Successful Use of Noninvasive Ventilation in Chronic Obstructive Pulmonary Disease

How Do High-Performing Hospitals Do It?

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Abstract

Rationale: Noninvasive ventilation (NIV) is a cornerstone of treatment for patients with severe exacerbations of chronic obstructive pulmonary disease (COPD), where it has been shown to reduce the need for intubation, hospital length of stay, and mortality. Despite high-quality evidence and strong recommendations in clinical guidelines, use of NIV varies widely across hospitals.

Objectives: To identify approaches used by hospitals that have been successful in implementing NIV to treat patients with severe exacerbations of COPD.

Methods: Adopting a positive deviance approach, in-depth interviews were conducted with key stakeholders from a sample of high-performing hospitals selected from a large and representative network of 386 U.S. hospitals. High performers were defined as hospitals in which a high proportion of patients with COPD requiring mechanical ventilation were treated with NIV, and that also achieved low risk-adjusted mortality for all patients with COPD. Interviews were audio-recorded and transcribed verbatim. Themes and subthemes were identified through iterative readings of the transcripts and discussion until the team agreed that all important themes and subthemes had been identified. All transcripts were coded by three or four researchers. Differences in coding were discussed to negotiate consensus, resulting in a single agreed-on set of coded transcripts.

Results: Interviews were conducted with 32 participants from seven hospitals. Hospitals were diverse regarding size, teaching status, and geographic location. Participants included respiratory therapists (n = 15), physicians (n = 10), and nurses (n = 7). The qualitative analyses revealed three interrelated domains that characterized effective NIV use: processes, structural elements, and contextual factors. Several themes comprised each domain. Key processes included timely identification of appropriate patients, early initiation of NIV, frequent reassessment of patients, and attention to patient comfort. Necessary structural elements included adequate equipment, sufficient numbers of qualified respiratory therapists, and flexibility in staffing. Important contextual factors included provider buy-in, respiratory therapist autonomy, interdisciplinary teamwork, and staff education. Hospital leaders, policies, and protocols were identified as playing a supporting role in promoting essential elements.

Conclusions: We identified factors, such as respiratory therapist autonomy, that facilitated essential processes (e.g., timely initiation) of NIV use at high-performing hospitals. These findings may be useful to hospitals seeking to optimize their use of NIV among patients with COPD.

Keywords: health services research; noninvasive ventilation; chronic obstructive pulmonary disease

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Chronic obstructive pulmonary disease (COPD) is a major public health problem. It affects more than 15 million people and is the third leading cause of death in the United States (1, 2). Acute exacerbations of COPD (AE-COPD) result in close to 700,000 hospitalizations annually (3). Noninvasive ventilation (NIV) has been established as an important component of treatment for patients with severe AE-COPD, and is the only treatment for AE-COPD that improves mortality. Other benefits of NIV include alleviation of dyspnea, reduced need for invasive mechanical ventilation (IMV), prevention of ventilator-associated pneumonia, and decreased hospital length of stay, compared with standard oxygen therapy (4–7).

Despite the well-established benefits of NIV, its application in routine clinical practice has been variable, with evidence that NIV is underused by some hospitals. In one study, only one-third of patients who met criteria for a trial of NIV before intubation received it (8). Other studies have found wide variation across hospitals in the use of NIV for patients with AE-COPD (9, 10). For example, one study found that the risk-standardized percentage of noninvasive ventilator starts ranged from 9 to 94%, in a large sample of U.S. hospitals (9).

Delivering NIV to patients with acute respiratory failure is a complex process that requires timely recognition, as well as communication and coordination across multiple disciplines. Therefore, it is not surprising that its adoption has been variable. Survey studies suggest that lack of physician knowledge, insufficient respiratory therapist training, inadequate equipment, and unavailability of a respiratory therapist or NIV equipment in the emergency department may explain low use rates (11, 12). Although previous studies have focused on barriers to NIV use, less is known about the strategies and factors associated with successful implementation.

Positive deviance is a research approach based on the premise that solutions for common problems can be discovered by studying successful organizations, or so-called “positive deviants” (13). The positive deviance approach has been used to identify strategies and contextual factors that facilitate improvement of complex clinical processes, such as reducing door-to-balloon time for acute myocardial infarction (14),

and interest in this method has been growing. We hypothesized that hospitals with high rates of NIV use may be able to offer insights into their success, which could be helpful for institutions seeking to improve their use of NIV. Accordingly, we adopted a positive deviance approach to identify strategies used by hospitals that have been successful in implementing NIV to treat respiratory failure among patients with COPD. Some of the results of this study have been previously reported in the form of an abstract (15).

Methods

Study Design and Sample

We conducted in-depth interviews with key stakeholders from a sample of high-performing hospitals selected from the Premier Analytic Database, a large and representative network of 386 U.S. hospitals. We defined “high performers” as hospitals with a high risk-standardized proportion of NIV use among ventilated patients, and a low in-hospital mortality rate among all patients with COPD. We chose to use the mortality rate among all patients with COPD as a criterion for selection, rather than the mortality rate among ventilated patients, to avoid the potential bias that might arise if high hospital use of NIV was the result of expansion of NIV in less severely ill patients.

Using data from the Premier Analytic Database, we computed risk-standardized rates of mechanical ventilation (NIV or IMV) and mortality among all patients hospitalized with COPD between July 1, 2009, and June 30, 2011. Restricting the sample to ventilated patients, we computed risk-standardized proportion of ventilator starts that were noninvasive, and NIV failure (proportion of patients started on NIV who required IMV). Models included patient age, sex, comorbidities, and prior hospitalization in the last year for COPD as previously described (9). To identify high-performing institutions, we first selected hospitals in the top quartile for risk-standardized NIV proportion ($>75\%$ of ventilator starts were NIV). We then limited the sample to hospitals whose risk-standardized mortality rate among all patients with COPD was below the median ($<2.05\%$). Finally, we restricted the sample to hospitals with an overall risk-standardized mechanical ventilation (NIV

or IMV) rate of at least 20%, to exclude hospitals that used mechanical ventilation infrequently.

A total of 44 hospitals met the above criteria. Staff within Premier sent an initial letter inviting high-performing hospitals to participate in the study. For those who expressed interest ($n = 11$), we contacted the hospital leader provided by Premier and requested names and contact information for stakeholders deemed most likely to be informative at their institution. Four hospitals declined to participate at this stage.

We conducted purposive sampling to ensure inclusion of participants with varied roles at each hospital. At each of the participating hospitals, we sought to interview individuals with specific relevant knowledge of NIV use at their institution and to include individuals with diverse perspectives on NIV use. This included respiratory therapist and physician directors of respiratory care, medical directors of the intensive care unit (ICU), medical and nursing leaders from the emergency department, nurse managers on general medicine units, and front-line clinical staff (physicians, nurses, respiratory therapists). We asked interviewees to suggest other key informants to ensure we interviewed all stakeholders with relevant knowledge of NIV use. The Institutional Review Board at Baystate Medical Center approved the study. Study participants gave informed consent for participation in the study.

Data Collection

We developed an interview guide (see Table E1 in the online supplement), using existing literature of barriers and facilitators of NIV use (11, 16), hypotheses generated from studies of implementation of other complex clinical processes (14), and input from clinicians with experience providing NIV. We conducted pilot interviews with individuals who were representative of our target study population, including ICU leaders and frontline clinicians responsible for providing NIV. We revised the interview guide on the basis of these interviews.

After undergoing interview training, one member of the research team (L.A.W.) conducted in-depth, open-ended interviews with all participants. The interviewer was closely supervised by members of the investigator team experienced in training and supervising interviewers. All interviews

covered the topics in the interview guide. In addition, open-ended probes were used to explore themes that arose in individual interviews and to elicit details about participants' experiences. Interviews were audio-recorded and transcribed verbatim. Transcripts from initial interviews were reviewed, prompting minor revisions to the interview guide to improve the interview flow.

Data Analysis

Using thematic analysis (17), themes and subthemes were inductively generated through iterative readings of a subset of transcripts, and discussion among team members until consensus was reached that all important themes and subthemes had been identified. As additional transcripts were read, the coding framework was expanded until no new themes emerged. All interview transcripts were coded manually by a team of three or four researchers (V.R., L.A.W., K.A.F., K.M.M.) with diverse backgrounds including critical care medicine, health services research, and qualitative research. All transcripts were first coded independently by two researchers, and then discussed by the full coding team to negotiate consensus and result in a single agreed-on set of coded transcripts. We achieved thematic saturation with no new themes identified during coding of the final 21 transcripts.

We took several measures to ensure trustworthiness of our findings. These included triangulation of sources (sampling participants with divergent perspectives) and analysts (multiple independent coders) (18). In addition, we used an audit trail to track discussion of the framework and changes to the framework at all stages. All data were entered into SPSS version 22

(IBM, Armonk, NY) to facilitate data review, manipulation, analysis, and reporting.

Results

The characteristics of the participating hospitals ($n = 7$) are shown in Table 1. Hospitals were diverse regarding size, teaching status, and geographic location. Interviewees included respiratory therapists ($n = 15$), physicians ($n = 10$), and nurses ($n = 7$). Stakeholders representing at least two different roles were included at all hospitals with more than one participant. Of the 32 interviewees, 25 were employed by the hospital in question within the timeframe that was used for determination of NIV performance, and six of the remaining participants joined the high-performing hospital within 1 year.

The qualitative analyses revealed three interrelated domains that characterized effective NIV use: processes, structural elements, and contextual factors. Each domain was composed of several themes. We present a model (Figure 1) of the potential relationship between domains and themes suggested by our findings. All domains and themes were identified by at least one participant from all seven hospitals.

Processes

Timely identification of appropriate patients and early initiation of NIV. Most participants identified timely initiation of NIV as critical to the successful use of this intervention. Participants cited delays in NIV initiation as increasing the likelihood of needing intubation. For example, one

respiratory therapist described, "*The more you wait, the odds of it working dwindle. Ten minutes can be the whole difference*" (#32).

Participants specified several approaches that facilitate timely identification of appropriate patients and early initiation of NIV (Table 2). Nurses and respiratory therapists were recognized as playing a key role in identifying patients who might benefit from NIV because of their more frequent presence at the bedside as compared with physicians. Features of the decision-making process that promoted NIV use included being willing to try NIV on most patients, while being cognizant of contraindications. One physician stated, "*unless they actually meet the criteria for intubation...our go-to is noninvasive*" (#59).

Frequent reassessment of patient status and maintenance. Frequent reassessment of patients after NIV initiation was considered essential. One physician stated "*You can't just strap a machine on someone and walk away. It takes time, it takes adjustment, and you have to be committed to trying to use the device and try to troubleshoot it instead of just putting it on and assuming it's going to solve all of your problems*" (#57).

This was achieved via close monitoring. Many hospitals required transfer to the ICU to provide close monitoring. At least one participant from each hospital recognized the importance of responding to changes in patient status and being prepared to escalate care if the patient did not respond to NIV. Comprehensive treatment, including attention to other therapies for AE-COPD such as bronchodilators and steroids, as well as addressing comorbidities, fluid status, nutrition, and physical therapy, was universally noted to be necessary for NIV to be successful.

Table 1. Characteristics of participating high-performing hospitals

Hospital	No. of Participants Interviewed	Setting	Teaching Status	Licensed Beds	Location	Risk-Standardized NIV Proportion* (%)	Risk-Standardized NIV Failure† (%)	Risk-Standardized Mortality‡ (%)
1	7	Urban	Teaching	<200	Northeast	81.8	5.51	1.54
2	2	Urban	Teaching	>400	West	89.9	9.65	1.92
3	6	Urban	Teaching	>400	West	89.4	8.69	1.98
4	5	Urban	Nonteaching	200–400	South	80.9	6.86	1.59
5	1	Urban	Nonteaching	200–400	South	86.0	13.54	2.03
6	9	Urban	Nonteaching	<200	Northeast	87.4	5.95	1.61
7	2	Urban	Nonteaching	<200	South	78.7	8.91	1.89

Definition of abbreviation: NIV = noninvasive ventilation.

*Percentage of ventilated patients started on NIV.

†Percentage of patients started on NIV transitioned to invasive mechanical ventilation.

‡Percentage of all patients with chronic obstructive pulmonary disease, ventilated or not, who died in the hospital.

Figure 1. Relationship between domains and themes identified by high-performing hospitals. RT = respiratory therapist.

Maintaining patient comfort. Close attention to patient comfort on NIV was cited by participants from all hospitals as central to their success. One participant stated, “If the patients can be comfortable with this mask, it’s going to be worth a lot more to them than not using it at all” (#9). However, this was also identified as a challenge because “many of these patients are extremely anxious and panicking and getting them to accept using a face mask can be challenging” (#51). High-performing hospitals employ multiple approaches to maintain patient comfort on NIV (Table 2).

Structural Elements

Equipment. Adequate equipment was noted to be essential because providers “have to have the right equipment that they need to do their jobs” (#5). Several interviewees encountered challenges with having sufficient numbers of NIV machines. Strategies for overcoming this resource limitation included renting units, and the availability of ventilators capable of delivering IMV or NIV. NIV machine quality was also noted by participants to contribute to successful NIV use. Benefits of high-quality machines cited by participants included increased patient comfort and compliance, ease of ascertaining delivered volumes, transport capability, and less noise. Participants noted the importance of NIV mask quality and having a range of mask types and sizes. Several participants commented on

improvements in masks, with newer masks that “fit better, they don’t have to be put on as tightly” (#68) resulting in increased patient comfort and less skin breakdown.

Staffing. Adequate number and skill level of respiratory therapists was identified as crucial to NIV implementation. Successful use of NIV can be time intensive, requiring “someone staying with the patient so they understand getting used to the machine” (#1). In addition, adequate staffing is required to closely monitor patients. One participant noted “staffing is a big deal because these patients, if they’re not looked at, they can turn bad pretty quickly” (#30). Many participants faced challenges in meeting staffing needs. In some cases, this was overcome by flexibility in deployment of respiratory therapists depending on patient needs and acuity. Many participants also noted the availability of pulmonologists or intensivists as important to their success.

Contextual Factors

Buy-in. Nearly all participants highlighted the central role of clinician buy-in with statements indicating that clinicians are generally “on board” with NIV as preferential to intubation. This was described by one nurse as “buy-in all the way around, from the physicians, to the nurses, to the respiratory therapists...everybody has realized that that’s a better way of managing patients instead of intubating them and putting them on a ventilator” (#4).

Buy-in translated into a default approach to start with NIV, as a “knee jerk reflex for them to give to somebody...having COPD flare and then they just ask for NIV” (#52). This approach in turn led to improved identification of appropriate patients and more timely initiation of NIV. Several factors were noted as leading to buy-in, including education of providers (Table 3).

Respiratory therapist autonomy. All high-performing hospitals gave respiratory therapists the autonomy to perform many activities related to NIV independently. This was cited as a key factor in ensuring timely initiation of NIV, where “giving the therapists the ability to have the responsibility or whatever to respond and initiate and not be standing there waiting for somebody to tell them that they can or what they should or, that’s I think 100% the main factor” (#32).

The degree of respiratory therapist autonomy varied among hospitals. At some, participants described “respiratory kind of has free range” (#36), whereas at others it is “a relatively informal process that’s still compliant with the necessity to have a physician order” (#38). Activities that respiratory therapists performed autonomously included initiating NIV, establishing initial settings, mask fitting, and titrating settings. In some hospitals, respiratory therapists initiated NIV, and then asked physicians for an order. Even in cases where respiratory therapists were not fully autonomous, they were considered to be highly influential, especially regarding the decision to initiate NIV. Interviewees identified several factors that contribute to respiratory therapist autonomy (Table 3).

Teamwork. Nearly all participants noted the importance of interdisciplinary teamwork. One physician described it as follows: “So definitely there is kind of a collaborative team approach of multiple members of the health care team, not just the physicians, but also RT, kind of recognizing when noninvasive ventilation might be useful” (#13).

Some participants also cited the importance of teamwork among respiratory therapists with systems to provide support and backup. Most participants described a positive relationship between respiratory therapists and nurses, although two interviewees indicated that tension with nurses over conflicting priorities could be a barrier to keeping patients on NIV. Open

Table 2. Key processes for noninvasive ventilation use and strategies that facilitate processes at high-performing hospitals

Process	Facilitators
Timely identification of appropriate patients and early initiation of NIV	Initiation of NIV not restricted to intensive care unit
General	Rapid response team
	Education of providers regarding importance of timely initiation
	Storing NIV equipment in easily accessible location
Emergency department specific	Respiratory therapist autonomy to initiate NIV
	Prehospital notification by emergency medical services of patients who might need NIV
	Availability of NIV equipment in the ED
	Respiratory therapist dedicated to the ED
Maintain patient comfort on NIV	
Relational approaches	Establish trust with the patient
	Comfort and calm the patient
	Educate the patient regarding expected benefits of NIV
Physical approaches	Involve the patient's family as part of the care team
	Convince patients to try NIV for a short time
	Careful attention to mask fit
	Measures to prevent skin breakdown
	Judicious use of anxiolytics
	Slow increase (ramp) in inspiratory pressure
	Minimize noise from alarms
	Individual adjustment of room temperature and air circulation

Definition of abbreviations: ED = emergency department; NIV = noninvasive ventilation.

and easy communication between team members was noted as essential to interdisciplinary teamwork. Physicians were described by a respiratory therapist as *"always receptive to our calls. They want us to help them take care of their patients"* (#38). Factors promoting teamwork and communication are presented in Table 3.

Education. Didactic education and experiential learning were noted to increase uptake and use of NIV and to ensure appropriate application. One hospitalist described the importance of *"an educational piece to give us a little bit more information and tools for us as hospitalists to feel more comfortable ordering it and becoming a little bit more savvy about how to adjust the settings...His efforts have been really valuable in helping a broader spectrum of doctors to better utilize NIV"* (#13).

Respiratory therapists frequently mentioned the need for ongoing in-services to keep them informed of new developments in NIV use. Several participants also noted the importance of nurse education with one nurse stating, *"If something happens, or what not, we need to know if something's wrong. We need to be educated on this"* (#61). In addition to didactic education, participants described

how experiential learning led to increased NIV use through greater provider experience, comfort, and buy-in.

System-Level Approaches

Hospital policies and protocols. Hospital policies and protocols were described by most participants as playing a supporting role in NIV implementation. Protocols were noted by many participants as a means of increasing respiratory therapists' autonomy, which in turn facilitated timely intervention. Other participants noted the usefulness of protocols in making NIV more accessible to all physicians because *"creating clear protocols make it easier to follow and implement"* (#3). Protocols were also noted to be useful in delineating which patients are appropriate for NIV, directing proper NIV settings, and establishing clear parameters for follow-up assessments. Several participants reported that the lack of an NIV protocol at their hospital was a limitation to NIV use.

Several hospital policies were identified as relevant to NIV implementation. The most commonly mentioned policy was not restricting NIV initiation to the ICU. Some

hospitals required patients who were started on NIV to be transferred to the ICU or step-down unit, whereas others left this to the discretion of the bedside providers. In many cases, participants indicated that they were unfamiliar with or did not know if their hospital had policies related to NIV.

Hospital leadership. Participants described the role of hospital leadership as providing funding for equipment and staffing (structural elements), and support for contextual elements such as teamwork, respiratory therapist autonomy, and protocol development. As stated by one participant, *"the administration has to support your process. They have to support your team approach, that you...have the resources, whether it be respiratory therapists or physicians to manage all the pieces"* (#22).

Quality improvement efforts. Most participants indicated that their hospitals had not undertaken NIV-specific quality improvement (QI) efforts. However, many participants described QI efforts targeting related topics that might indirectly affect NIV use, such as efforts to prevent ventilator-associated pneumonia, decrease ventilator days, and shorten hospital length of stay. Participants at one hospital reported monthly meetings to review patients who failed NIV and attention to the number of days that patients were treated with NIV as an effort to improve NIV use. Other participants described education of respiratory therapists, efforts to prevent skin breakdown, NIV machine cleaning, and avoiding inappropriate use of NIV as approaches to ensuring quality regarding NIV use. In one case, a QI initiative led to stocking of higher quality NIV masks that resulted in improved patient comfort and decreased skin breakdown.

Discussion

To our knowledge, this is the first study to use a positive deviance approach to characterize NIV implementation at hospitals that achieve a high rate of NIV use with good outcomes for patients with AE-COPD. The most salient features of NIV use described by all participating hospitals in our study included timely initiation, frequent reassessment of patients, and close attention to patient comfort. These were achieved through adequate resources and specific contextual factors. Systems-based

Table 3. Contextual factors that promote noninvasive ventilation use and facilitators of contextual factors at high-performing hospitals

Contextual Factor	Facilitators
Buy-in	Provider education Physician champion(s) Focus on data such as ventilator days Appreciation of NIV benefits through positive experience with NIV (experiential learning)
Respiratory therapist autonomy	Limited physician availability (necessity) Respiratory therapist–driven protocols Respiratory therapist expertise and capability Supportive hospital leadership Collegial relationship between respiratory therapists and physicians
Teamwork	Trust and respect between team members Geographic assignments of respiratory therapists or physicians Electronic medical record Electronic communication devices (cell phones, two-way communicators)

Definition of abbreviation: NIV = noninvasive ventilation.

approaches appeared to play a supporting role in NIV use. This study identifies specific processes and approaches that hospitals seeking to improve their use of NIV can adopt to optimize application of this evidence-based treatment.

Previous studies of NIV use have identified physician awareness, adequate equipment, staffing, and the presence of guidelines or protocols as being associated with NIV use (11, 12, 19, 20). These studies have been limited by their use of participant estimation of NIV use to measure associations. Our work expands on these findings by sampling participants from hospitals identified as high-performers through direct ascertainment.

We have identified several novel characteristics of high-performing hospitals that appear to be essential to the successful application of NIV. In particular, respiratory therapist autonomy, interdisciplinary teamwork, and provider buy-in were universally reported by all participating hospitals as crucial factors in their success. Prior studies have not identified these characteristics, likely due to methodologic differences and lack of respiratory therapist and/or nursing participation in some studies (11, 19, 21). These findings are consistent with positive deviance studies in other clinical areas, including myocardial infarction treatment (14, 22), reducing readmissions (23), and improving discharge planning (24), which have similarly found contextual factors such as interdisciplinary collaboration, shared goals (buy-in), and

staff autonomy to be important themes in high-performing hospitals, illustrating the value of this approach.

Our findings suggest respiratory therapist autonomy is key to achieving timely initiation of NIV, often facilitated by the use of protocols. This is in keeping with the literature demonstrating the benefits of autonomous respiratory therapist practice through the use of therapist-driven protocols in several clinical areas including weaning from mechanical ventilation (25, 26), ensuring proper allocation of respiratory care services (27, 28), educating patients in COPD self-management (29), and weaning from NIV (30). Our work suggests that increasing respiratory therapist autonomy to initiate NIV, while providing appropriate supervision after initiation, may be an effective improvement strategy for hospitals with low rates of NIV use.

Effective interdisciplinary teamwork was a prominent feature of high-performing hospitals in our study. In particular, a positive, trusting relationship between respiratory therapists and physicians was noted to be an important facilitator of respiratory therapist autonomy. Studies of teamwork in other industries have suggested that a flat hierarchical structure may promote teamwork by allowing members to feel comfortable raising concerns (31). It is possible that by flattening the hierarchy that traditionally characterizes medicine, respiratory therapist autonomy may in turn promote effective teamwork, suggesting a bidirectional relationship between these elements.

The importance of interdisciplinary teamwork suggests that approaches to support and encourage teamwork may promote successful NIV use. Teamwork training has been shown to improve the performance of other complex and time-sensitive clinical processes in diverse fields including trauma (32), and obstetrics (33, 34). Teamwork training is therefore one promising means of achieving this, although our study was not designed to evaluate this. Tension between nurses and respiratory therapists was occasionally noted even among the high-performing hospitals in our study. It is possible that nursing and respiratory therapist interactions may be a barrier to NIV use at hospitals with low use and an important target for improvement, although our study was not designed to confirm this.

Clinician buy-in to NIV as a beneficial therapeutic option was a crucial component of NIV implementation at all hospitals. Our empiric finding confirms earlier assertions of the importance of buy-in to NIV implementation (35, 36). We identified several means of promoting buy-in, many of which relied on education and experiential learning. This is consistent with survey studies, which have found lack of physician knowledge and insufficient respiratory therapist training as common reasons for perceived lower use of NIV (11, 12, 19).

Our study has several strengths. We used an open-ended interview approach that allowed us to identify novel characteristics of effective NIV use. Rather than being limited to academic centers, the high-performing hospitals included in our sample were drawn from a geographically and structurally diverse network, enhancing the generalizability of our findings. We interviewed multiple types of providers, ensuring representation of all relevant perspectives. Finally, using a positive deviance approach, our study provides concrete strategies hospitals can pursue to improve the use of NIV.

Despite these strengths, our results should be interpreted in light of several limitations. The sample size is small, and therefore we may not have identified all strategies used by high-performing hospitals. Our definition of high-performing hospitals includes those with a low risk-standardized mortality among patients with COPD. This measure accounts for several patient characteristics, but does not include physiologic variables that reflect disease

severity. It is therefore possible that the low risk-standardized mortality in our high-performing hospitals is in part related to caring for less severely ill patients. Some participants were not employed by the hospital at the time it was determined to be a high-performing hospital. However, the vast majority (>95%) were either working at the hospital at the time of the NIV performance determination or within 1 year, during which timeframe many of the elements described are unlikely to have changed substantially. Although we describe characteristics of hospitals that are currently known to be high-performers, the factors needed to improve performance may differ. We present a model

(Figure 1) as a way of conceptualizing potential relationships between factors likely to affect NIV use and to provide a framework for generating hypotheses, but acknowledge these relationships are not definitively established by our findings. Finally, because we did not compare high-performing hospitals with low-performing hospitals, we cannot confirm whether the findings we report distinguish high-performing from low-performing hospitals.

Conclusions

Using a positive deviance approach, we have characterized key aspects of the complex process of NIV implementation at

high-performing hospitals and have described several important, yet previously unidentified features, including interdisciplinary teamwork, respiratory therapist autonomy, and provider buy-in. Quantitative studies are needed to test which of the factors we identified are associated with NIV performance in a large sample of hospitals. ■

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