

Research Article

Improving internal medicine resident proficiency in non-invasive positive pressure ventilation and oxygen modalities through simulation training

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Abstract

Introduction

Simulation-based training is increasingly used to teach respiratory interventions, but limited studies have evaluated its impact on both non-invasive positive pressure ventilation (NIPPV) and supplemental oxygen delivery systems. We assessed changes in internal medicine residents' knowledge and attitudes before and after a simulation-based training program.

Methods

This is a retrospective study of a simulation-based training program. There were 78 internal medicine residents from postgraduate first year (PGY1), postgraduate second year (PGY2), and postgraduate third year (PGY3) who participated in a one-hour training session, including lecture and three simulation stations covering oxygen delivery devices, high-flow nasal cannula, and bi-level positive airway pressure/continuous positive airway pressure (BIPAP/CPAP). Pre- and post-training questionnaires assessed attitudes and knowledge.

Results

Attitudes for comfort level or recognition increased after training (all $p < 0.001$), and attitudes for needing more training decreased after training (all $p < 0.001$). Specific knowledge increased after training with percentage-point differences ranging from 48.7% to 60.3% for all of the questions (all $p < 0.001$). Case scenario knowledge increased after training with percentage-point differences ranging from 29.4% to 48.7% (all $p < 0.001$). Knowledge differences between postgraduate years were mostly eliminated after training. All residents rated the training highly.

Conclusion

Simulation-based training improved attitudes and knowledge for both oxygen modalities and NIPPV. PGY1 and PGY2 residents achieved knowledge levels similar to PGY3 residents after the training. We recommend incorporating simulation-based respiratory training into residency programs to improve resident competency for both oxygen modalities and NIPPV.

INTRODUCTION

Airway management and oxygen delivery are essential components of medical training for internal medicine residents who frequently care for acutely ill patients. Non-in-

vative positive pressure ventilation (NIPPV) is the use of bi-level positive airway pressure (BIPAP) and/or continuous positive airway pressure (CPAP).¹ Also, high-flow nasal cannula (HFNC) is an important oxygen modality. Both are key interventions in managing acute respiratory failure.²

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In hospitalized patients with respiratory illness, HFNC reduced the need for invasive mechanical ventilation but was not associated with mortality.³ In patients with acute respiratory failure, NIPPV reduced both mortality and intubation rates by 29% and 31%, respectively.⁴ NIPPV also decreased hospital length of stay.⁵

Simulation-based training has been successfully used for managing respiratory care. For invasive ventilation, simulation-based assessments for mechanical ventilation improved knowledge scores among medical residents.⁶ A simulation-based ventilator training program enhanced general ward nurses' knowledge and self-efficacy for mechanical ventilation management.⁷ For NIPPV, high-fidelity simulation curricula increased medical residents' knowledge, skills, and confidence in managing non-invasive respiratory support.⁸ The incorporation of breathing simulators in educational settings enhances the realism and effectiveness of NIPPV training for clinical practice.⁹

The previous studies on NIPPV simulation training did not focus on the separate type of therapeutic treatment of usage of supplemental oxygen delivery systems.^{9,10} Supplemental oxygen delivery systems are an important area of focus, as they encompass both oxygen delivery and the necessary training for understanding when to use these systems. Our study introduces a simulation-based training program to teach trainees both the use of NIPPV and the appropriate usage of supplemental oxygen delivery systems. We compare knowledge and attitudes before and after the training program among internal medical residents across different postgraduate years.

METHODS

SETTING AND PARTICIPANTS

Ethics approval was received from the Nassau Health Care Corporation Institutional Review Board on October 17, 2024 (IRB#24-276). A waiver for informed consent was obtained due to the retrospective nature of the study. This is a retrospective evaluation of a simulation-based training program to teach internal medicine trainees the use of NIPPV, with a focus on the appropriate usage of supplemental oxygen delivery systems. The study sample comprised 78 of the 92 internal medicine residents at a public community hospital in a New York City suburb. The 14 residents were not included as scheduling challenges precluded their attendance at any of the six training sessions. There were four educators who specialized in pulmonary and critical care topics (three fellow physicians and one attending physician with more than 10 years of pulmonary and critical care medicine experience). The fellow physicians were the facilitators who gave the presentation, provided the simulation training, and administered the questions before and after the training program. The fellow physicians were also the simulation designers and administered the self-report evaluations. The attending physician reviewed content before the training program, was present at the training program, where he added his clinical experience and expertise and was available to answer questions from the fellow physician trainers

and the resident physician trainees. The educational program occurred from July 2023 through May 2024.

PROCEDURE

Shortly before the training, participants completed a questionnaire assessing attitudes, knowledge, and demographic content. The one-hour training session consisted of an introductory 15-minute lecture on the use of NIPPV and supplemental oxygen delivery systems. Topics included evaluation of requirements, initial settings titration, and basic troubleshooting of NIPPV and supplemental oxygen delivery system modalities. Participants were divided and rotated into three different stations for simulation training. The first station was about the use of oxygen delivery devices, including various types of nasal cannulas and face masks. The second station was about the use of venturi-mask and high-flow nasal cannula. The third station was about the use of BIPAP and CPAP modes of ventilation with adjustment of settings. Each station was for a maximum of 10 minutes and consisted of an introductory explanation, a practical simulation of the use of equipment, and then the opportunity to ask questions. Practical simulation topics included 1) what settings to instruct the respiratory therapist to use (i.e., numbers from low to high), 2) what settings to use if the patient's health deteriorates 3) when to recognize that treatment is not working, 4) hands on practicing with equipment on a dummy applying the modalities taught, and 5) practice of different case scenarios. The training session concluded with a summary of the skills learned, the opportunity to ask additional questions, and provided contact information of the educators for any future questions. Immediately after the training, participants completed a questionnaire assessing the same attitudes and knowledge questions as assessed before the training. They also completed satisfaction questions.

MEASURES

Demographic variables consisted of age (years), sex (male/female), race/ethnicity (white, black or African American, Asian/Asian-American, Hispanic American, South Asian [India, Pakistan, surrounding areas], Other), and postgraduate training level (postgraduate year 1 (PGY1), postgraduate year 2 (PGY2), postgraduate year 3 (PGY3) (see [Table 1](#)). There were seven attitude questions measured on a Likert-style scale ranging from 0=strongly disagree to 4=strongly agree. There were five questions on comfort level (questions #1, 2, 3, 5) or recognition (question #4) and two questions on needing more training (questions #6, 7) (see [Table 2](#)). There were six multiple-choice knowledge questions, each with four possible answers, only one of which was correct, scored as either incorrect or correct. There were three questions on specific knowledge (questions #1, 2, 3) and three questions on case scenarios (questions #4, 5, 6) (see [Tables 3](#) and 4; [Table 4](#) has the same question numbers as in [Table 3](#) and is shown in a briefer format). There were three satisfaction questions about training experience measured on a Likert-style scale ranging from 0=strongly disagree to 4=strongly agree (see [Table 5](#)).

Table 1. Sample characteristics of 78 medical residents

Variable	Mean (SD) or # (%)
Age (years)	30.7 (2.49)
Sex (female)	42 (53.8)
Race/ethnicity	
White	7 (9.0)
Black or African American	6 (7.7)
Asian/Asian-American	14 (17.9)
Hispanic American	17 (21.8)
South Asian (India, Pakistan, surrounding areas)	28 (35.9)
Other	6 (7.7)
Training level	
Postgraduate year 1	30 (38.5)
Postgraduate year 2	27 (34.6)
Postgraduate year 3	21 (26.9)

Note: M=mean

Table 2. Attitude comparisons between before and after the training workshop

Item	Before M (SD)	After M (SD)	p-value	Hedges' g (95% CI)
1) I am comfortable choosing the appropriate oxygen modality for patients experiencing respiratory failure	1.7 (1.14)	2.8 (0.91)	<0.001	-1.1 (-1.37, -0.81)
2) I am comfortable for when to start bilevel positive airway pressure (BIPAP) therapy for a patient	1.8 (1.08)	3.0 (0.71)	<0.001	-1.3 (-1.55, -0.95)
3) I am comfortable adjusting the settings of the bilevel positive airway pressure (BIPAP) device	1.6 (1.06)	3.0 (0.75)	<0.001	-1.4 (-1.69, -1.07)
4) I can recognize when the bilevel positive airway pressure (BIPAP) therapy is not working properly	1.7 (1.16)	2.9 (0.81)	<0.001	-1.3 (-1.58, -0.98)
5) I am comfortable knowing when to use high-flow nasal cannula therapy	1.8 (1.15)	2.9 (0.82)	<0.001	-1.00 (-1.24, -0.70)
6) I need more training in the modality of oxygen therapy	3.1 (1.01)	2.4 (1.00)	<0.001	0.6 (0.37, 0.85)
7) I need more training in the modality of positive pressure ventilation therapy	3.1 (0.97)	2.5 (0.95)	<0.001	0.6 (0.31, 0.79)

Note: M=mean, SD=standard deviation, CI=confidence interval

STATISTICAL ANALYSIS

Mean and standard deviation described the continuous variables. Frequency and percentage were used to describe the categorical variables. The paired *t*-test was used to compare the continuous variables. Effect size comparisons used Hedge's *g* correction for Cohen's *d*. Effect size value levels are small=0.2, medium=0.5, large=0.8, and very large=1.3.⁹ The McNemar test or the McNemar exact test compared the before and after the training workshop categorical variables of answering questions correctly. The Pearson chi-square test or Fisher's exact test (when the expected cell size was less than 5) compared the postgraduate years to the separate outcomes of before and after the training workshop categorical variables of answering questions correctly. Multivariate logistic regression analyses for the predictor variable of postgraduate years were conducted for the outcome of before the training workshop categorical variables of answering questions correctly, and adjusted for covariates of age and sex. Multivariate logistic regression analyses for the predictor variable of postgraduate years

were conducted for the outcome of categorical variables after the training workshop of answering questions correctly, and adjusted for covariates of age, sex, and the corresponding categorical variable before the training workshop of answering questions correctly. All *p*-values were two-tailed. Alpha level for significance was *p* < 0.05. IBM SPSS Statistics version 28 (IBM Corporation, Armonk, NY, 2021) was used for all analyses.

RESULTS

[Table 1](#) shows the sample characteristics. Mean age was almost 31 years. More than half were female, the largest race/ethnicity category was South Asian at more than one third, and postgraduate year had slightly higher percentages from the first year as compared to the second and third years.

[Table 2](#) shows attitude comparisons with the paired *t*-test between before and after the training workshop. For the five attitude items measuring comfort level or recognition, all significantly increased (all *p* < 0.001) from before to after the training workshop. There were either large or

Table 3. Knowledge comparisons between before and after the training workshop

Item	Correct Before # (%)	Correct After # (%)	p-value
1) What do the two airway pressures in bilevel positive airway pressure (BIPAP) represent?	29 (37.2)	74 (94.9)	< 0.001
2) What is the primary function of bilevel ventilation (IPAP and EPAP)?	27 (34.6)	74 (94.9)	< 0.001
3) What is the advantage of using a Venturi mask?	32 (41.0)	70 (89.7)	< 0.001
4) A 64-year-old obese patient presents with dyspnea and wheezing. Initial arterial blood gas (ABG) shows pH of 7.18, CO ₂ of 84 mm Hg, and PaO ₂ of 108 mmHg. Started on bilevel positive airway pressure (BIPAP) therapy with an inspiratory positive airway pressure (IPAP) of 10 cm H ₂ O and expiratory positive airway pressure (EPAP) of 5 cm H ₂ O. After one hour, the patient continues to have dyspnea with repeat ABG showing PCO ₂ of 79 mm Hg and SpO ₂ of 89%. Mask fitment is appropriate. What is the appropriate next step?	42 (53.8)	68 (87.2)	< 0.001
5) Bilevel positive airway pressure (BIPAP) settings are adjusted appropriately for the 64-year-old patient above. After 30 minutes, the nursing staff alerts you that the patient is starting to breathe faster with a respiratory rate of 40 breaths/minute, with accessory muscle use. Mask fitment is appropriate. SpO ₂ is unchanged at 89%. What is the appropriate next step in management?	47 (60.3)	70 (89.7)	< 0.001
6) A 58-year-old patient presents with difficulty breathing and productive cough. The chest X-ray reveals right lower lobe opacities consistent with community-acquired pneumonia. The patient is euolemic on the exam with reduced breath sounds on the right side and answers questions appropriately. Non-rebreather mask (NRB) is at 15 L/min. Vitals are now BP of 130/86, HR of 98, RR of 24, and SpO ₂ of 86% on nasal cannula. What is the immediate next step of action?	24 (30.8)	62 (79.5)	< 0.001

Note: IPAP=inspiratory positive airway pressure, EPAP=expiratory positive airway pressure, BP=blood pressure, HR=heart rate, RR=respiratory rate

very large effect sizes. For the two items measuring needing more training, all significantly decreased (all $p < 0.001$) from before to after the training workshop. There were medium effect sizes.

[Table 3](#) shows knowledge comparisons with the McNemar test between before and after the training workshop. For the three specific knowledge items, all significantly increased (all $p < 0.001$) from before to after the training workshop. Percentage-point differences ranged from 48.7% to 60.3%. For the three case scenario items, all significantly increased (all $p < 0.001$) from before to after the training workshop. Percentage-point differences ranged from 29.4% to 48.7%.

[Table 4](#) shows knowledge comparisons between the postgraduate year groups for before and after the training workshop. In the multivariate logistic regression analyses, for before the training workshop, for the three specific knowledge items, PGY1 and PGY2 each had significantly lower knowledge than PGY3. For the three case scenario items, for started on BIPAP, PGY1 and PGY2 each had significantly lower knowledge than PGY3. For adjusted bilevel positive airway pressure, PGY1 had significantly lower knowledge than PGY3. For chest X-ray findings, there were no significant differences between the PGY groups. For after the training workshop, the only significant difference in the multivariate analysis was for chest X-ray findings, where PGY1 had significantly lower knowledge than PGY3. It is noteworthy that after the training workshop, all PGY3 answered 100% correctly on all knowledge multiple-choice items except for the one item on chest X-ray findings where 20 of 21 (95.2%) residents answered correctly. [Table 5](#)

shows that all three satisfaction items were rated highly from agree to strongly agree.

DISCUSSION

We found that attitudes for comfort level items (i.e., choosing the appropriate oxygen modality, when to start BIPAP, adjusting the settings of BIPAP, and knowing when to use high-flow nasal cannula therapy) or recognition when BIPAP is not working properly increased after training and attitudes for needing more training decreased after training. We found that for specific knowledge and case scenarios that knowledge increased after training. For the specific knowledge questions, in an analysis comparing the different postgraduate year levels, as expected before the training, PGY1 and PGY2 had lower knowledge than PGY3. After the training, for almost all analyses and PGY levels, this difference was no longer present. All sessions were rated highly.

Our study found that attitudes for comfort level or recognition increased after training. A study found that residents had increased comfort for performing noninvasive ventilation after training.⁸ Our study findings for a similar program about education for performing noninvasive ventilation that also included oxygen modality use showed a similar pattern. Changes in attitude and practice can occur with educational interventions to increase knowledge, challenge taboos, and facilitate discussion.¹¹ Our multifaceted approach of both lecture-based learning as well as practical hands-on simulation training demonstrated positive increases in attitudes for the topics taught.

Table 4. Knowledge correct comparisons between the postgraduate year groups for before and after the training workshop

Item	PGY1 Correct # (%) (n = 30)	PGY2 Correct # (%) (n = 27)	PGY3 Correct # (%) (n = 21)	Univariate p-value	Multivariate p-value
1) Bilevel positive airway pressure: Before	6 (20.0)	6 (22.2)	17 (81.0)	< 0.001	PGY1:p < 0.001 PGY2:p < 0.001
2) Bilevel ventilation: Before	5 (16.7)	6 (22.2)	16 (76.2)	< 0.001	PGY1:p = 0.001 PGY2:p < 0.001
3) Venturi mask: Before	7 (23.3)	10 (37.0)	15 (71.4)	0.002	PGY1:p < 0.001 PGY2:p = 0.01
4) Started on bilevel positive airway pressure: Before	11 (36.7)	13 (48.1)	18 (85.7)	0.002	PGY1:p < 0.001 PGY2:p = 0.002
5) Adjusted bilevel positive airway pressure: Before	14 (46.7)	17 (63.0)	16 (76.2)	0.10	PGY1:p = 0.01 PGY2:p = 0.08
6) Chest X-ray findings: Before	5 (16.7)	9 (33.3)	10 (47.6)	0.06	PGY1:p = 0.52 PGY2:p = 0.81
1) Bilevel positive airway pressure: After	28 (93.3)	25 (92.6)	21 (100.0)	0.55	PGY1:p = 1.00 PGY2:p = 1.00
2) Bilevel ventilation: After	27 (90.0)	26 (96.3)	21 (100.0)	0.45	PGY1:p = 1.00 PGY2:p = .00
3) Venturi mask: After	25 (83.3)	24 (88.9)	21 (100.0)	0.14	PGY1:p=1.00 PGY2:p=1.00
4) Started on bilevel positive airway pressure: After	22 (73.3)	25 (92.6)	21 (100.0)	0.01	PGY1:p = 1.00 PGY2:p = 1.00
5) Adjusted bilevel positive airway pressure: After	22 (73.3)	27 (100.0)	21 (100.0)	<0.001	PGY1:p = 1.00 PGY2:p = 1.00
6) Chest X-ray findings: After	22 (73.3)	20 (74.1)	20 (95.2)	0.10	PGY1:p=0.03 PGY2:p=0.06

Note: PGY1: postgraduate year 1, PGY2: postgraduate year 2, PGY3: postgraduate year 3. For each of the variable topics shown in a briefer format, the number before the item is the same numbering as in the complete item description shown in Table 3. Pearson chi-square test analyses conducted for before the training workshop. Fisher's exact test analyses conducted for after the training workshop. Logistic regression analyses conducted for the multivariate analyses with the reference group of postgraduate year 3.

Table 5. Satisfaction items after training session

Item	M (SD)
The topics taught were relevant to my clinical practice	3.7 (0.60)
I am more comfortable in choosing the appropriate oxygen modality for my patients	3.4 (0.77)
The instructors were knowledgeable about the topics taught	3.7 (0.54)

Note: M=mean, SD=standard deviation

We found increased knowledge after the training program. One of the topics taught was non-invasive ventilation. Non-invasive ventilation is the mainstay for the treatment of patients who require augmentation of ventilation to address acute and chronic respiratory failure.¹² A similar training program that included simulation demonstrated an increase after the training session in clinical knowledge for non-invasive ventilation topics of correctly recognizing the indications and contraindications of BIPAP and appropriately adjusting BIPAP and HFNC settings.⁸ Our findings for increased knowledge for both the more complex non-invasive ventilation topics and the less complex but often misunderstood oxygen modality topics are similar to this pattern. The findings from our study and the other study suggest that there is a consistent approach: education on

these topics can be useful for conveying knowledge to others.

Our findings showed that our educational program improved the knowledge level in residents with fewer years of training (i.e., PGY1 and PGY2) to be similar to those with the highest level of training (i.e., PGY3). Previous research shows that one month after education and simulation training of PGY1 residents that PGY1 and PGY3 residents had similar skills for performing lumbar puncture, splinting, venipuncture, and suturing on models.¹³ Our study is similar to this pattern and shows that education and simulation training can improve the skills of residents with fewer years of training (i.e., PGY1 and PGY2) to be similar to those with the highest level of training (i.e., PGY3). We also show that this improved knowledge works

for two types of knowledge, consisting of general knowledge and specific case-scenario knowledge.

Simulation-based training is a valuable tool to address the gap between knowledge and attitude and implementation, enabling clinicians to develop the requisite knowledge and skills in a safe, controlled environment. The utility of simulation-based training for NIPPV is supported by several studies.^{9,14,15} A strength of our study was the use of simulation training to educate about supplemental oxygen delivery systems.

This study has several limitations. First, educational training for health topics can focus not only on short-term knowledge retention but also on long-term knowledge retention.¹⁴ Our study only measured short-term knowledge retention. Future research should study whether the knowledge learned was retained over a longer period of time. Second, we taught all PGY levels at one time. It is possible that if there were separate training sessions by PGY level, some individuals at lower PGY levels may have been more comfortable with asking certain questions to those at their training level rather than not asking any questions. Also, separate training sessions by PGY level may have allowed for tailoring of content by PGY level.

CONCLUSION

In conclusion, we found that simulation-based training for medical residents can increase attitudes for comfort level items (i.e., choosing the appropriate oxygen modality, when to start BIPAP, adjusting the settings of BIPAP, and knowing when to use high-flow nasal cannula therapy) or recognition when BIPAP is not working properly and can increase knowledge for respiratory topics of NIPPV and oxygen modality. We recommend that hospitals consider providing educational training programs to improve the

knowledge of their residents. Future research should consider educational training by separate PGY levels.

CONTRIBUTIONS

All authors contributed to the conception or design of the work, the acquisition, analysis, or interpretation of the data. All authors were involved in drafting and commenting on the paper and have approved the final version.

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COMPETING INTERESTS

All authors have completed the ICMJE uniform disclosure form and declare no conflict of interest.

ETHICS

Ethics approval was received from the Nassau Health Care Corporation Institutional Review Board on October 17, 2024 (IRB#24-276).

AI STATEMENT

The authors confirm that no generative AI or AI-assisted technology was used to generate content.

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