Novel Uses of Noninvasive Ventilation

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Summary

Noninvasive ventilation (NIV) and continuous positive airway pressure (CPAP) have been used in various unusual settings to assist breathing. NIV is now frequently used to treat exacerbations of chronic obstructive pulmonary disease and chronic respiratory failure in neuromuscular disease. This paper discusses CPAP and NIV for postoperative hypoxemia, preventing intubation in high-risk bronchoscopy, respiratory failure in pandemics, obesity hypoventilation syndrome, and respiratory support during percutaneous endoscopic gastrostomy tube placement. Key words: noninvasive ventilation, NIV, continuous positive airway pressure, CPAP, bronchoscopy, pandemic, obesity hypoventilation syndrome. [Respir Care 2009;54(2):212–219. © 2009 Daedalus Enterprises]

Introduction

In the past 30 years, dramatic strides have been made in the development of noninvasive ventilation (NIV). Negative-pressure ventilation devices were used during the polio epidemics up through the 1950s, then positive-pressure ventilation via nasal or face mask gained acceptance, and nasal and face masks underwent rapid development in the 1980s.1 Mask were initially used with continuous positive airway pressure (CPAP) to treat sleep apnea, but soon the masks were used with volume-control and pressure-control ventilators to treat patients with neuromuscular and chest-wall restrictive diseases2-4 as well as acute respiratory failure. NIV has also been extensively used for exacerbations of chronic obstructive pulmonary disease (COPD) and is now considered almost the standard of care for acute hypercarbic exacerbations of COPD in the emergency department and intensive care unit (ICU).5 NIV has yet to be shown to have efficacy for chronic respiratory failure in COPD.6 This paper discusses novel applications of CPAP and NIV, such as for postoperative hypoxemia, prevention of intubation in high-risk bronchoscopy patients, respiratory failure in pandemics, obesity hypoventilation syndrome, and during percutaneous endoscopic gastrostomy tube placement.
Continuous Positive Airway Pressure and Noninvasive Ventilation in the Postoperative Period

Respiratory insufficiency in patients undergoing major surgery, especially of the chest or upper abdomen, is relatively common. After abdominal surgery, respiratory complications occur in approximately 10% of patients, and reintubation represents 30% of those complications. Pain, splinting, and respiratory muscle dysfunction are likely contributors to hypoxemia and respiratory insufficiency. Common methods to prevent this in the postoperative period have included incentive spirometry, chest physiotherapy, mucolytics, and intermittent positive-pressure breathing. Recently there have been trials of CPAP and NIV to reduce postoperative respiratory complications. Case series have used preventive CPAP or NIV in the recovery room or ICU, and the results are promising, with reports of prevention of reintubation ranging up to 100%. However, the lack of control groups limits interpretation of those studies. Three randomized controlled trials have been performed: 2 with CPAP and one with NIV.

Squadrone et al performed a large multicenter trial that involved 15 centers in Italy. They included patients who had undergone upper-abdominal surgery of at least 90 min and had a ratio of $P_{aO2}/FIO2$ of $\leq 300$ mm Hg. Patients were excluded if they had a history of cardiac disease, COPD, pH $< 7.30$, $P_{aco2} > 50$ mm Hg, hematocrit $< 30\%$, or coma. They randomized 104 subjects to the control arm, who received $FIO2$ of 0.5 via air-entrainment mask, and 105 subjects to the treatment arm, who received $FIO2$ of 0.5 and CPAP at 7.5 cm H2O. At the end of a 6-hour treatment period both groups were placed on FIO2 of 0.3. If $P_{aO2}/FIO2$ was $\leq 300$ mm Hg, the patient was placed back on his or her assigned treatment. With standardized criteria for the decision to intubate, there was a markedly lower intubation rate and lower rates of pneumonia and sepsis in the treatment arm (Fig. 1).

In a similar study that used CPAP to prevent post-extubation respiratory complications in patients who underwent repair of thoracoabdominal aneurysm, Kindgen-Milles et al compared controls to patients who were treated with CPAP for 12–24 hours after surgery. The patients were extubated in the ICU when standard extubation criteria were met, then randomized. The control group received oxygen via non-occlusive face mask at 25 L/min; other routine medical therapies (eg, morphine for pain, and stress ulcer prophylaxis); and CPAP for 10 min every 4 hours. The experimental group received the same standard therapies plus CPAP at 10 cm H2O for 12–24 hours after the procedure, and they had better oxygenation, fewer pulmonary complications, and shorter hospital stay than the controls.

Auriant and colleagues performed a randomized trial of NIV in postoperative respiratory failure. Patients were included if they met 3 of 4 criteria for respiratory insufficiency after extubation following lung-resection surgery: respiratory rate $> 25$ breaths/min, accessory muscle use, $P_{aO2}/FIO2 < 200$ mm Hg, and chest radiograph abnormalities such as atelectasis or consolidation. Subjects were randomly assigned to standard postoperative care and supplemental oxygen or standard postoperative care plus NIV via oronasal mask and a bi-level pressure-support ventilator adjusted to generate a tidal volume of 8–10 mL/kg, to maintain oxyhemoglobin saturation $> 90\%$, and to keep respiratory rate $< 25$ breaths/min. The study was stopped after the first interim analysis because of dramatic differences in reintubation rate and mortality. Approximately 21% of the subjects in the NIV arm were reintubated, according to standardized criteria, compared to 50% in the control arm. In-hospital mortality was 37.5% in the control arm, and 12.5% in the treatment arm.

Although the above-described 3 studies were small, it appears that positive airway pressure improves outcomes in patients who develop postoperative respiratory insufficiency. It is not known whether CPAP or NIV is the better mode.

Continuous Positive Airway Pressure and Noninvasive Ventilation During Bronchoscopy

Bronchoscopy in patients with respiratory disease can present a substantial challenge. The bronchoscope occupies approximately 10% of the normal airway and can increase work of breathing and decrease $P_{aO2}$ by 10–20 mm Hg, which can cause respiratory complications and cardiac arrhythmia. Several investigators have evaluated CPAP and NIV for preventing these complications in at-risk patients, and case series have had success with CPAP and NIV.

Fig. 1. Kaplan-Meier estimates of intubation risk in the group that received supplemental oxygen alone (control) versus the group that received continuous positive airway pressure (CPAP). The control patients had a higher risk of intubation ($P = .005$ via log rank test). (From Reference 16, with permission.)
Maitre et al24 conducted a randomized controlled trial of bronchoscopy with CPAP versus with high-flow oxygen in patients at high risk for respiratory complications (PaO2/FIO2 < 125 mm Hg on high-flow mask). The mask/CPAP device (Fig. 2) delivers either high-flow oxygen or high-flow oxygen plus CPAP (at 7.5 cm H2O) during bronchoscopy. The study outcomes were oxygenation during and after bronchoscopy, and respiratory complications, including intubation. Fifteen patients were entered into each arm of the study. Figure 3 shows the oxygenation results. Seven patients in the oxygen group needed some form of ventilatory support (4 intubations) in the 6 hours following the procedure, as opposed to only one patient in the CPAP group, although that difference is not statistically significant.

In another randomized controlled trial, Antonelli et al used NIV in high-risk patients undergoing bronchoscopy.25 Patients who required bronchoscopy and had a PaO2/FIO2 < 200 mm Hg were randomized to receive an FIO2 of 0.9 via face mask, or NIV via oronasal mask, with inspiratory pressure of 15–17 cm H2O, expiratory pressure of 5 cm H2O, and FIO2 of 0.9. During bronchoscopy, FIO2 was reduced to maintain oxygen saturation (measured via pulse oximetry) > 92%. PaO2/FIO2 was substantially higher both during bronchoscopy (261 mm Hg vs 139 mm Hg) and one hour after bronchoscopy (176 mm Hg vs 140 mm Hg), although both groups started at essentially the same PaO2/FIO2 at baseline (143 mm Hg vs 155 mm Hg). Whether NIV reduces the requirements for bronchoscopy-associated intubation in high-risk patients remains unknown. It does appear that both CPAP and NIV are safe and effective for maintaining oxygenation in relatively hypoxemic patients undergoing bronchoscopy.

**Noninvasive Ventilation During Percutaneous Gastrostomy Tube Placement**

For patients with neuromuscular disease, swallowing problems and malnutrition can become major and life-threatening issues. Percutaneous endoscopic gastrostomy tube placement may prevent large-volume aspiration by bypassing the dysfunctional swallowing muscles, thus protecting the airway from aspiration and providing adequate calories. Sedation is required for this procedure, and for patients with respiratory muscle insufficiency and low vital capacity, sedation may add significant risk of respiratory complications. Intubation of patients with neuromuscular disease is associated with prolonged and sometimes permanent invasive mechanical ventilation.26 In fact, the American Academy of Neurology issued a practice parameter that percutaneous gastrostomy tubes should be placed before the forced vital capacity drops below 50% of predicted, to reduce the risk of respiratory failure.27

Unfortunately, some patients fall below that level prior to receiving a percutaneous gastrostomy tube. NIV has been used in several groups of neuromuscular patients during percutaneous endoscopic gastrostomy tube placement, even when the forced vital capacity is quite low (Fig. 4). Boitano et al used bi-level NIV to support 5 patients with amyotrophic lateral sclerosis and forced vital capacity that ranged from 21% to 44% of predicted during percutaneous endoscopic gastrostomy tube placement, and had no complications.28 Similarly, in a group of patients...
with Duchenne muscular dystrophy, Birnkrant et al had successful and uncomplicated percutaneous endoscopic gastrostomy tube placement in patients in whom vital capacity was nearly unmeasurable.29

**Noninvasive Ventilation in Pandemic Respiratory Infections**

Recently, because of the threats of severe acute respiratory syndrome (SARS), avian flu, and bioterrorism, there has been widespread discussion of respiratory-care issues in pandemic and mass-casualty situations,30-35 NIV has been suggested as a possible treatment for patients with milder respiratory failure, or to decrease the intubation rate. The major debate is on the safety of NIV, because infectious exhaled aerosol can enter the ambient air through the exhalation ports in the NIV mask or tubing. The evidence on this topic is of 2 kinds: reports of NIV use during the SARS epidemic of 2003, and bench modeling of droplet release and spread with an NIV model.

Cheung et al reported their experience with NIV and SARS at the Pamela Youde Nethersole Eastern Hospital in Hong Kong.36 During March and April of 2003 they used NIV to treat 20 patients with SARS. To reduce the risk from droplets they employed 3 strategies: oronasal mask to prevent large leaks through the mouth; exhalation valve (Whisper-Swivel II, Respironics, Murrysville, Pennsylvania), which they thought should have a lower likelihood of producing jets of droplets; and viral/bacterial filter (AirLife, Allegiance Healthcare, McGaw Park, Illinois) in-line before the exhalation valve. The mean duration of NIV was 84.3 hours, and they indicated that 14 intubations were avoided. Those treated with NIV had shorter ICU stay than the intubated patients (3.1 d vs 21.3 d). During that time they also monitored the health and SARS serologic status of the 105 clinicians who came into contact with the patients on NIV. There were no seroconversions or symptoms consistent with SARS in any of the clinicians, although 3 of them declined the blood draw. The clinicians were protected initially with N95 masks, and later with powered air-purifying respirators, although the proportion of each was not reported.

In a related study, Yam et al retrospectively compared the above results from the NIV strategy at Pamela Youde Nethersole Eastern Hospital to those from 13 other hospitals in Hong Kong that only used intubation and invasive ventilation during the SARS epidemic.37 Data were obtained from the Hong Kong Hospital Authority SARS database, which contains data on all patients with confirmed SARS during that period in 2003. Compared to the hospitals that used invasive ventilation only (451 patients), the hospital that used NIV (42 patients) had a lower adjusted odds ratio for intubation (0.36, 95% confidence interval [CI] 0.64–0.79, \( P = .01 \)) and death (0.24, 95% CI 0.08–0.72, \( P = .01 \)). Patients also improved more rapidly after steroid pulse rescue. The severity of disease at presentation was slightly worse at the NIV hospital.

In a retrospective epidemiologic study of clinicians exposed to the SARS virus during the outbreak of 2003, Fowler and colleagues found that direct involvement with intubation of a SARS patient carried the highest risk of contracting the infection, and working with patients on NIV did not have a statistically significant risk of developing infection in the clinician.38 However, the number of instances of NIV use was quite small (6 uses of NIV devices), which makes it difficult to interpret the findings.

In another retrospective analysis of clinician exposure to a SARS-infected index case, Scales49 reported that of 22 clinicians present in the room while the patient was on NIV, 4 developed SARS and were in the room for >31 min. Only one of those clinicians was wearing a mask. Of 18 clinicians who did not develop SARS, only one was in the room for >31 min and was wearing a mask, gown, and gloves. Thus, the epidemiologic data are mixed at best, and the actual risk of SARS spread with NIV is not known.

Obviously, only a prospective study could determine the effectiveness of NIV versus invasive ventilation in the management of SARS.

Hui et al40 conducted a bench study of aerosol dispersion during NIV. A mannequin wearing an oronasal NIV mask was exposed to various ventilating pressures while known concentrations of aerosol particles were instilled into the artificial lung. The aerosol that exited the mask exhaust ports was visualized with laser light and recorded with a computer (Fig. 5). The dispersion maps (Fig. 6) showed that, at an inspiratory pressure of 18 cm H2O and an expiratory pressure of 4 cm, dispersion ranged up to 0.5 m from the mask, which is certainly enough to contaminate clinicians.

**Fig. 4.** Patient with amyotrophic lateral sclerosis undergoing percutaneous endoscopic gastrostomy tube placement with noninvasive ventilatory support.
At present, despite conflicting data, we must assume that there is at least some contamination risk from infectious droplets when treating an infected patient with NIV, and that clinicians must take careful precautions.

The American Association for Respiratory Care recently issued a statement concerning ventilation in mass-casualty situations, including pandemics. They recommended against NIV in pandemic flu, because flu often progresses to acute respiratory distress syndrome, for which NIV is not the standard of care. Also, the 1–2-hour respiratory-therapist time commitment to initiate NIV would probably be impossible in a pandemic situation. The debate on this continues.

Continuous Positive Airway Pressure for Obesity Hypoventilation Syndrome

Obesity hypoventilation syndrome describes an individual with obesity (body mass index $\geq 30$ kg/m$^2$), awake hypercapnia ($P_{aCO_2} \geq 45$ mm Hg), and sleep-disordered breathing. Ninety percent of the sleep-disordered breathing in obesity hypoventilation syndrome consists of obstructive sleep apnea. The remaining 10% of these patients have an apnea-hypopnea index $< 5$ events/h, and their problem has been referred to as sleep-related hypoventilation, which is defined by a nocturnal $P_{aCO_2}$ elevation of 10 mm Hg. Compared to eucapnic obese patients, patients with even mild obesity hypoventilation syndrome ($P_{aCO_2} \geq 45–50$ mm Hg) have a lower quality of
life, more daytime hypersomnolence, and higher health-care costs.\(^4\) The generation of obesity hypoventilation syndrome is complex. Figure 7 presents a potential physiologic explanation. The reason for the elevated daytime PaCO\(_2\) has not been entirely elucidated, but most experts agree that it involves renal buffering of PaCO\(_2\) with HCO\(_3^-\) that persists during the daytime.\(^4\)\(^5\)–\(^4\)\(^8\)

Positive airway pressure can ameliorate obesity hypoventilation syndrome. The sleep-disordered breathing comes in 3 varieties: obstructive sleep apnea with hypopneas, obstructive hypoventilation due to upper-airway resistance syndrome, and central hypoventilation.\(^4\)\(^9\) A treatment algorithm for obesity hypoventilation syndrome has been proposed, based on the frequency of occurrence of the disordered sleep patterns (Fig. 8). Obstructive sleep apnea is the most common sleep disorder, so CPAP is tried first. If the oxyhemoglobin saturation cannot be brought above 90%, NIV is tried, with inspiratory pressure increased above the last expiratory pressure setting by at least 8–10 cm H\(_2\)O to bring the saturation above 90%. If that is not effective, then supplemental oxygen is added to bring the saturation above 90%. If none of those interventions are successful, then weight-loss surgery or even tracheostomy and invasive ventilation are considered.

A recent prospective trial of CPAP versus NIV included 23 patients with obesity hypoventilation syndrome, who were compared to 23 matched patients who had eucapnic obstructive sleep apnea.\(^4\)\(^8\) In 57% of the subjects with obesity hypoventilation syndrome, CPAP alone relieved sleep-disordered breathing and hypoxemia, with an optimal mean CPAP pressure of 13.9 ± 3.1 cm H\(_2\)O. The remaining 43% required various levels of NIV and supplemental oxygen to maintain saturation above 90%.

In another retrospective study, Pérez et al studied 54 patients with obesity hypoventilation syndrome who underwent NIV.\(^4\)\(^3\) Outcomes measured included survival, clinical status, and arterial blood gas values. At the end of the follow-up period (mean duration 50 months), PaO\(_2\) had increased by 24 mm Hg from baseline (95% CI 21–28 mm Hg, \(P < .001\)) and PaCO\(_2\) had decreased by 17 mm Hg (95% CI 13–20 mm Hg, \(P < .001\)). NIV improved subjective sleepiness (mean Epworth sleepiness scale score decreased from 16 ± 5 to 6 ± 2, \(P < .001\)), and dyspnea decreased in all but 4 patients. During follow-up, 3 patients died (one of them due to the progression of respiratory failure). NIV was withdrawn in 5 patients who had achieved sufficient weight loss, and the condition of 16 patients was maintained without respiratory failure by the use of simple therapy with CPAP.

It is clear that for the majority of patients with obesity hypoventilation syndrome CPAP is generally adequate, though NIV and supplemental oxygen may be needed if

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**Table 1. Evidence About Novel Uses of CPAP and NIV**

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* A: Good scientific evidence suggests that the potential benefits substantially outweigh the risks. Discuss the treatment with eligible patients.

B: At least fair scientific evidence suggests that the potential benefits outweigh the risks. Discuss the treatment with eligible patients.

C: At least fair scientific evidence suggests that there are benefits, but the balance between benefits and risks is too close to make a general recommendation. Do not offer the treatment unless there are individual considerations that suggest it.

D: At least fair scientific evidence suggests that the risks outweigh the potential benefits. Do not routinely offer the treatment.

I: Evidence is insufficient to recommend for or against the treatment.

† Noninvasive ventilation (NIV) should be used if continuous positive airway pressure (CPAP) is found ineffective.

(Based on data in Reference 50.)
CPAP is inadequate; this therapy improves daytime blood gas values, quality of life, and probably survival.

Summary

Table 1 summarizes the strength of the evidence for currently novel CPAP and NIV applications. The use of CPAP and NIV will probably continue to grow as improved technology and creative clinicians attempt to treat more complicated conditions.

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33. Li TS, Gomersall CD, Joynt GM, Chan DP, Leung P, Hui DS. Long-term outcome of acute respiratory distress syndrome caused by


Discussion

Hill: Upper-abdominal surgery has for years been on many lists of contraindications to NIV, on the reasoning that the sutures might be stressed by the pressure. Was there any comment on that in the literature you reviewed? Is there good reason for that concern?

Benditt: I did not see any articles that stressed that point, though they did list complications related to surgical mishaps from overinflation. At my hospital a lot of surgeons go to CPAP or BiPAP [bi-level positive airway pressure] ventilation very quickly, especially after thoracic surgery—right after extubation.

Hill: I’m not aware of any literature that substantiates that concern. We use relatively low NIV pressures, of course, and studies that have used postoperative CPAP or NIV have not reported any problems with suture integrity,1,2 but this concern seems to be universal. Many people have told me, “Our surgeons are really hesitant to use NIV.” Has anybody else encountered that?


Nava: Yes. Think about what you do with these patients. You get the physiotherapist to do some exercises right after surgery, because you want to avoid atelectasis, and they sometimes apply the positive pressure. So I think we are a little bit misled by that paper, because it tells us that you can do physiotherapy without a human being there, because CPAP is a physiotherapy approach; it’s not ventilatory support.

Hill: You’re saying that you need to expand the lungs?

Nava: Exactly. Instead of having a physiotherapist come twice a day, you apply the helmet and you do physiotherapy. When you expand the lungs, even voluntarily, you generate an “abnormal” pressure, so it’s the same concept.

Hill: But the pressure that surgeons are concerned about is on the upper gastrointestinal tract. With physiotherapy, you wouldn’t be applying pressure there. So maybe it would be a preferable therapy?

Benditt: In one study1 they gave all patients physiotherapy and acetylcysteine to try to control for that. I think the intervention had an effect beyond the physiotherapy. But I agree that it
has to do with maintaining patency of airways and alveoli.


Gay: Probably 4 or 5 times in the past couple of years I’ve seen patients with acromegaly who needed pituitary resection. They’ve got severe apnea and obviously they’re going to have potential cerebrospinal-fluid disruption, so surgeons aren’t going to want any positive pressure near that at all. There is debate whether one should get a tracheostomy. There are some anecdotal reports, but nothing that provides a good guide, and I’ve seen both extremes. On the one hand there are patients with relatively minor OSA [obstructive sleep apnea] with their noses packed, and they’re miserable postoperatively and getting narcotics; they don’t get CPAP and they get into a lot of trouble. Then there are those you anticipate and tracheotomize, but they might have just flown through this. Most of the surgeons urge no postoperative positive airway pressure at all, so we do end up tracheotomizing some of the more serious OSA patients now.

Benditt: We do not see those kinds of patients.

Doyle:* At the last AARC [American Association for Respiratory Care] meeting I saw an abstract on auto-titrating CPAP with undiagnosed OSA patients postoperatively. They used a modified Berlin questionnaire before intubation in the operating room, and found significant postoperative improvement with CPAP. Did you see any papers on that application?

Gay: Anesthesiologist Bhargavi Gali, at Mayo Clinic, does a preoperative assessment of higher-risk OSA patients, with the Calgary score. They identify higher-risk patients, and if the patient desaturates for an extended period in the recovery room, they go to a more heavily monitored area. They’re not really determining a treatment approach; they’re determining who needs to be monitored more carefully. When we try to do just-in-time rescue therapy with CPAP, then it is difficult. Think about it: these patients are miserable; they’re just getting out of surgery; the mask is on for about 10 minutes and then it’s on the floor. So trying to figure out where best to monitor these people is the better mindset. Perhaps the more important thing is making a decision on where to monitor them without swallowing up every ICU bed.

Mehta: Baillard et al1 used NIV prior to semi-urgent intubation, and NIV reduced the nadir of oxygen saturation during the intubation. Did you review that paper?


Benditt: I did not.

Mehta: Yes, the saturation was higher.

Hill: They had such a good response to oxygen, I wondered why they intubated all of them afterwards.

Doyle: Regarding concern about NIV with infectious-disease patients, clearly there’s a plume of aerosol coming out of the opening of a single-limb NIV system, but the exhaled gas from an intubated patient also ends up in the ambient air unless the exhaled gas is filtered. However, many of the invasive ventilators do not have exhalation filters, so clinicians may have a false sense of security with invasive ventilation. Near the gas output port they could be exposed to an infectious aerosol. In those studies was the gas filtered?

Kacmarek: In every one that I’m aware of the recommendation is to put a filter on the expiratory port, which is easy with an intubated patient, and very difficult without NIV.

Hill: I have a problem with the AARC’s statement that NIV should not be used for SARS. I think that’s going too far on the available data. I don’t think we know what happens under these circumstances, and I don’t know that David Hui’s findings tell us exactly what’s going to happen. A couple other studies found very low rates of disease transmission when health-care workers were exposed to patients with SARS on NIV. So I’m not convinced that NIV is a poor choice.

There are ways to filter expired air from BiPAP, and you can use a dual-limb circuit during NIV if you’re really concerned about infectious aerosol. As Geeta [Mehta] pointed out, in the Toronto epidemic it was during intuba-
tion that there seemed to be a lot of trouble. I don’t think we have enough evidence to make a firm statement that NIV is contraindicated. If I get pneumonia from bird flu, I’ll try NIV first, and you can intubate me if it doesn’t work.


**Benditt:** Actually I think the AARC statement didn’t address the infectious aerosol. Rather, the statement was based on the prediction that many of pandemic patients will progress to ARDS [acute respiratory distress syndrome] (though the evidence on that is debatable) and NIV is not the standard of care for ARDS. And in a mass-casualty situation the time required for NIV initiation would be prohibitive.

**Hill:** Now wait a damn minute! I know you’re just describing what they said, but how much time does it take to intubate someone? How much skill does it take? In an epidemic are you going to have hundreds of health-care workers greasing up endotracheal tubes to intubate all these people? Come on: NIV is so much easier to apply, and with a cooperative patient who has some dyspnea it doesn’t necessarily take a lot of additional time. I don’t buy that.

**Kacmarek:** I respectfully disagree. In that situation it’s much easier to deal with an intubated patient. You’ve done it; it takes a long time to acclimate a patient to NIV. If any of the predictions are near correct about the number of health-care workers that will be available, we will not be able to do NIV. If 40% of the population is sick and you’ve cut down your staff by 40% and you’ve doubled or tripled or quadrupled the number of patients with acute respiratory failure, you will not be able to spend an hour or two to initiate NIV. These patients can be intubated in minutes and started on mechanical ventilation. From the work perspective, I agree 100% that NIV would be difficult to do. I don’t think there is as much concern about transmitting the organism via NIV as is raised in some of the discussions, but from a work perspective I think intubation clearly is the way to go in that setting.

**Keenan:** Where I work we simply would not be able to provide enough invasive ventilation during an epidemic, because we don’t have enough ventilators, so we would be forced to use everything available to us, including NIV. The most important thing is to know how to make NIV safe in that setting, and it appears that if you’re properly gowned and protected, you can probably use NIV. I understand the concern that patients will develop ARDS [acute respiratory distress syndrome], and some of them will decompensate and not be adequately supported by NIV, and will require intubation. However, even today we have difficulty coping with our current patient needs for ventilatory support. I don’t know how we would cope with a superimposed epidemic. I imagine we would have to pull out all available ventilators, including NIV. So it may not be ideal, but we need to know how to do it safely.

**Kacmarek:** You can use noninvasive ventilators invasively. There’s no reason to relegate them only to NIV. Most NIV ventilators that are designed for use in acute care are approved for invasive use, and those that are not can be safely used if monitors are added.

**Mehta:** I respectfully disagree with Nick. With a patient with influenza or another highly contagious respiratory disease, if I had the choice of NIV or intubation, I would intubate. We had SARS at my hospital, and I think the risk of transmitting infection is a lot higher with NIV than with intubation, as your image of the NIV exhaled aerosol plume showed. And we don’t have enough negative-pressure rooms, which would be even more important for patients treated with NIV.

**Hill:** I’ll have to take a minority position here. With regard to preventing transmission, protection is the most important thing. Regarding clinician work load, we found that it takes a bit more time to initiate NIV, but I don’t think it requires 90 to 120 minutes of dedicated time at the bedside. It’s possible to initiate multiple masks if the patients are near to each other.


**Kallet:** I side with Bob on this. I think it’s going to be a crap-shoot! Patients with fulminate ARDS will get intubated straight away.

**Hill:** I don’t argue with that, but I think there are people who are going to be on the edge, who are dyspneic and hypoxemic but otherwise stable, and you’re going to have to use what you have. I’m not saying everybody should go on NIV. My objection is that if you say NIV should not be used, that’s going too far. There may be patients in whom NIV is appropriate, and I think the AARC statement should say that patients with fulminant ARDS...
should definitely be intubated, but that you can consider NIV in dyspneic, hypoxemic patients who are less ill.

**Kallet:** That’s very reasonable. When we were talking about preparing for an avian flu pandemic, one idea that came up was to maybe find a way to cheaply mass-produce something like the old Down’s flow generators for mask CPAP. A lot of people may be able to get that and we’ll just have to cross our fingers that it’ll be sufficient. We’re going to have to triage our equipment in a pandemic situation. At my hospital we’re not going to have the luxury of spending much time with any one patient. Each respiratory therapist might have to cover 20 or more ventilators, whether invasive or NIV. So I think the situation will dictate what actually happens: whether we do the therapy the way we want to do it or we’re just trying to stabilize oxygenation and save as many people as possible.

**Nava:** Would you use an air-entrainment mask, or a reservoir mask? The aerosol contamination risk is about the same with supplemental oxygen or NIV, I suspect. I agree with Nick that not all hypoxic patients need to be intubated, and I don’t think we can afford to intubate all the patients. NIV is for a subset of less-sick patients. This may be a situation in which a helmet is useful, because it would protect clinicians from aerosol infection risk, because everything is enclosed inside it. And the risk of putting on or removing a helmet should be the same as that of extubating or suctioning a patient with an endotracheal tube.

**Benditt:** A bench study found that the spread of aerosol particles was clearly related to the pressure in the mask, and at lower pressure there was a much lower dispersion, so I don’t think an air-entrainment mask has the same risk as BiPAP at, say, 18/4 cm H₂O. I think they showed that pretty clearly.