outcomes associated with superspreading events (SSE) since the 2003 SARS outbreak was another reason critical care physicians have rejected the use of NIV during an epidemic. During the 2003 epidemic, about 75% of SARS infections in Hong Kong and Singapore were associated with SSEs, confronting epidemiologists and clinicians with the task of identifying the hospital procedures contributing to this phenomenon and modifying their infection control measures.²¹ Yu et al analyzed the factors responsible for hospital spreading of SARS infection and found 6 significant risk factors: minimum distance between beds (≤ 1 m), the availability of washing or changing facilities for staff, administering resuscitation in the ward, staff members

TABLE 2

Infection Rate of Health Care Workers in the 2003 SARS Epidemics^a

Area	No. of Patients	Affected Health Care Workers	
		No.	%
Canada	251	109	43
China	5327	1002	19
Hong Kong	1755	386	22
Singapore	238	97	41
Vietnam	63	36	57
Phillippines	14	4	29
Total	8096	1706	21

^aEstenssoro et al.¹⁷

TABLE 1

Use of Noninvasive Ventilation (NIV) in Previous Epidemics

Authors	Epidemic	No. of Patients	Total No. of Patients Receiving Ventilation	No. and Rate of Patients Receiving NIV	No. and Rate of Successfully Ventilated Patients With NIV
Masclans et al ¹⁸	H1N1 2009-2010	685	489	177 (36.2%)	72 (40.7%)
Rello et al ¹⁶	H1N1 2009	32	24	8 (33.3%)	2 (25%)
Estenssoro et al ¹⁷	H1N1 2009	—	337	64 (19%)	43 (67%)
Cheung et al ¹⁹	SARS 2003	—	—	20	14 (70%)

working while experiencing symptoms, and whether the host patient (index patients or the first patient admitted to a ward) required oxygen therapy or bilevel positive airway pressure ventilation.²²

The experience in Singapore, however, demonstrated that following the development of proper infection control measures, which consisted of staff personal protection, patient risk categorization, and reorganization of operating room workflow process, no transmission of SARS had occurred within the operating room complex.²³ Moreover, it was well known that NIV is not the only procedure that carries an increased risk of transmitting acute respiratory infection pathogens to staff. In their systematic review of literature concerning aerosol-generating procedures and the risk of transmitting acute respiratory infection to HCWs, Tran and coworkers found that tracheal intubation, tracheotomy, and manual ventilation before intubation were procedures with significantly increased risk of transmission—as much as with NIV. Furthermore, they found that tracheal intubation was the procedure most consistently associated with the transmission of SARS virus to HCWs.²⁴

Several reports on the 2003 SARS epidemic reported good clinical results with NIV use, which was also associated with reduced intubation rate and mortality.^{19,25,26} Zhao et al compared 4 treatment modalities for hospitalized SARS patients and reported that the best clinical improvement was achieved in patients who received early high-dose steroids combined with nasal continuous positive airway pressure.²⁶ Importantly, in a retrospective analysis comparing the efficacy of NIV against invasive ventilation in SARS patients with respiratory failure, Yam et al reported that no HCW caring for NIV patients was infected and that standard personal protective equipment, including surgical masks, was as effective as the more sophisticated protective equipment used later in the outbreak.²⁴ Cheung et al reported the use of noninvasive positive pressure ventilation (NIPPV) in 20 patients with acute respiratory failure due to SARS. Their results showed that in patients with NIPPV, tracheal intubation was avoided in 14 cases. Also, the length of stay in ICU was shorter compared to that for intubated patients, and, importantly, no HCW caring for patients with NIPPV was infected.¹⁹

RECOMMENDATIONS ON THE USE OF NIV IN EPIDEMICS

Following the 2003 to 2007 avian influenza A (H5N1) epidemics in Asia, Africa, Europe, Near East, and the Pacific, the World Health Organization's document "Clinical management of human infection with avian influenza A(H5N1) virus" included a statement that NIPPV cannot be recommended for patients with respiratory failure resulting from A (H5N1) virus infection. This document highlighted concerns associated with the potential increased risk of generating infectious aerosols in the course of this method of respiratory support.²⁷ Research using experimental lung

models demonstrated that exposure to exhaled air from patients receiving NIV with face mask occurs within 1 m.²⁸ Likewise, guidelines for the acquisition of ventilators to meet the demands for pandemic flu and mass casualty incidents, published in 2006 by the American Association of Respiratory Care, recommended the avoidance of NIV in case of contagious respiratory diseases due to contamination risk.²⁹

The Task Force on Mass Critical Care voiced similar opinions regarding noninvasive ventilation during their summit meeting in January 2007. Their suggestions regarding interventions for emergency mass critical care and the use of mechanical ventilation during a disaster recommended only the "provision of a basic mode of sustained, positive pressure ventilation" without any reference to NIV.³⁰ The task force further declared NIV a high-risk procedure due to the potential for air flow from the mask to increase the risk of infectious transmission to the staff and to other patients.^{27,29}

Since 2009, however, some published documents have mentioned NIV as a possible procedure during an epidemic. In a position statement, the Australian Society for Infectious Diseases recommends "reserving negative-pressure ventilation rooms (if available) for intensive care patients, especially those receiving non-invasive ventilation."³¹ The UK Department of Health, in "Guidance for infection control in critical care for pandemic influenza," approved the use of NIV under strict infection control measures. Emphasis was given to staff training in infection control and the use of personal protection by gown, gloves, eye protection, and a filtering half mask with exhalation valve (FFP3) respirator; negative pressure rooms; nonvented mask or helmet; applying and fitting the mask before turning on the respirator; and removing the mask after turning off the respirator.³²

The recommendation for NIV use during an epidemic is also consistent with the Institute of Medicine's 2012 "Crisis standards of care: a systems framework for catastrophic disaster response." The institute's expert panel emphasized the obligation for matching patients' health care needs with a level of care capable of meeting those needs during a disaster, such as an epidemic.³³ For some patients during a disaster, regardless of the cause of their respiratory insufficiency, NIV will serve this need very well.

DISCUSSION

In most health care systems, mechanical ventilation is usually the first limited resource in disaster situations. Based on information from previous influenza epidemics in the United States, almost 100% of the available ventilators were in use.³⁴ Ventilator-allocation plans, increasing the supply of ventilators, and use of ventilator "alternatives" are solutions,³⁴ and NIV fits perfectly into all of these plans. Consistent with addressing crisis standards of care, the use of NIV is not only directed to individual patient outcomes, but it fulfils a

responsibility to the population. Significant effort must be focused on applying the most ethical triage concepts associated with ventilator-allocation principles for patients with respiratory insufficiency during disasters.^{35,36} As such, incorporating NIV in the allocation and decision-making process for preparedness planning will augment the capacity for respiratory support and reduce patient and population mortality during a disaster. The Institutes of Medicine emphasizes the importance of this point:

“Plans and protocols that shift desired patient care outcomes from the individual to the population must be grounded in the ethical allocation of resources, which ensures fairness to everyone... The emphasis in a public health emergency must be on improving and maximizing the population’s health while tending to the needs of patients within the constraints of resource limitations.”³³

In disaster situations, medical care occurs across 3 phases on a continuum³³:

- Conventional care, with the maximal use of the resources;
- Contingency care, with the aim of ensuring functionally equivalent care; and
- Crisis care, with care provided to the highest level possible and incorporating prioritized strategies for fixed resources.

The implementation of NIV in epidemic situations can be incorporated into all 3 phases of the continuum, especially as functionally equivalent care for some patients. Another benefit associated with resource utilization strategies is that NIV is very suitable to the principle of resource adaptation; for the NIV application we can use almost all types of respirators, anesthesia machines, and bi-level positive pressure machines.^{37,38}

The strict adherence to infection-control guidelines, including pre-exposure prophylaxis for vaccine-preventable diseases,^{39,40} such as hand hygiene before and after patient care⁴¹ and wearing protective equipment such as gloves, gowns, surgical masks, N95 respirators, or surgical masks and eye shields, is paramount to the safety of HCWs.³⁹ Regardless of whether the infected patient is receiving NIV, has been intubated, or merely has a cough or a sneeze, wearing protective equipment is imperative for any close contact and is one of the best protective measures.

For NIV use, it is very important to apply and fit the mask tightly to the face before turning on the respirator and removing the mask after turning off the respirator.³² Another key element in preventing patient-to-patient transmission of respiratory infection is rapid patient isolation in a negative pressure room with air being directly exhausted out, or cohorting similarly exposed and infected patients.⁴² Isolation and patient cohorting are very important regardless of which type of respiratory support is used, because the risk of transmission is uniformly increased in all procedures with

airway manipulation and artificial ventilation.²³ Reducing the spread of hospital infection and protecting HCWs requires continual re-education, staff training, and monitoring infection-control guidelines. By incorporating all of these infection-control measures, our hospitals can be appropriately prepared for the safe and successful use of NIV during epidemics.

CONCLUSION

Evidence points to NIV as a preferred clinical choice for some patients with respiratory failure.⁶⁻¹⁰ The use of NIV can contribute to a shorter length of stay in an ICU and less dependency on respiratory support compared to invasive ventilation.¹⁹ We emphasize that NIV should primarily be allocated for patients with strong and proved indications for NIV such as COPD, pulmonary edema resulting from heart failure, or neuromuscular diseases. Using NIV under epidemic conditions, frees up respirators and other ICU equipment for patients with respiratory insufficiency who require invasive ventilation.

To our knowledge, no prospective, controlled randomized studies have been conducted at present on NIV utilization during an epidemic. However, clinical experiences from previous epidemics and reports from hospitals where NIV has been used during an epidemic should be systematically reviewed for consideration of future NIV use in a variety of clinical settings. The threat of pandemics and other catastrophic events that will place high demands on resources and personnel should catalyze objective considerations of NIV use. We consider the use of NIV during an epidemic an important strategy that will balance the clinical and ethical obligations addressing the needs of affected individuals and populations.

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