RESEARCH ARTICLE

Initiation of Noninvasive Ventilation for Acute Respiratory Failure in a Pediatric Intermediate Care Unit

Alla Smith, MD,[a] Daniel P. Kelly, MD,[a] Julie Hurlbut, BS,[a] Patrice Melvin, MPH,[b] Christiana M. Russ, MD[a]

ABSTRACT

BACKGROUND: Noninvasive ventilation (NIV) is increasingly used to manage acute respiratory failure in children, decreasing the need for mechanical ventilation. Safely managing these patients outside of the ICU improves ICU resource use. We measured the impact of a guideline permitting initiation of NIV in an intermediate care unit (IMCU) on ICU bed use.

METHODS: A guideline for an NIV trial for acute respiratory failure was implemented in a 10-bed IMCU. The guideline stipulated criteria for initiation and maintenance of NIV. There were 4.5 years of intervention data collected. Baseline data were gathered for patients with acute respiratory failure who were transferred from the IMCU to the ICU for NIV initiation in the 3.25 years before guideline implementation.

RESULTS: Three hundred eight patients were included: 101 in the baseline group and 207 in the intervention group. In the intervention group, 143 patients (69%) remained in the IMCU after NIV initiation, and 64 (31%) transferred to the ICU. A total of 656.4 ICU bed-days were saved in the intervention period (3.3 days per patient initiated on NIV in the IMCU). There was a significant decrease in the rate of intubation in the IMCU for patients awaiting ICU transfer (3 patients in the baseline group versus 0 patients in the intervention group; $P = .035$).

CONCLUSIONS: The initiation of NIV in the IMCU for pediatric patients with acute respiratory failure saved ICU bed-days without increasing intubation in the IMCU for patients awaiting transfer. Close monitoring of these critically ill patients is a key component of their safe care.

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Address correspondence to Alla Smith, MD, Department of Medicine Critical Care, Boston Children's Hospital, 333 Longwood Ave, Boston, MA 02115. E-mail: alla.smith@childrens.harvard.edu

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[a]*Division of Medicine Critical Care and* [b]*Program for Patient Safety and Quality, Boston Children's Hospital, Boston, Massachusetts*

Given the morbidity associated with invasive mechanical ventilation,[1] noninvasive ventilation (NIV) has emerged as a compelling alternative for the management of acute respiratory failure in certain clinical scenarios.[2] Authors of observational studies have reported a reduction in the need for intubation when NIV (both continuous positive airway pressure [CPAP] and bilevel positive airway pressure [BiPAP]) is used to treat multiple etiologies of acute respiratory failure in children, including pneumonia and bronchiolitis.[3–6] The authors of 2 small randomized controlled trials reported improvement in respiratory symptoms with no increase in adverse events for children with status asthmaticus who were trialed on NIV after failure of first-line therapies.[7,8]

Pediatric patients who require NIV for acute respiratory failure have historically been managed in the ICU. However, a significant proportion of adult patients admitted to the ICU never require intubation and mechanical ventilation.[9,10] Studies from the adult population reveal that these patients can be effectively treated in intermediate care units (IMCUs).[11] Although there is no standard definition of an IMCU, generally it is a unit where there is increased nursing and auxiliary staffing compared with a typical inpatient unit but less nursing and auxiliary staffing compared with an ICU.[11] IMCUs are variably staffed by intensivists, hospitalists, or subspecialists.

Appropriate triage of adult patients to IMCUs has been shown to result in better ICU bed use in both retrospective and prospective studies.[12] Receiving care in an IMCU may also decrease medical costs for patients with respiratory illnesses and may improve patient outcomes.[11,13] Given the benefits conferred by the presence of an IMCU, it is unsurprising that the number of adult patients cared for in these units is increasing.[14] Seventeen percent to 55% of pediatric hospitals in North America have an IMCU.[15,16] Children with respiratory distress are frequently admitted to the IMCU[15]; however, there is a paucity of published studies on the initiation of NIV for pediatric acute respiratory failure in an IMCU.

In April 2012, we launched a new guideline for the initiation of NIV for pediatric patients with acute respiratory failure in an IMCU. Our aim for the guideline was to reduce unnecessary ICU resource use. In this study we examine the effect of this guideline on ICU use, specifically in the number of ICU bed-days that were saved by initiating NIV in the IMCU. In addition, we sought to identify risk factors for ICU transfer among patients who were started on NIV in the IMCU. In an effort to measure the safety of this guideline, we examined its impact on the number of patients with respiratory failure who were intubated in the IMCU while awaiting ICU transfer and its impact on the number of patients intubated in the ICU within 24 hours of transfer from the IMCU. Finally, we examined the impact of the guideline on hospital length of stay (LOS).

METHODS

In this study, we examined implementation of an NIV initiation guideline in the IMCU in a freestanding children's hospital. At the time of this guideline change, the IMCU was a 10-bed unit adjacent to the medical ICU. Staffing was stable throughout the baseline and intervention periods and included a nursing ratio of 1 nurse for every 2 patients, a dedicated respiratory therapist, a weekday nurse practitioner, 1 to 2 interns, a supervising resident, and 24/7 in-house attending coverage by pediatric hospitalists during the day and by pediatric intensivists overnight.

Since its inception in 2003, this IMCU has supported children in respiratory distress via the initiation of high-flow nasal cannula with the close support of respiratory therapists. In addition, patients with intensive nursing needs who required nocturnal NIV for chronic respiratory failure have historically been cared for in the unit. However, before this guideline change, any patient with acute respiratory failure who required the initiation of new NIV or an increase in their baseline NIV settings was transferred to the ICU.

Acute NIV Initiation Guideline

An interdisciplinary team developed a new guideline that allowed for a closely monitored period of NIV initiation (NIV trial) in the IMCU. The NIV trial was a 2-hour period of NIV, during which the team assessed whether the initiation of NIV improved the patient's clinical status to the point in which they could safely stay in the IMCU or whether the patient required ICU transfer for management of progressive respiratory failure.

Inclusion criteria for an NIV trial were development of acute hypoxic or hypercapnic respiratory failure (based on attending physician determination) for patients already admitted to the IMCU. Exclusion criteria were the following: weight <4 kg (given difficulties with the NIV mask interface), respiratory failure secondary to capillary leak (eg, septic shock and pancreatitis), history of known difficult airway (Modified Cormack-Lehane classification grades 3 and 4), and patients with a diagnosis of status asthmaticus who required concomitant heliox use (because we were unable to provide heliox through the NIV interface). We did not exclude patients who required NIV at baseline for chronic respiratory failure, but they were only included in this study if they had acute respiratory failure requiring an increase in their NIV pressures or duration of use.

To implement an NIV trial, a bedside huddle was performed with the attending physician, charge nurse, respiratory therapist, bedside nurse, and pediatric physician trainees. The huddle flow process is outlined in Fig 1.

In the event of subsequent respiratory decompensation, the clinical team could adjust NIV settings, but a repeat bedside huddle was required to reconsider if it was appropriate for the patient to remain in the IMCU. Weaning patients off NIV was at the discretion of the clinical team. If, at any point, the IMCU attending decided that the patient was at a high risk of requiring intubation or if nursing cares intensified to require a 1:1 nurse-patient ratio, then the patient was transferred to the ICU.

Data Collection

The new guideline launched in April 2012. Identifiers for patients with acute NIV

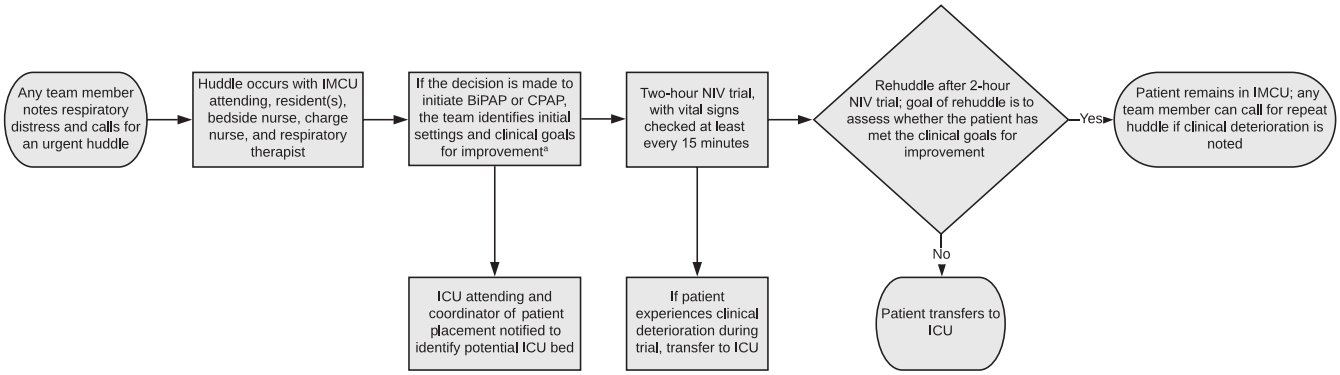


FIGURE 1 NIV trial huddle. [a] The decision to initiate NIV, the choice of CPAP versus BiPAP, the interface used, and the start settings for NIV were left to the discretion of the clinical team.

initiation were initially collected manually by daily report; however, starting in September 2013, these data were captured by using a survey tool: the attending provider responded to an electronic health record–enabled mandatory survey for each patient that was used to query whether NIV had been initiated in the IMCU in the past 24 hours. For patients from April 2012 to October 2016 who met inclusion criteria, a manual chart review was performed to identify patient and hospital characteristics. In addition, the Pediatric Health Information System (PHIS) database was queried for these individuals to identify any complex chronic condition flags.[17]

To evaluate the possible effects of the guideline change on hospital LOS, the rate of intubation in the IMCU for patients awaiting ICU transfer, and the rate of intubation in the ICU within 24 hours of transfer from the IMCU, we identified patients who would have been candidates for a NIV trial in the IMCU before our guideline change. These baseline patients were admitted from January 2009 to March 2012. These patients were identified by using a manual chart review of all patients transferred from the IMCU to the ICU for initiation of NIV or for an increase in NIV settings above their home settings during the baseline period. Patients were included in the baseline group if they would have met inclusion criteria for an IMCU NIV trial but, at that time, before guideline initiation, were all transferred to the ICU for NIV initiation for acute respiratory failure.

This study received approval with a waiver of consent from the hospital's Institutional Review Board.

Data Measures

For the baseline and intervention patient groups, we tracked patient characteristics, including age, sex, primary diagnosis, relevant comorbidities (history of prematurity, history of aspiration, seizure disorder, and neuromuscular disorder), chronic use of NIV, and home NIV settings. We calculated ICU bed-days saved for patients in the intervention group by examining the IMCU LOS while on NIV for those with no chronic NIV and the IMCU LOS while on NIV with settings above home settings for those with chronic NIV use.

We also examined overall hospital LOS as well as a critical care LOS, defined as combined IMCU and ICU days (excluding any general inpatient unit days). Critical care LOS reflects time in the IMCU and ICU but is not necessarily a reflection of the duration of time the patient received critical care services.

For balancing measures, we tracked the rate of emergent intubations in the IMCU for patients awaiting transfer to the ICU. In the intervention period, we included all intubations of patients in the IMCU with respiratory failure, regardless of whether they had been placed on the NIV guideline. In both the baseline and intervention periods, we excluded patients who were intubated in the IMCU for airway protection in the setting of status epilepticus and those who were intubated as part of the management of cardiac arrest. We also tracked the rate of intubations in the ICU within 24 hours of transfer from the IMCU.

Statistical Analysis

We compared patients in the intervention group with those in the baseline group on demographic features, clinical characteristics, and hospital resource use. We reported frequencies and percentages for categorical variables and medians and interquartile ranges (IQRs) for continuous variables. Differences between baseline and intervention patient groups were assessed by using χ^2 and Fisher's exact tests for categorical variables and the Wilcoxon-Mann-Whitney test for patient age in years. A segmented regression analysis of interrupted time series was used to evaluate the impact of the intervention on age-adjusted hospital LOS and critical care LOS (IMCU + ICU LOS). Quarterly average LOS was calculated throughout the baseline and intervention periods. Intervention effects on outcome were estimated, accounting for baseline trend, correlation across time, and seasonality. Autoregressive models with stepwise autoregression, maximum likelihood method, and lags = 5 were used.

We ran a subgroup analysis on our intervention group to assess differences in demographic and clinical characteristics among patients who remained in the IMCU and those who transferred to the ICU. We used χ^2 and Fisher's exact tests for categorical variables and the Wilcoxon-Mann-Whitney test for patient age in years.

We considered $P < .05$ statistically significant. All analyses were performed by using SAS version 9.4 (SAS Institute, Inc, Cary, NC).

RESULTS

There were 207 patients who met criteria for an NIV trial in the IMCU in the 4.5-year implementation period, representing 4% of admissions. The average age was 8.3 years (IQR 2.4–14.5). The most common diagnosis was pneumonia (38.2%). Thirty patients (14.5%) had baseline nocturnal NIV use. One hundred thirty-seven patients (66.2%) had a complex chronic condition flag within the PHIS database (Table 1). There were 656.4 ICU bed-days saved over the 4.5-year intervention period. This is an average of 3.3 (SD 5.2) days per patient initiated on NIV in the IMCU.

There were 101 patients during the 3.25-year baseline period who would have met criteria for NIV initiation in the IMCU but, at that time, were required to transfer to the ICU for NIV initiation. This represents 3% of admissions during the baseline period. These patients in the baseline group were significantly younger than patients in the intervention group (average age of 3.6 years [IQR 0.– 9.7] for patients in the baseline group versus 8.3 years [IQR 2.4–14.5] for patients in the intervention group; $P = .001$). Patients in the baseline group were also significantly more likely to be premature (22.8% of patients in the baseline group versus 7.7% of patients in the intervention group; $P \leq .001$). The 2 groups did not significantly differ in the sex breakdown, primary diagnosis, presence of a complex chronic condition flag in the PHIS, or baseline NIV use (all $P > .05$; Table 1).

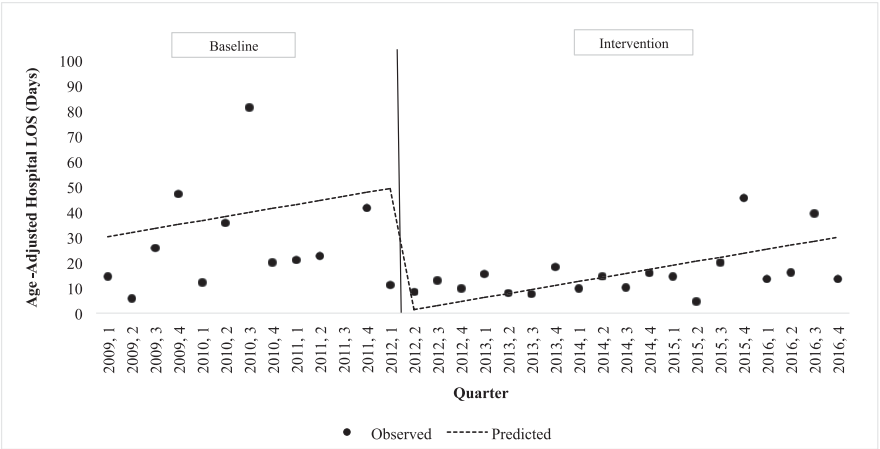
When looking at overall hospital LOS and critical care LOS, we adjusted for age given the significantly younger median age in the baseline group. In the interrupted time series model, overall hospital LOS was shorter for the intervention group, as evidenced by the significant level change (Fig 2). Although critical care LOS decreased in the intervention group, that change was not significant (Fig 3).

When evaluating balancing measures, there was a significant decrease in the number of patients who required emergent intubation in the IMCU while awaiting ICU transfer (3 patients in the baseline group versus 0 patients in the intervention group; $P = .035$). The number of intubations within 24 hours of transfer to the ICU was lower in the intervention group and approached statistical

TABLE 1 Patient Characteristics

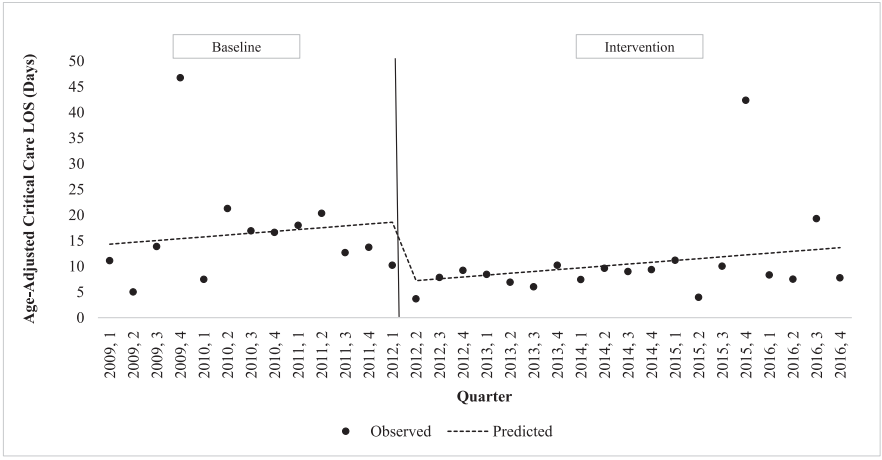
	Total	Baseline	Intervention	*P*
N (%)	308 (100)	101 (33)	207 (67)	—
Age, y, median (IQR)	6.2 (1.5–13.3)	3.6 (0.5–9.7)	8.3 (2.4–14.5)	<.001
Female sex, *n* (%)	151 (49)	46 (45.5)	105 (50.7)	.250
Primary diagnosis, *n* (%)				
Pneumonia	118 (38.3)	39 (38.6)	79 (38.2)	.775
Other	60 (19.5)	17 (16.8)	43 (20.8)	—
Bronchiolitis	55 (19.9)	21 (20.8)	34 (16.4)	—
Asthma	50 (16.2)	18 (17.8)	32 (15.5)	—
Cystic fibrosis	15 (4.9)	3 (3.0)	12 (5.8)	—
Asthma and pneumonia	10 (3.3)	3 (3.0)	7 (3.4)	—
Comorbidities, *n* (%)[a]				
Seizure disorder	85 (27.6)	26 (25.7)	59 (28.5)	.611
History of aspiration	64 (20.8)	21 (20.8)	43 (20.8)	.997
Neuromuscular disease	42 (13.6)	14 (13.9)	28 (13.5)	.936
History of prematurity	39 (12.7)	23 (22.8)	16 (7.7)	<.001
Baseline NIV, *n* (%)				
None	267 (86.7)	90 (89.1)	177 (85.5)	—
CPAP	29 (9.4)	7 (6.9)	22 (10.6)	—
BiPAP	11 (3.6)	3 (3.0)	8 (3.9)	.376
Complex chronic condition flag, *n* (%)	205 (66.6)	68 (67.3)	137 (66.2)	.796

NIV, noninvasive ventilation; —, not applicable.
[a] More than 1 comorbidity could have been selected for each patient.



	Coefficient	SE	*P*
Hospital LOS (Days)			
Intercept	28.68	11.19	—
Baseline trend	1.59	1.08	.153
Level change (baseline to postintervention)	–49.52	20.35	.021

FIGURE 2 Interrupted time series model for age-adjusted hospital LOS.



	Coefficient	SE	*P*
Critical Care LOS (Days)			
Intercept	13.98	3.45	—
Baseline trend	0.36	0.33	.294
Level change (baseline to postintervention)	−11.74	6.28	.072

FIGURE 3 Interrupted times series model for age-adjusted critical care LOS.

significance (19 patients [18.8%] in the baseline versus 22 patients [10.6%] in the intervention group; $P = .05$)

Of the 207 patients in the intervention group, 143 (69%) remained in the IMCU after initiating NIV, and 64 (31%) were transferred to the ICU. For patients who were transferred to the ICU, the median time from initiation of NIV to transfer was 6 hours. A subgroup analysis of the intervention group was conducted to identify characteristics of patients who were at a high risk of ICU transfer. The patients who required ICU transfer were significantly younger (mean age 4.5 years [IQR 1.1–10.6] than the patients in the transfer group versus 9.8 years [IQR 3.9–14.9] in the patients who remained in the IMCU; $P = .002$). Patients requiring ICU transfer were also significantly more likely to have a history of prematurity (14.1% of patients in the transfer group versus 4.9% of the patients who remained in the IMCU; $P = .023$). The 2 groups were otherwise statistically equivalent regarding the sex breakdown, primary diagnosis, presence of a complex condition flag in the PHIS, and other tracked comorbidities (Table 2).

DISCUSSION

The implementation of a guideline for NIV initiation in the setting of acute respiratory failure in an IMCU successfully reduced ICU bed use without increasing intubation for patients in the IMCU. Most patients who were initiated on NIV in the IMCU were able to remain there, with only 31% requiring ICU transfer.

Although we are not aware of comparable studies in pediatrics, the safe initiation of NIV in the IMCU setting has been described in the adult population. One large study revealed that even patients who were severely acidotic (pH <7.25) with acute hypercapnic respiratory failure can be safely managed with NIV in an

TABLE 2 Intervention Group Patient Characteristics by Transfer Status

	Intervention Group Total	Remained in IMCU	Transferred to ICU	*P*
N (%)	207 (100)	143 (69)	64 (31)	—
Age, y, median (IQR)	8.3 (2.4–14.5)	9.8 (3.9–14.9)	4.5 (1.1–10.6)	.002
Female sex, *n* (%)	105 (50.7)	71 (49.7)	34 (53.1)	.644
Primary diagnosis, *n* (%)				
Pneumonia	79 (38.2)	54 (37.8)	25 (39.1)	.916
Other	43 (20.8)	29 (20.3)	14 (21.9)	—
Bronchiolitis	34 (16.4)	22 (15.4)	12 (18.8)	—
Asthma	32 (15.5)	23 (16.1)	9 (14.1)	—
Cystic fibrosis	12 (5.8)	10 (7.0)	2 (3.1)	—
Asthma and pneumonia	7 (3.4)	5 (3.5)	2 (3.1)	—
Comorbidities, *n* (%)				
Seizure disorder	59 (28.5)	39 (27.3)	20 (31.3)	.558
History of aspiration	43 (20.8)	25 (17.5)	18 (28.1)	.081
Neuromuscular disease	28 (13.5)	21 (14.7)	7 (10.9)	.467
History of prematurity	16 (7.7)	7 (4.9)	9 (14.1)	.023
Complex chronic condition flag, *n* (%)	137 (66.2)	90 (62.9)	47 (73.4)	.056
Baseline NIV requirement, *n* (%)	30 (14.5)	21 (14.7)	9 (14.1)	.906

NIV, noninvasive ventilation; —, not applicable.

IMCU.[18] However, some of the disease processes that drive respiratory failure in the adult population (chronic obstructive pulmonary disease and heart failure) are less common in the pediatric population. We cannot infer that pediatric patients with acute respiratory failure can be safely managed with NIV in an IMCU from adult data alone.

In this article we have described the initiation of NIV in an IMCU for 207 pediatric patients with acute respiratory failure without an increase in the need for emergent intubation. By initiating NIV outside of the ICU, we decreased ICU bed needs: we saved 3.3 (SD 5.2) ICU days per patient initiated on NIV in the IMCU. We also see that patients who initiated NIV in the IMCU had a significantly shorter hospital LOS, although it is unclear whether the 0.5-day reduction is clinically significant. Although there is ongoing debate about the etiology and magnitude of the critical care physician shortage, there is consensus that reducing the strain on ICU resources remains an important goal.[19–21] IMCUs can reduce the burden on ICU staff by caring for patients who require intensive nursing or respiratory therapist care but do not require invasive interventions. The NIV trial guideline described supported a more refined triage process, in which 69% of patients with acute respiratory failure who would have previously required an ICU bed but received no invasive therapies were safely managed outside of the ICU.

The staffing of our IMCU, which includes a 1:2 nursing ratio and a dedicated respiratory therapist, is critical to understanding the generalizability of this intervention. This population of patients who are critically ill requires close monitoring. We believe that this guideline was successful, in part, because of the use of the NIV trial initiation huddle, which aligned the team to a common goal and allowed all team members the opportunity to voice concerns. Repeat bedside huddles with clinical deterioration and NIV setting adjustments continually readdressed the ability of the IMCU to safely care for patients. We hypothesize that this process resulted in rapid detection of patients with decompensation, reflected in the significant decrease in the number of patients who required emergent intubation in the IMCU while awaiting ICU transfer. Our staffing model also included overnight coverage by intensivists. However, the guideline for NIV initiation was the same for both hospitalists and intensivists, and intensivists were not consulted for daytime NIV initiation.

Our study should be considered in light of several limitations. First, this was a single-site study, and its generalizability may be limited because of site-specific practices and policies, including available nursing and respiratory therapy support for the IMCU, as described previously. Furthermore, we did not conduct a cost analysis, which may have further revealed the importance of the decreased ICU bed use. We acknowledge 2 significant differences between our baseline and intervention groups (age and history of prematurity), although other characteristics are similar. This would not impact the reduction we saw in ICU bed use, but the significant decline in intubations in the intervention group for those patients in the IMCU who are awaiting ICU transfer should be considered in light of these discrepancies. Finally, we also note that in the intervention, we did not have a strict definition of acute respiratory failure but relied on attending physician determination. However, attending physician coverage remained stable during the study period.

Identifying patients who are at a high risk of NIV trial failure in an IMCU is an important step in improving ICU triage and reducing the need for intrahospital transfer. In this study, younger age and a history of prematurity were risk factors for failing an IMCU NIV trial, but further investigations are required to better identify this high-risk group. Larger randomized studies are also needed to compare the safety and efficacy of NIV in the ICU with the safety and efficacy of NIV in the IMCU.

CONCLUSIONS

With appropriate supportive processes and staffing, the initiation of NIV in the IMCU for acute respiratory failure saved ICU bed-days without increasing the rate of patients who were intubated in the IMCU while awaiting ICU transfer. The majority of patients who initiated NIV in the IMCU never required an ICU transfer.

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