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Original Research

CRITICAL CARE

Use and Outcomes of Noninvasive Positive Pressure Ventilation in Acute Care Hospitals in Massachusetts

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Background: **This study determined actual utilization rates and outcomes of noninvasive positive pressure ventilation (NIV) at selected hospitals that had participated in a prior survey on NIV use.**

Methods: **This observational cohort study, based at eight acute care hospitals in Massachusetts, focused on all adult patients requiring ventilatory support for acute respiratory failure during predetermined time intervals.**

Results: **Of 548 ventilator starts, 337 (61.5%) were for invasive mechanical ventilation and 211 (38.5%) were for NIV, with an overall NIV success rate of 73.9% (ie, avoidance of intubation or death while on NIV or within 48 h of discontinuation). Causal diagnoses for respiratory failure were classified as (I) acute-on-chronic lung disease (23.5%), (II) acute de novo respiratory failure (17.9%), (III) neurologic disorders (19%), (IV) cardiogenic pulmonary edema (16.8%), (V) cardiopulmonary arrest (12.2%), and (VI) others (10.6%). NIV use and success rates for each of the causal diagnoses were, respectively, (I) 76.7% and 75.8%, (II) 37.8% and 62.2%, (III) 1.9% and 100%, (IV) 68.5% and 79.4%, (V) none, and (VI) 17.2% and 60%. Hospital mortality rate was higher in patients with invasive mechanical ventilation than in patients with NIV (30.3% vs 16.6%, $P < .001$).**

Conclusions: **NIV occupies an important role in the management of acute respiratory failure in acute care hospitals in selected US hospitals and is being used for a large majority of patients with acute-on-chronic respiratory failure and acute cardiogenic pulmonary edema. NIV use appears to have increased substantially in selected US hospitals over the past decade.**

Trial registry: **ClinicalTrials.gov; No.: NCT00458926; URL: www.clinicaltrials.gov**

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Abbreviations: ARF = acute respiratory failure; CHF = congestive heart failure; CPE = cardiogenic pulmonary edema; DNI = do not intubate; DNR = do not resuscitate; ETI = endotracheal intubation; INV = invasive mechanical ventilation; NIV = noninvasive positive pressure ventilation; PNA = pneumonia; SAPS = Simplified Acute Physiology Score

Use of noninvasive positive pressure ventilation (NIV) as a first-line therapy for acute respiratory failure (ARF), especially that associated with exacerbations of COPD, acute cardiogenic pulmonary edema (CPE), and immunocompromised states, is increasing worldwide.[1-10] Due to the lack of information on NIV use in the United States, we performed a survey in 2002 and 2003 of utilization patterns in acute care hospitals in Massachusetts and Rhode Island.[11] The overall average estimated utilization rate was 20%, but it varied considerably between hospitals from none to >50%. A substantial number of hospitals (42%) were considered as low NIV utilizers (<15% of ventilator starts).

In the present study, we sought to establish more accurate rates for utilization, success, and mortality for NIV in the United States, based not on practitioners' estimates of use in response to questionnaires, but rather via on-site data collection at selected hospitals that participated in our previous survey. We hypothesized that overall use has increased because of the accumulating evidence for the efficacy of NIV. We

prospectively identified patients started on ventilators at selected Massachusetts hospitals that were low utilizers of NIV in our previous study.

Materials and Methods

Study Centers

Eight of 76 medical centers from our prior survey[11] were selected based on their willingness to participate, distance < 90 miles from Boston, and ability to provide a mix of teaching and nonteaching hospitals. The institutional review boards of participating institutions approved the study (Tufts ID #7642) and waived the need for patient consent because it was observational only. Characteristics of the eight acute care hospitals are presented in Table 1. Participating hospitals were estimated to have NIV utilization rates < 15% at the time of the prior survey.

Patients

Patients were enrolled prospectively at each institution during sequential 3-month data collection periods between January 1, 2004, and August 3, 2007. All adult patients receiving ventilator assistance in the form of NIV (CPAP or pressure support ventilation and positive end expiratory pressure) or invasive mechanical ventilation (INV) at any time throughout their hospitalization were screened.

Screened patients were included if they required ventilator support for ARF. Exclusions were as follows: long-term use of NIV without an acute deterioration, initiation of endotracheal intubation (ETI) or NIV prior to admission, use of INV for surgery or procedures only, or presence of a tracheotomy. In each hospital, a respiratory therapist prospectively enrolled each patient and completed a standardized data form. Patients were then followed for up to 30 days after enrollment or until they died, whichever occurred first.

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Table 1—*Characteristics of Participating Hospitals*

Hospital	Type	No. of ICU Beds	No. of Hospital Beds	ED Annual Visits in Thousands
T1	T	62	496	129
T2	T	46	382	47
C1	NT	26	220	58
C2	NT	12	155	55
C3	NT	14	210	45
C4	NT	12	182	55
C5	NT	10	157	35
C6	T	10	200	45
Total	...	192	2,002	469

C = community; NT = nonteaching; T = teaching.

Data Collection

Respiratory therapists recorded the following pertinent information at the time of enrollment: time of initiation, equipment applied, and patient demographics and characteristics. Investigators filled in any missing information post hoc by reviewing medical records on-site and recording duration of use, diagnoses, complications, and clinical outcomes. Investigators also reviewed respiratory therapy department billing records to ascertain that no qualifying ventilator starts were missed.

The main indications for ventilatory support were classified into six groups according to etiology of ARF using a system modified from Demoule et al[9]: group I, acute-on-chronic lung disease (ie, COPD, asthma, OSA syndrome); group II, de novo ARF (ie, pneumonia [PNA] and acute lung injury/ARDS); group III, CPE; group IV, ARF associated with neurologic diseases; group V, cardiopulmonary arrest; and group VI, others (ie, postoperative, massive trauma, burns, sepsis, and other cardiac).

Outcome Variables

The primary outcome was the utilization rate of NIV as a percentage of all ventilator starts to treat ARF. The success rate of NIV and in-hospital mortality rates were secondary outcomes. Success was defined as avoidance of ETI or death during use of NIV or the subsequent 48 h, including patients discontinued because of improvement or intolerance, and patients discharged on NIV or still using NIV on day 30. Failure was defined as ETI or death during NIV application or within 48 h of discontinuation.

Statistical Analysis

Statistical analysis was performed using SPSS statistical analysis software, version 12.0 (IBM). Utilization, success, and 30-day hospital mortality rates were calculated based on all patients placed on ventilators for acute respiratory problems, but most patients in categories IV (neurologic) and V (cardiac arrest) and some in VI (others) were intubated primarily for airway protection (n = 189). Although these were included for calculation of NIV utilization rates to render our data comparable with that of Demoule et al,[9] they were also analyzed separately to compare characteristics of subgroups. Two-tailed standard statistical analyses were used when appropriate. Median or Kruskal-Wallis tests were carried out to compare baseline characteristics between the NIV and INV groups (Table 2). The χ^2 test was used for categorical data when appropriate. Data are ± interquartile range unless otherwise specified. A P value of $< .05$ was considered significant.

Table 2—*Characteristics of Patients Treated With NIV vs INV and Those With IAP*

Characteristic	NIV (n = 211)	INV (n = 148)	*P* Value	IAP (n = 189)	*P* Value[a]
Age (range), y	71 (61-80)	70 (56-79)	NS	60 (48-77)	.000
Females, No. (%)	101 (48)	71 (48)	NS	89 (47)	NS
BMI,[b] kg/m^2	26 (22-33)	24 (21-29)	NS	26 (23-30)	NS
DNR/DNI, No. (%)/No. (%)	47 (22.3)/45 (21.3)	20 (13.5)/11 (7.4)[c]	.000	11 (5.8)/5 (2.6)[c]	.000
Prior NIV use at home, No. (%)	15 (7.1)	1 (0.7)	.000	2 (1.1)	.002
SAPS II[d]	34 (28-43)	48 (36-58)	.000	45 (32-60)	.000
Vital signs and ABG findings					
Heart rate,[e] min	99 (86-115)	110 (92-127)	.002	100 (77-115)	NS
Respiratory rate,[f] min	26 (22-32)	27 (19-34)	NS	18 (12-24)	.000
Systolic BP,[g] mm Hg	134 (108-154)	124 (98-150)	NS	128 (90-160)	.028
pH[h]	7.30 (7.23-7.37)	7.30 (7.18-7.38)	NS	7.30 (7.15-7.40)	NS
$PaCO_2$,[i] mm Hg	62 (48-79)	47 (36-63)	.000	43 (36-57)	.001
PaO_2/FIO_2[j]	172 (116-241)	124 (85-209)	.004	217 (128-277)	.015
HCO_3,[k] mEq/L	30 (24-37)	23 (18-28)	.000	23 (18-26)	.000

Values are median ± (interquartile range) unless otherwise indicated. ABG = arterial blood gas; DNI = do not intubate; DNR = do not resuscitate; HCO_3 = bicarbonate; IAP = intubated for airway protection; INV = invasive mechanical ventilation; NIV = noninvasive positive pressure ventilation; NS = nonspecific; SAPS = Simplified Acute Physiology Score.

[a]*P* value for comparison of IAP group with NIV group.

[b]Data available for 334 cases.

[c]Sixteen patients with DNR/DNI orders reversed their DNI status and were intubated.

[d]Data available for 353 cases.

[e]Data available for 313 cases.

[f]Data available for 308 cases.

[g]Data available for 286 cases.

[h]Data available for 259 cases.

[i]Data available for 262 cases.

[j]Data available for 167 cases.

[k]Data available for 260 cases.

Results

Overall NIV Utilization

Figure 1 shows that of 1,153 episodes of mechanical ventilation screened, 605 were excluded and 548 episodes in 540 patients met entry criteria. The utilization rate of NIV as a first-line ventilator modality was 38.5% among all ventilator starts. NIV was discontinued early (prior to meeting weaning criteria) in 75 NIV starts (35.5%). Twenty, discontinued after a median of 3.6 hours of NIV (interquartile range, 0.4-20.3), required no further ventilatory assistance, survived, and were considered successes. The other 55 (26.1%) failed NIV (Fig 1), of whom 37 (17.5%) were intubated after a median of 9.3 h (interquartile range, 4.8-42.9) of NIV, and 18 died within 48 h of NIV discontinuation. Although not included in our primary analysis, which examined only initial ventilator starts, 18 patients were placed on NIV postextubation after initial INV (5.3% of INV starts), and 13 used NIV postextubation after INV for initial NIV failure (24% of NIV failures).

Baseline characteristics of patients on NIV, INV, or intubated for airway protection are compared in Table 2. The patients on NIV more often had a do not intubate (DNI)/do not resuscitate (DNR) status and used NIV at home, had a lower Simplified Acute Physiology Score (SAPS) II, and had arterial blood gas results showing more hypercapnia, consistent with the higher prevalence of COPD in this group.

Utilization of NIV According to Etiology at Individual Participating Centers

As shown in Table 3, NIV was used most commonly for patients with acute-on-chronic lung disease (group I) and CPE (group III) but almost never for patients with neurologic diseases or cardiopulmonary arrest. Use of NIV was higher overall in nonteaching than teaching hospitals (43.2% vs 31.7%, respectively, $P = .007$). Higher utilization rates in nonteaching hospitals reflected a higher percentage of patients with group I ARF (28.4% vs 16.5%, $P < .05$).

NIV Utilization, Success, and Mortality Rates for Specific Diagnoses

Surprisingly, > 40% of patients with PNA received NIV, but NIV was not used for patients with ARDS (Table 4). The success rate was > 75% for COPD and CPE, but < 50% for patients with PNA. Mortality rates tended to be lower for NIV than INV in most categories and was significantly lower for NIV overall, as would be expected. However, patients with CPE treated either with NIV or INV had similar mortalities of roughly 17%. Patients with a DNI status who

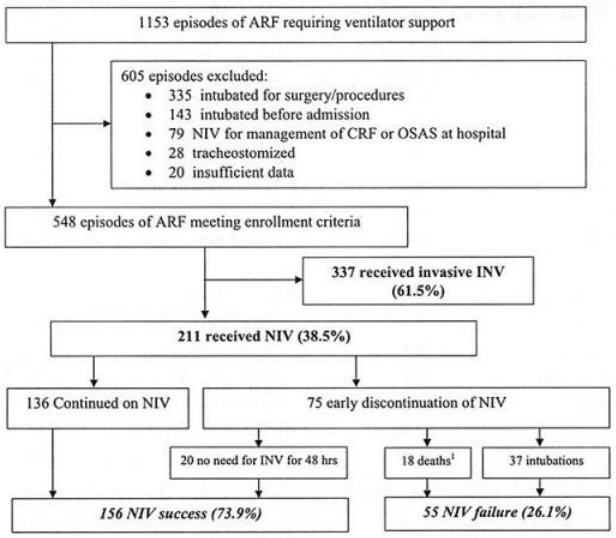

FIGURE 1. Distribution of patients with ARF according to type of ventilator support and response to treatment in NIV arm. [1]This includes mortality secondary to NIV withdrawal. ARF = acute respiratory failure; CRF = chronic respiratory failure; INV = invasive mechanical ventilation; NIV = noninvasive positive pressure ventilation; OSAS = OSA syndrome.

received NIV had an overall mortality of 38%, reaching 42% in the CPE group, significantly higher than in patients on NIV without a DNI status.

NIV Outcomes at Different Hospitals

NIV utilization and mortality rates were significantly different ($P < .05$) between hospitals (Fig 2). Institutions with higher mortality rates for patients using NIV also had higher SAPS II scores and a higher proportion of patients with DNI/DNR. NIV failure rates tended to be higher at institutions with lower utilization rates (C1) and lower at those with higher utilization rates (C3 and C4). Mean duration of NIV was approximately one-half that of INV ($P < .05$), although total hospital length of stay was similar between the groups (Table 5).

Technical Aspects of NIV Initiation

Full-face, nasal, and Total (Respironics, Inc/Koninklijke Philips N.V.) masks were used in 86.7%, 7.1%, and 0.5% of NIV starts, respectively (5.7% unknown). Bilevel-type pressure-limited ventilators were used in 91.4% of applications and an ICU-type ventilator in 4.3% (4.3% unknown). Initial inspiratory positive airway pressure, expiratory positive airway pressure, and CPAP settings were 12.5 ± 2.4, 5.5 ± 1.2, and 8.8 ± 2.4 (mean $\pm$ SD, cm H_2O), respectively. Among patients on pressure-limited modes, bilevel was selected in 87.7% of patients on NIV (mean backup rate 12.0 ± 3.8/min) and CPAP in 12.3% of patients, mainly with CPE.

Tolerance of NIV

Twenty patients (9.5%) were intolerant of NIV and discontinued early, mainly due to mask discomfort. Five of these subsequently required intubation. Complications and side effects due to NIV were infrequent but included gastric distension (two patients), pneumothorax (two patients), vomiting (two patients), and anxiety (two patients). Additionally, PNA occurred in four patients after they were intubated for NIV failure.

Out of 211 patients on NIV, sedation/analgesia was used in 33 patients (15.6%). Eighteen patients received morphine, 10 alprazolam, two temazepam, one fentanyl, one propofol, and one the combination of morphine and alprazolam.

DISCUSSION

Our study demonstrates that use of NIV is quite common in selected acute care hospitals in the United States, even among low utilizers in a previous survey.[11] As anticipated, use of NIV depends heavily on

Table 3—*Use of NIV in Hospitals According to Diagnostic Categories of Respiratory Failure*

Hospital	No. of Patients Enrolled in Study	Diagnostic Category of ARF No. of NIV/Total Ventilator Starts in Diagnostic Category (NIV%)						
		I	II	III	IV	V	VI	Total
T1	70	9/10 (90)	1/4 (25)	6/7 (85.7)	0/19 (0)	0/18 (0)	4/12 (33.3)	20/70 (28.6)
T2	83	10/11 (90.9)	5/17 (29.4)	8/15 (53.3)	0/16 (0)	0/12 (0)	1/12 (8.3)	24/83 (28.9)
C1	88	9/13 (69.2)	4/14 (28.6)	6/15 (40)	0/17 (0)	0/15 (0)	2/14 (14.3)	21/88 (23.9)
C2	52	6/12 (50)	4/10 (40)	8/9 (88.9)	0/9 (0)	0/6 (0)	1/6 (16.7)	19/52 (36.5)
C3	55	12/19 (63.2)	6/11 (54.5)	4/5 (80)	0/6 (0)	0/3 (0)	1/4 (25)	23/55 (41.8)
C4	78	29/32 (90.6)	7/12 (58.3)	18/18 (100)	2/7 (28.6)	0/7 (0)	0/2 (0)	56/78 (71.8)
C5	51	13/16 (81.3)	4/17 (23.5)	4/6 (66.7)	0/2 (0)	0/2 (0)	0/2 (0)	21/51 (41.2)
C6	71	11/16 (68.8)	6/13 (46.2)	9/17 (52.9)	0/16 (0)	0/3 (0)	1/6 (16.7)	27/71 (38)
Total	548	99/129 (76.7)	37/98 (37.8)	63/92 (68.8)	2/92(2.2)	0/67 (0)	10/58 (17.2)	211/548 (38.5)

Group I: acute-on-chronic lung disease; group II: de novo acute respiratory failure; group III: cardiogenic pulmonary edema; group IV: neurologic diseases; group V: cardiopulmonary arrest; group VI: others. ARF = acute respiratory failure. See Table 1 and 2 legends for expansion of other abbreviations.

Table 4—*Initiation, Failure, and Mortality Rates of Patients on NIV and INV as Per Etiology of ARF and DNI Status*

	NIV				INV, No. (%)		
			30-d In-Hospital Mortality				
Diagnostic Category	Initial Use, No. (%)	Failure, No. (%)	Total, No. (%)	DNI Subset No. Died/Total DNI (%)	Initial Use	30-d In-Hospital Mortality	Tracheostomy
I. Acute-on-chronic lung disease	99 (76.7)[a]	24 (24.2)	15 (15.1)	9/23 (39)[b]	30 (23.3)	7 (23.3)	0 (0)
COPD[c]	74 (82.2)	19 (25.3)	9 (12.2)	7/21 (33)	16 (17.8)	4 (25)	0 (0)
Asthma	5 (45.5)	1 (20)	0	0	6 (54.5)	0	0 (0)
Restrictive lung disease	2 (50)	0 (0)	0	0	2 (50)	1 (50)	0 (0)
Lung cancer	5 (50)	3 (60)	4 (80)	2/2 (100)	5 (50)	2 (40)	0 (0)
Decompensated OSA	13 (92.9)	2 (15.4)	2 (15.4)	0/2 (0)	1 (7.1)	0	0 (0)
II. De novo acute respiratory failure	37 (37.8)[a]	20 (54.1)	10 (27.0)	2/8 (25)	61 (62.2)	19 (31.1)	4 (6.6)
Pneumonia	36 (41.4)	19 (52.8)	9 (25)	2/7 (29)	51 (58.6)	16 (31.4)	4 (7.8)
ARDS	0	NA	0	0	6 (100)	1 (16.7)	0 (0)
Other	1 (20)	1 (100)	1 (100)	0/1 (0)	4 (80)	2 (50)	0 (0)
III. Cardiogenic pulmonary edema[c]	63 (68.5)[a]	13 (20.6)	11 (17.5)	5/12 (42)[b]	29 (31.5)	5 (17.2)	1 (3.4)
IV. Neurologic diseases	2 (1.9)[a]	1 (50)	0	0	102 (98.1)	21 (20.6)	2 (2)
V. Cardiopulmonary arrest	0	NA	0	0	67 (100)	34 (50.7)	6 (9)
VI. Other[c,d]	10 (17.2)[a]	3 (30)	2 (20)	1/2 (50)	48 (82.8)	16 (33.3)	3 (6.3)
Total	211 (38.5)[a]	55(26.1)	35 (16.6)[a]	17/45 (38)[b]	337 (61.5)	102 (30.3)	16 (4.7)

CRF = chronic respiratory failure; OSAS = OSA syndrome; PNA = pneumonia. See Table 2 and 3 legends for expansion of other abbreviations.

[a]$P < .05$ compared with corresponding INV group.

[b]$P < .05$ compared with total mortality rate.

[c]One patient with COPD, one patient with cardiogenic pulmonary edema, and four patients with ARF postoperatively required NIV as initial type of mechanical ventilation to treat or to prevent postextubation failure.

[d]Postextubation failure, immune suppressed with respiratory failure, sepsis, and other diseases.

etiology of ARF and is most commonly applied in patients with COPD exacerbations and CPE, diagnoses for which it is recommended as a first-line therapy by current guidelines.[1,7,8]

In an early survey of NIV application in 15 acute care teaching hospitals in Ontario, Canada, 63% of respondents used NIV, mainly for patients with COPD and congestive heart failure (CHF).[12] Our prior survey

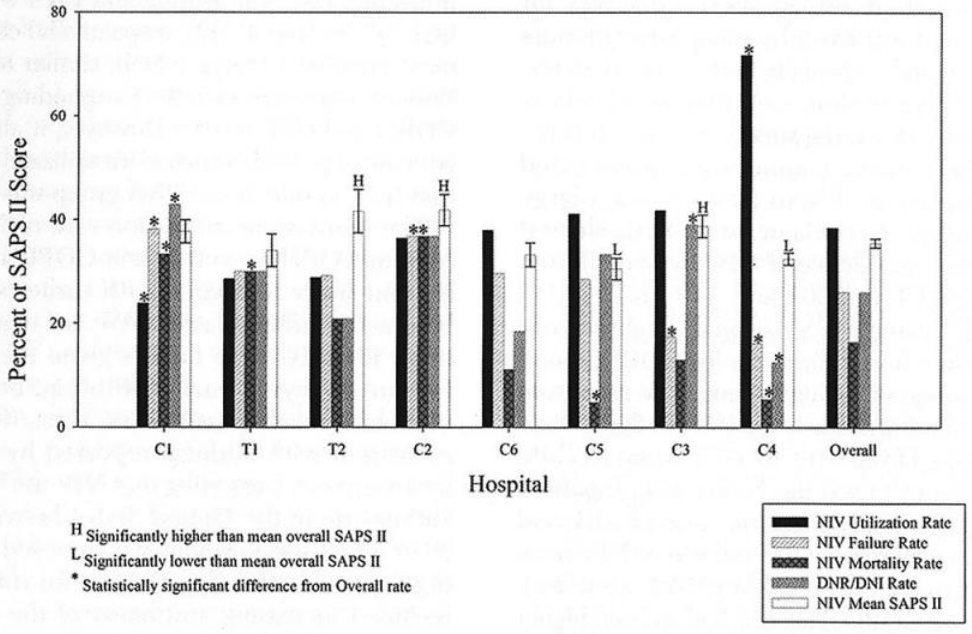

FIGURE 2. NIV utilization, NIV failure, in-hospital mortality, and DNI/DNR rates as a percentage of total patients receiving NIV and mean SAPS II score per hospital. H and L are both $P > .05$. *$P < .05$ compared with mean value. DNI = do not intubate; DNR = do not resuscitate; SAPS = Simplified Acute Physiology Score. See Figure 1 legend for expansion of other abbreviations.

Table 5—*Ventilator Duration and Hospital Lengths of Stay for NIV vs INV*

Hospital	Ventilator Duration (Days ± SEM)		Hospital LOS (Days ± SEM)	
	NIV	INV	NIV	INV
T1	1.46 (0.46)	8.43 (1.25)	10.2 (1.77)	13.92 (1.47)
T2	2.88 (1.92)	5.8 (0.91)	14.9 (2.25)	12.6 (1.28)
C1	1.32 (0.31)	4.16 (0.49)	7.67 (1.50)	9.54 (0.87)
C2	1.82 (0.75)	6.1 (1.22)	8.74 (1.86)	12.36 (1.70)
C3	1.44 (0.57)	2.33 (0.52)	5.87 (0.98)	6.35 (1.17)
C4	3.43 (0.71)	4.24 (1.09)	7.95 (0.83)	8.23 (1.63)
C5	1.44 (0.25)	2.54 (0.64)	7.95 (1.40)	8.23 (0.79)
C6	3.19 (1.27)	2.05 (0.29)	10.5 (1.51)	6.52 (1.02)
Overall	2.35 (0.31)	4.69 (0.33)[a]	9.10 (0.53)	9.86 (0.47)

LOS = length of stay. See Table 1 and 2 legends for expansion of other abbreviations.

[a]Paired *t* test analysis for duration of ventilation, $P = .008$ and $P = .914$ for hospital LOS; NIV vs INV.

of 82 acute care hospitals in Massachusetts and Rhode Island found an overall estimated utilization rate of 20%, with a range of 0% to 50% between hospitals.[11] Most respondents to more recent surveys[13-15] have estimated NIV utilization rates of > 20% for initial ventilator starts, higher for COPD and CHF; but some respondents continue to estimate low utilization rates. In one survey, for example, one-fifth of North American doctors and respiratory therapists responded that they used NIV for < 10% of patients with COPD and CHF.[13] Similarly, in a survey of Veterans Administration hospitals,[14] a majority of respondents estimated that NIV was used < 50% of the time for established indications. Thus, these surveys suggest that NIV for ARF remains underutilized by many practitioners throughout the world, especially in the United States.

Surveys also suggest, however, that use of NIV is increasing worldwide. Serial surveys in French ICUs in 1997 and 2002 showed an increase in estimated overall NIV use from 16% to 23%,[9,16] and a large international survey of ventilator use in ICUs showed an increase in the prevalence of NIV use overall from 4% in 1998 to 11% in 2004 and 14% in 2010.[10,17] Chandra et al,[18] using a US national database consisting of 7 million hospitalizations for COPD, found that the percentage of patients using NIV rose from 1.0% to 4.5% of admissions from 1998 to 2008 while INV starts dropped from 6.0% to 3.4%. More recently, Walkey and Wiener[19] used the Nationwide Inpatient Sample to identify nearly 3 million cases of ARF and noted in them an increase in overall use of NIV from 3.5% in 2000 to 12.3% in 2009 (250% increase). Patients without a COPD diagnosis had an even higher rate of increase in NIV use than those with COPD (1.2% in 2000 to 6.0% in 2009, a 400% increase).

Our overall NIV utilization rate (38.5%) is substantially higher than those reported in these surveys or in our prior survey (20%). In a more recent population-based cohort study, Wang et al[20] analyzed 364 patients with ARF admitted to two ICUs. Similar to the rates in our study, these authors reported an NIV utilization rate of 40% and an NIV success rate (excluding DNI and weaning patients) of 69%. Admittedly, these rates are not directly comparable between studies, considering that the large databases are dependent on coding accuracy and have used total COPD or all ARF cases as a denominator. The study by Wang et al[20] was retrospective and our prior Massachusetts and Rhode Island survey[11] used mailed questionnaires. The data in the current study were obtained via prospective identification of patients followed by on-site data extraction. As such, the utilization rates we report are actual rates and not estimates.

Our survey also detected high overall utilization rates in patients with ARF due to COPD and CPE (82.2% and 68.5%, respectively), the best accepted indications. These findings are particularly impressive considering that hospitals in our current survey had estimated overall utilization rates < 15% in our prior survey and a subgroup of hospitals estimated that NIV was used in only one-third of patients with COPD.[11] Taken together, these data strongly support the notion that NIV use has increased substantially over the past decade in the United States.

Our utilization rates are comparable to the NIV utilization rates of 76% and 62%, respectively, for patients with COPD and CPE estimated for Veterans Administration hospitals in a contemporary survey by Bierer and Soo Hoo.[14] On the other hand, our centers' NIV utilization rates for asthma and PNA were relatively high (45.5% and 41.4%, respectively) compared with most previous surveys, which, similar to Walkey and Wiener,[19] appears to reflect expanding uses beyond COPD and CPE.[11,13,14,19] However, it also raises concern about possible overzealous utilization, considering that success rate in our PNA group was < 50%.

The increase in utilization rate of NIV for ARF (due to COPD as well as non-COPD causes) in the current study compared with earlier surveys could be due to multiple factors. We are unable to definitively identify these factors given the single times for our surveys at each institution, but there are a number of likely possibilities. First, this increase is consistent with findings reported by contemporaneous surveys, suggesting that NIV use was increasing nationwide in the United States between 2000 and 2010,[19] and the hospitals we surveyed were reflecting this national trend. Drivers for this trend likely included increasing awareness of the evidence and guidelines favoring increased NIV use for diagnoses like COPD and CHF.[7,21-25] Improvements in technology (ventilators and masks) as well as the experience and skill of caregivers were also likely factors. Furthermore,

the caregivers at the institutions we were surveying knew that we were examining their use of NIV and this awareness may have encouraged greater use.

One unexpected finding was that nonteaching hospitals actually had higher overall NIV utilization rates than teaching hospitals, but these are probably explained by the higher proportion of patients with COPD and CPE at the nonteaching hospitals. This demonstrates that the increasing use of NIV is not just occurring at academic centers.

Techniques of NIV application in our study are consistent with other surveys,[9,11-16] with the majority of these patients (87.7%) initially using full-face masks and < 10% nasal masks. Pressure-limited bilevel-type ventilators were chosen in nearly 90% of NIV applications, with ICU ventilators in only about 5%. The Demoule et al[9] 2002 survey of French ICUs reported that only 12% of their patients used bilevel-type ventilators. However, a more recent European survey[15] found that a dedicated (ie, bilevel type) NIV ventilator was used for most cases of acute hypercapnic respiratory failure, whereas ICU ventilators with NIV modules were used more often for acute hypoxic respiratory failure.[15] NIV was also well tolerated and safe in our study, with a very infrequent occurrence of adverse events.

Our study has a number of limitations. We used an observational design, so we can draw no conclusions about effectiveness. In addition, although our total numbers are substantial, we enrolled a limited number of patients at each participating institution. Also, although we included a diverse group of hospitals, they were in one region and may not reflect practice in the United States generally. Our data-gathering method, while quite robust compared with previous surveys, was also labor intensive, necessitating that we collect data sequentially, not simultaneously. Thus, the passage of time might have been responsible for some of the differences in NIV use among hospitals. However, no association was found with participation order and utilization rates. Also, our data were gathered > 5 years ago, raising concerns about current relevancy. However, the high utilization rates for COPD and CHF we found are unlikely to have risen much more during the interim.

In conclusion, we found remarkably high NIV utilization rates as a proportion of initial ventilator starts, approaching 40%, almost double what was estimated in our earlier survey. This increase in use was mainly for patients with recommended diagnoses for NIV, COPD exacerbations, and CPE. Overall outcomes were good, with success rates exceeding 70% overall. NIV appears to be occupying an increasingly important role in the management of ARF in US acute care hospitals, paralleling similar trends reported throughout the world.

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