ORIGINAL RESEARCH

Check for updates

Developing and Implementing Noninvasive Ventilator Training in Haiti during the COVID-19 Pandemic

Peter Jackson[1], Trishul Siddharthan[2], Ivet T. Cordoba Torres[3], Barth A. Green[4], Chantal Jean-Pierre Policard[3], Jerry Degraff[5], Roma Padalkar[6], Kathryn B. Logothetis[1], Jeffrey A. Gold[7], and Alexander C. Fort[3]

[1]Division of Pulmonary and Critical Care, Virginia Commonwealth University, Richmond, Virginia; [2]Division of Pulmonary and Critical Care, [3]Department of Anesthesiology, Perioperative Medicine and Pain Management, and [4]Department of Neurosurgery, University of Miami Miller School of Medicine, Miami, Florida; [5]Hospital Bernard Mevs, Port-au-Prince, Haiti; [6]Rowan University School of Osteopathic Medicine, Stratford, New Jersey; and [7]Department of Pulmonary and Critical Care, Oregon Health & Science University, Portland, Oregon

ORCID ID: 0000-0001-5108-9381 (P.J.)

ABSTRACT

Background: Noninvasive ventilation (NIV) is an important component of respiratory therapy for a range of cardiopulmonary conditions. The World Health Organization recommends NIV use to decrease the use of intensive care unit resources and improve outcomes among patients with respiratory failure during periods of high patient capacity from coronavirus disease (COVID-19). However, healthcare providers in many low- and middle-income countries, including Haiti, do not have experience with NIV. We conducted NIV training and evaluation in Port-au-Prince, Haiti.

(Received in original form May 24, 2021; accepted in final form December 7, 2021)

Supported by the Haitian Global Health Alliance in Support of GHESKIO, which received grant funding through Pfizer; the University of Miami Miller School of Medicine; and Project Medishare.

Author Contributions: All authors contributed to this work in accordance with ICMJE guidelines. This included assisting with study design, questionnaire development, navigation of ethical review boards and protocols, data review and analysis and contributions to this manuscript. All authors approved of the final manuscript and agree to be accountable for all aspects of the work.

Correspondence and requests for reprints should be addressed to Peter Jackson, M.D., Division of Pulmonary and Critical Care, Virginia Commonwealth University, 1200 East Broad St., Box 980050, Richmond, VA 23298-0050. E-mail: peter.jackson@vcuhealth.org.

ATS Scholar Vol 3, Iss 1, pp 112–124, 2022

DOI: 10.34197/ats-scholar.2021-0070OC

Objectives: To design and implement a multimodal NIV training program in Haiti that would improve confidence and knowledge of NIV use for respiratory failure.

Methods: In January 2021, we conducted a 3-day multimodal NIV training consisting of didactic sessions, team-based learning, and multistation simulation for 36 Haitian healthcare workers. The course included 5 didactic session and 10 problem-based and simulation sessions. All course material was independently created by the study team on the basis of Accreditation Council for Continuing Medical Education–approved content and review of available evidence. All participants completed pre- and post-training knowledge-based examinations and confidence surveys, which used a 5-point Likert scale.

Results: A total of 36 participants were included in the training and analysis, mean age was 39.94 years (standard deviation [SD] = 9.45), and participants had an average of 14.32 years (SD = 1.21) of clinical experience. Most trainees (75%, $n = 27$) were physicians. Other specialties included nursing (19%, $n = 7$), nurse anesthesia (3%, $n = 1$), and respiratory therapy (3%, $n = 1$). Fifty percent ($n = 18$) of participants stated they had previous experience with NIV. The majority of trainees (77%) had an increase in confidence survey score; the mean confidence survey score increased significantly after training from 2.75 (SD = 0.77) to 3.70 (SD = 0.85) ($P < 0.05$). The mean knowledge examination score increased by 39.63% (SD = 15.99%) after training, which was also significant ($P < 0.001$).

Conclusion: This multimodal NIV training, which included didactic, simulation, and team-based learning, was feasible and resulted in significant increases in trainee confidence and knowledge with NIV. This curriculum has the potential to provide NIV training to numerous low- and middle-income countries as they manage the ongoing COVID-19 pandemic and rising burden of noncommunicable disease. Further research is necessary to ensure the sustainability of these improvements and adaptability to other low- and middle-income settings.

Keywords:
COVID-19; noninvasive ventilation; acute respiratory failure; global health; noncommunicable disease

Noninvasive ventilation (NIV) is a method of providing respiratory support through the application of oxygen and positive airway pressure via a nasal or facial mask or, occasionally, a helmet delivery system. NIV is considered the standard of care for the initial treatment of exacerbations of chronic obstructive pulmonary disease (COPD) with hypercapnia and acute pulmonary edema from congestive heart failure (CHF) (1, 2). Although the role of NIV is less clear in acute respiratory failure (ARF) due to viral or bacterial pneumonia, data suggest that NIV use in selected patients with close monitoring is of likely benefit (1, 3, 4).

The COVID-19 pandemic has created challenges in the management of respiratory disease globally because of high rates of COVID-19–induced ARF and limitations in resources and hospital capacity. In low- and middle-income countries (LMICs), such as Haiti, there is a longstanding shortage of critical care staff, beds, and equipment at baseline; estimates suggest that many LMICs have fewer than 5 intensive care unit (ICU) beds per 100,000 people as compared with 35 per 100,000 in the United States (5). NIV can provide temporizing and destination therapy for patients with respiratory failure due to a range of etiologies; therefore, NIV may mitigate the effects of COVID-19 outbreaks on fragile healthcare systems in LMICs (1, 3, 6). Recently, NIV was conditionally recommended for ARF in COVID-19 by the World Health Organization, likely because of its clinical efficacy for select patients and to reduce strain on ICU resources during the pandemic (6).

The COVID-19 pandemic provides a rationale for urgently increasing NIV capability in LMICs, and the ongoing rise of noncommunicable diseases, including COPD and heart failure, suggest that NIV capacity will have durable benefits (7). More than 90% of COPD deaths now occur in LMICs, where the prevalence of COPD has continued to increase; meanwhile, CHF prevalence doubled from approximately 33 million in 1990 to 66 million in 2017 and carries the highest mortality in LMICs (7, 8). NIV is proven to decrease mortality during exacerbations of both CHF and COPD (1, 9). In addition, there is possible benefit of NIV for ARF in patients with human immunodeficiency virus (HIV); HIV remains most prevalent in LMICs, and ARF is the leading cause of death in patients with HIV (2, 10–12). Given the urgent need for NIV for COVID-19 in LMICs and its utility in diseases endemic to these settings, programs to improve NIV capacity are clearly warranted.

Despite the clinical benefits and need for NIV in LMICs, its use is not common in these settings (13). This is likely due to numerous barriers to NIV uptake. Although cost is one consideration, studies have generally shown NIV to be cost effective (14, 15). There is no research on limitations for NIV use in LMICs; however, studies evaluating general care for patients with ARF in LMICs identify staff training as a significant limitation to appropriate care of critically ill patients with ARF (13, 16, 17). Studies in high-income countries that evaluated barriers specific to NIV use also found staff familiarity and adequate NIV training are important predictors of use (18–20). Furthermore, research on how to best deliver training to improve staff familiarity and competence with NIV suggests that didactic education together with in-person simulation is most effective (21–23).

Given the urgent need to increase critical care capacity and the large potential benefit of NIV use within Haiti and other LMICs, we created a multimodal NIV curriculum to improve NIV user confidence and knowledge. This training was in conjunction with a previously planned distribution of bilevel positive airway pressure (BPAP) and continuous positive airway pressure (CPAP) machines within the country by the Ministry of Public Health and Population (MSPP).

METHODS

Setting

Haiti is a low-income country located in the Caribbean with approximately 11 million people, divided into 10 administrative units or “departments.” The country has a shortage of physicians, with only 25 per 100,000 people. In addition, there is a severe lack of critical care resources.
A survey in 2019 of 51 health facilities in

Table 1. Participants' demographics

Background Demographics	Overall (*n* = 36)	Missing
Age, yr*	39.94 (SD = 9.5)	2
Sex, female	22 (61.1)	0
Total years of clinical experience	13.97 (11.3)	5
Experience with NIV	18 (50)	0
Specialty		
General medicine/internist	14 (38.9)	—
Anesthesiologist	8 (22.2)	—
Nurse	7 (19.4)	—
Pulmonologist	3 (8.3)	—
Surgeon	1 (2.7)	—
Nurse anesthetist	1 (2.7)	—
Respiratory therapist	1 (2.7)	—
Pediatrician	1 (2.7)	—

Definition of abbreviations: NIV = noninvasive ventilation; SD = standard deviation.
Data are frequency (%) unless indicated.
*Mean age.

Haiti revealed only 124 ICU beds and the capacity to ventilate just 66 patients throughout the entire country (24). Before training, discussion with Haitian physicians identified key personnel involved in NIV administration. Nurses and physicians are both involved in NIV application and troubleshooting; initiation of NIV and all NIV settings are directed by physicians, as there is a severe lack of respiratory therapists. This informed the inclusion of a range of healthcare workers in the training (Table 1).

In January 2021, three anesthesia critical care physicians (A.C.F., I.T.C.T., and C.J.-P.P.), two pulmonary and critical care physicians (T.S. and P.J.), and one respiratory therapist (J.D.) conducted a 3-day multimodal NIV course consisting of didactic sessions, team-based learning, and multistation simulation training.

Didactic sessions were delivered in English with real-time translation to French with occasional clarifications in Haitian Creole. There were five didactic sessions: NIV indications, choosing and titrating NIV settings, machine and mask setup, physiology of NIV, and expanded NIV use and NIV failure. All didactic sessions were created by the aforementioned trainers and were based on literature review and Accreditation Council for Continuing Medical Education (ACCME)–accredited open-source content from medmastery.com (25).

Simulation and team-based learning problems were independently created by the trainers and reviewed by the study team. Study team review focused on ensuring all content was evidence based, addressed within didactic sessions, and reflected in the knowledge-based assessments.

Simulation consisted of 10 stations ranging from hands-on application of NIV on a low-fidelity simulation mannequin to a megacase with real-time narrative feedback on trainee decisions. Specific attention was given to trainees' recognition of NIV contraindications and failure during simulation. All simulation and team-based learning included native Haitian translators for real-time feedback and team-based discussion.

Trainees were asked to complete pre- and post-training surveys to assess their confidence with NIV in a clinical setting. Confidence surveys consisted of 12 items using a Likert scale to reflect participants' comfort with various aspects of initiating and managing patients on NIV. Likert scores ranged from 1 to 5, with 1 indicating a participant was "very uncomfortable" and 5 indicating the participant was "very comfortable" with an aspect of care. Trainees also completed a pre- and post-training knowledge examination. This examination was based on the didactic sessions and modified assessments from medmastery.com, which produces open-source ACCME-approved content (25). Knowledge-based examinations consisted of five domains: modes of NIV, physiology of NIV, general NIV uses, expanded NIV uses, and practical applications of NIV. Both the confidence survey and knowledge examination were translated from original English to French by Haitian translators who work with Medishare Haiti. Translators were also available for questions during the administration of all assessments.

All in-person sessions were conducted with appropriate personal protective equipment and social distancing as mandated by local policies. Didactic training occurred within ventilated areas whenever possible; simulation and team-based learning was conducted at multiple physically distanced stations to limit congregation of participants. All trainers were fully vaccinated and had negative COVID-19 test results before training and after training. In-person sessions were approved by the Haitian MSPP and Bernard Mevs Hospital; all trainings were attended by MSPP representatives to ensure compliance with local COVID-19 guidelines. Institutional Review Board (IRB) approval was obtained before delivery of the curriculum by the University of Miami (IRB #20210030). Bernard Mevs Hospital does not have an institutional IRB. The Haitian Ministry of Health acted as the local IRB of record and exempted the study from full local IRB review while deferring additional regulatory oversight to the University of Miami IRB.

Biostatistical Methods

Mean scores were calculated as a composite measure of each instrument before and after the educational intervention, with lower scores indicating lower knowledge assessment. Missing values on knowledge tests were scored as incorrect and assigned 0 points. For confidence surveys, subjects with surveys containing five or more missing values were excluded, resulting in 31 participants for analysis. The decision to exclude participants with high numbers of missing values (>40%) on the confidence assessment was based on the inability to determine whether missing values denoted low or high confidence. In addition, previous studies show bias when imputation is used in Likert surveys with >20% of values missing (26). Imputation of means was also calculated to ensure no large differences and is reported. For included subjects, missing values on confidence surveys were excluded in the calculation of means. Given an approximate normal distribution for Likert scale data, paired parametric *t* tests were used to assess differences between groups on both knowledge and confidence assessments. All associations were considered statistically significant at *P* values of 0.05 or less. Data were analyzed using R version 3.6.1.

RESULTS

A total of 36 participants participated in the study (Table 1). The mean age of trainees was 39.94 years (standard deviation [SD] = 9.45), mean years of clinical experience was 14.32 (SD = 1.21), 61.1% were female ($n = 22$), and the majority (75%, $n = 27$) were physicians. Other specialties included nursing (19%, $n = 7$), nurse anesthesia (3%, $n = 1$), and respiratory therapy (3%, $n = 1$). Fifty percent ($n = 18$) of participants stated they had previous experience with NIV. Of the 36 participants, there was representation from 8 of the 10 departments of Haiti and 15 different medical centers (Figure 1). Twenty-three (63.9%) of the participants practiced in the largest department, Ouest, where Port-au-Prince is located.

Five participants' pretraining confidence surveys had five or more missing values and were excluded from confidence survey analysis. In the 31 subjects who completed pre- and post-training confidence surveys, the scores were normally distributed, with a mean pretraining score of 2.75 (SD = 0.77) on a 5-point Likert scale, with 5 indicating the highest confidence. The average improvement was 0.95 (SD = 0.29) points after training, resulting in a post-training mean of 3.70 (SD = 0.85), which represented a significant improvement ($P < 0.001$). Imputation of means for missing values resulted in similar results: mean pretraining score, 2.76 (SD = 0.72); post-training score, 3.72

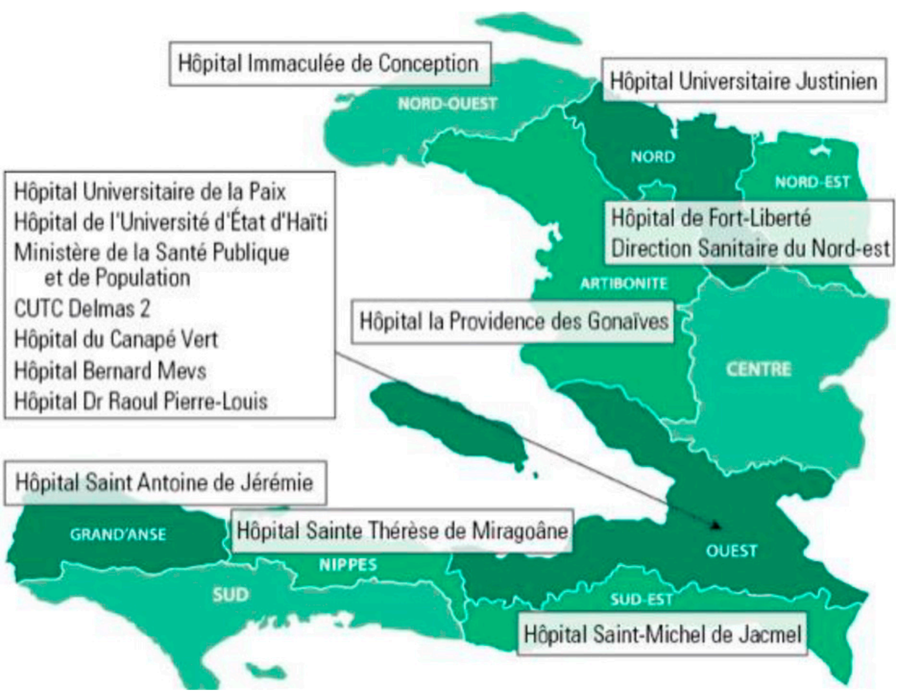

Figure 1. Map of Haiti with the 10 administrative districts outlined and labels indicating the primary practice location of the 36 participants, representing 15 different medical centers. Reproduced by permission from Reference 31.

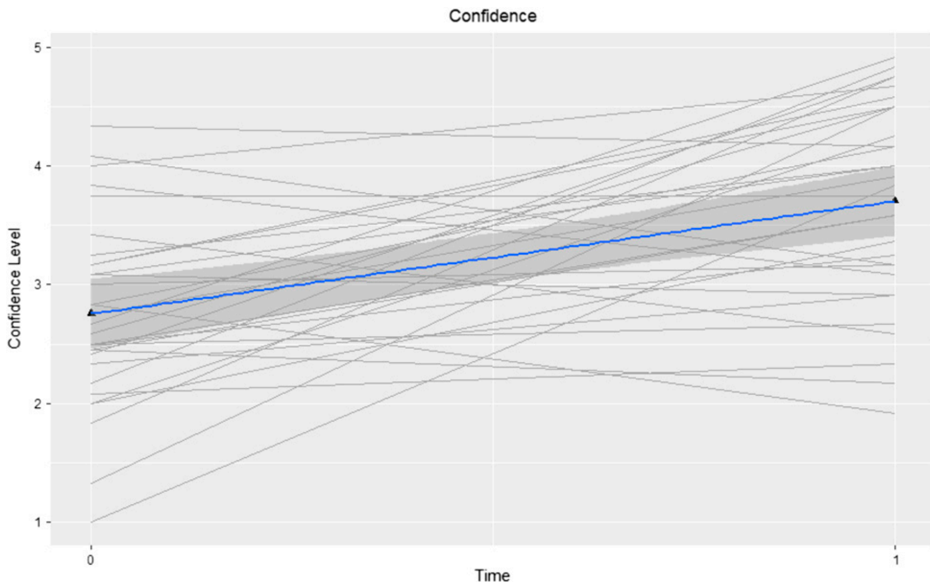

Figure 2. Each line represents an individual trainee's ($n = 31$) average confidence score among 12 tested items before and after training on a Likert scale, with 1 indicating low comfort and 5 indicating high comfort. The blue line represents the group average, and shading represents the 95% confidence interval. Time 0 = before training; Time 1 = after training.

(SD = 0.80); and mean improvement, 0.96 (SD = 0.27).

The majority of trainees (24 of 31, 77%) demonstrated an increase in mean overall confidence score (Figure 2). The item with the largest increase in confidence after training was item 1, selecting modes of NIV (BPAP or CPAP) for patients with respiratory failure, which had a mean pretraining rank of 2.84 (SD = 1.23) and post-training rank of 4.29 (SD = 0.91), reflecting an increase of 1.45 points or 29.03% ($P < 0.001$). Item 9, confidence managing COPD patients with NIV, showed the second-largest increase after training: a mean pretraining rank of 2.55 (SD = 1.01) and a post-training rank of 3.83 (SD = 1.31), reflecting an increase of 1.28 points or 25.69% ($P < 0.001$).

The knowledge assessments all showed a significant increase after training ($P < 0.001$), and this was true of all five domains. The average knowledge examination score before training was 24.60% correct (SD = 9.53%), with average improvement of 39.63% (SD = 15.99%) after training, resulting in a mean post-training examination score of 64.22% (SD = 17.54%). Among all attendees, 35 (97.2%) showed improvement in score between pre- and posttests. The domain with the most notable improvement was "general uses of NIV," which had a pretraining mean score of 31.25% (SD = 22.66%) and post-training mean of 72.91% (SD = 20.16%), representing a 41.66% improvement in post-training testing. The posttest average in this domain was significantly greater than that for all other domains ($P = 0.037$ for the closest comparator, physiology of NIV). The domain with the least improvement after training and lowest post-training average was the "modes" domain, which focused on mode selection for different indications of NIV. The modes domain pretraining average was 20.27% (SD = 12.06%) and post-training average was 53.06% (SD = 22.90%), correlating to a mean improvement of 32.84% after training, which was significant ($P < 0.001$). This

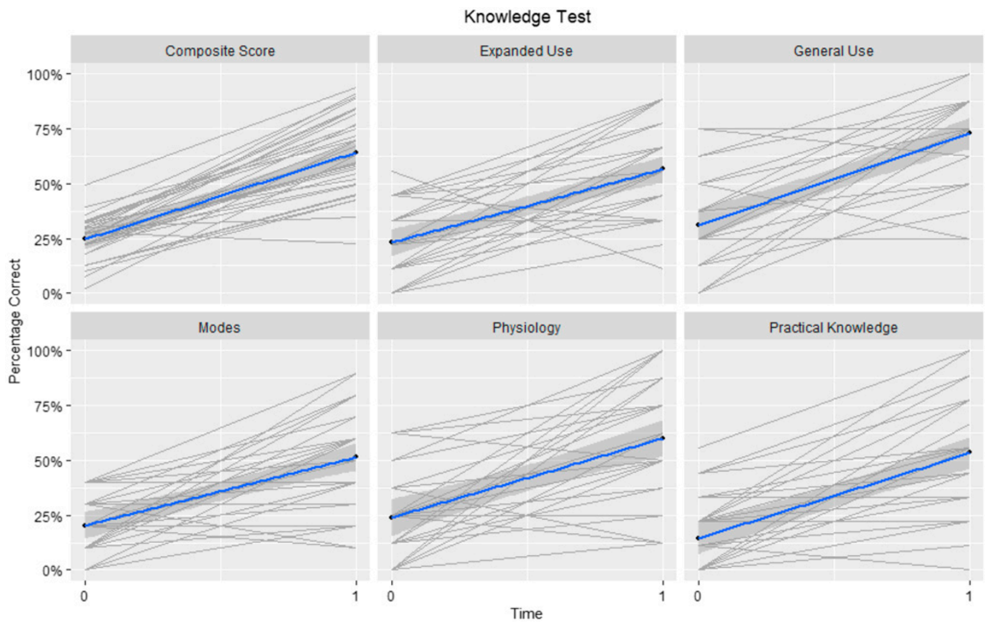

Figure 3. Each line represents one of 36 trainees who completed pre- and post-training knowledge assessments. The blue lines represent the average domain score, and shading represents the 95% confidence interval. There was a significant improvement ($P < 0.001$) for all domains after training. The panels correspond to the five knowledge domains tested and the composite knowledge examination score. Time 0 = before training; Time 1 = after training.

domain's post-training average was not significantly different from post-training scores in other domains with the exception of "general use" ($P < 0.001$) (Figure 3).

DISCUSSION

In this study, we describe the development and implementation of a multimodal NIV training over 3 days in Haiti, an LMIC in the Caribbean. Among 36 participants, there was significant improvement in confidence using NIV and NIV knowledge measured in five domains. After the removal of confidence surveys with five or more missing values, we noted a significant improvement in the mean confidence score after training (0.95 points), and the majority of trainees (24 of 31, 77%) demonstrated improved confidence scores. The knowledge examination also demonstrated marked improvement in all five measured domains, with an overall mean improvement of approximately 40%. It is difficult to determine whether this will translate to improved application of NIV, and this will require long-term follow-up.

It is worth noting that these postcurriculum improvements are in line with previous work detailing trainings of similar content and in similar settings. In one recent study in the United States, a 3-day, multi-institutional, ventilator waveform training showed improvement in post-training knowledge examination of 37% (27). Another study of short-term, multimodal, advanced cardiac life support training, which occurred in Haiti, demonstrated postcurriculum knowledge improvement of 22% after one training (28). This suggests that our training was of similar efficacy in knowledge transfer to other well-designed curricula.

In the knowledge examination, the domain with the largest improvement tested general uses of NIV, including

COPD and CHF, diseases with high prevalence in LMICs and strong evidence for benefit with NIV treatment (7). This domain had a significantly higher post-training average than all other domains. The reason for this is likely related to a concerted effort during training to encourage use of NIV in clinical conditions with the best evidence for efficacy. Conversely, the domain testing modes of ventilation had the lowest pretraining and post-training average and demonstrated the least improvement. It is reassuring that post-training improvement in the modes of ventilation domain remained statistically significant and did not differ significantly from other post-training domain averages, with the exception of general use. The reasons for lower scores in the domain evaluating mode selection in NIV are not clear, and additional attention should be paid to this content in future trainings. It may also be of benefit to and evaluate individual questions, in the modes domain and others, to reveal outliers that may be modified or excluded in future testing. Overall, the average percentage correct was relatively low, even after training. It is important to note, however, that the questions used were modified from ACCME-based content and represented advanced concepts. Further work is necessary to ensure there is ongoing education and that knowledge is retained.

One potential limitation of our training was that the increase in confidence, 2.75 (SD = 0.77) to 3.70 (SD = 0.85), was not as great as that in some related studies in the region. For example, in a study evaluating a multimodal emergency medical service skills course conducted in Port-au-Prince over 4 days, there was an improvement in "self-efficacy" Likert scale scores from 1.5 to 4.25 after the training, an improvement of 2.75 ± 0.93 (28). The reasons for only 77% of our trainees noting improvement in confidence are also not clear. As noted previously, we elected to exclude confidence surveys with five or more missing values. These scores were omitted because it is not possible to ascertain whether missing values suggested high or low confidence of the participant, and the high number of missing values increased risk of bias with imputation (26). It may be that missing values indicated low confidence, which would have underestimated our training's overall effect. In addition, our pretraining average value was higher at baseline (2.7 vs. 1.5); this makes comparison of relative increases difficult to interpret. Regardless, in-depth interviews after subsequent trainings to understand participants' confidence in using NIV would be of value.

This study has several other limitations. First, although we were able to train a diverse group of providers from across Haiti, the intervention was held at a single site; this may limit the external validity of our results. In addition, the training period was short—the optimal length of NIV training curriculum cannot be concluded from our work. It is possible that shorter curricula provide equivalent improvements in confidence and knowledge, and if so, the short duration of our training may allow similar content to be delivered quickly during periods of increased need. In addition, whereas the focus of this training concerned knowledge and practical skills, any intervention requires longitudinal follow-up to ascertain implementation, sustainability, and the complex enablers and barriers to adoption in resource-limited settings.

Lack of local language fluency is another limitation we encountered. To address this, all lectures and workshops were interpreted in real-time in Haitian

Creole. In addition, confidence surveys and educational materials, including knowledge tests, were translated into French, as medical training in Haiti is generally conducted in French. Despite these efforts, there exist several different dialects of Haitian Creole, particularly in the northern districts of Haiti, where several of our trainees reside. Although this was addressed by using serial translation during the training, it is likely that this influenced these trainees' results. Future work in the region should ensure that translators fluent in these dialects are available.

Despite these limitations, this study showed notable improvement in NIV confidence and knowledge after the delivery of a short and targeted curriculum. The study also provides important insights into the implementation of formal training in NIV in a low-resource setting during the COVID-19 pandemic and provides a framework for future educational efforts as LMICs continue to face the rising burden of respiratory failure. Given the positive feedback from the attendees and requests for future training, additional educational initiatives are being discussed. Needs assessments conducted while in Haiti, which included stakeholder interviews and resource assessments, provided insight into future training and infrastructure needs. These gaps included a need for mechanical ventilation education and respiratory equipment, particularly disposable items such as ventilator tubing, masks, viral filters, and heat moisture exchangers. We intend to continue to provide training and capacity building to Haiti in the future.

The decision to provide in-person learning and simulation during the COVID-19 pandemic was based on several factors. Although there is limited research on modalities of NIV training, previous work evaluating methods of ventilator training found that simulation and in-person training have clear advantages (23). In fact, simulation-based testing for ventilator management has been incorporated and validated in Israel for anesthesia board examinations (29). The data on remote ventilator learning are less robust. One critical review of virtual training platforms concluded that there was no scientific evidence to show the efficacy of virtual ventilator training; furthermore, in our review of the literature, we did not find any virtual simulations for NIV (21). Virtual training has been necessary in the pandemic era, but coordination with hospitals lacking infrastructure in telemedicine poses real limitations and challenges. Although there is a risk to in-person training during the COVID-19 pandemic, all our trainers were vaccinated, masks were always required during the training, and health screening was performed by site staff before entry into the facility. Importantly, the Haitian medical community was directly involved during planning of this curriculum and specifically requested this NIV training for the successful rollout of the NIV program.

Conclusions

This study demonstrates the design and implementation of an NIV training program over 3 days in Haiti, a low-resource setting, with testing and confidence surveys demonstrating significant improvements after training. Ongoing work to establish a sustainable national NIV program in Haiti beyond training will be necessary to improve outcomes related to respiratory failure. The COVID-19 pandemic has highlighted gaps in care that exist in LMICs with significant increases in morbidity and mortality attributable to a lack of resources and knowledge in the treatment of respiratory failure (30). Unfortunately, given the slow rate of vaccination in LMICs, it is reasonable to assume that the effects of COVID-19 and increased need for NIV in these countries are likely to persist for some time. This initial medical training curriculum in NIV can inform future trainings to improve respiratory care not only in Haiti but in other LMICs across the globe.

Acknowledgment

The authors thank Larry Pierre, M.D.; Victor Valdes, M.D.; Jean William Pape, M.D.; and Elizabeth Greig, M.D. Lastly, the authors thank Michael Allison, M.D., and Franz Wiesbauer, M.D., M.P.H., of medmastery.com for sharing resources used to create our assessment tools and content.

Author disclosures are available with the text of this article at www.atsjournals.org.

REFERENCES

1. Rochwerg B, Brochard L, Elliott MW, Hess D, Hill NS, Nava S, *et al.* Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure. *Eur Respir J* 2017;50: 1602426.

2. Hilbert G, Gruson D, Vargas F, Valentino R, Gbikpi-Benissan G, Dupon M, *et al.* Noninvasive ventilation in immunosuppressed patients with pulmonary infiltrates, fever, and acute respiratory failure. *N Engl J Med* 2001;344:481–487.

3. Scala R, Pisani L. Noninvasive ventilation in acute respiratory failure: which recipe for success? *Eur Respir Rev* 2018;27:180029.

4. Masclans JR, Pérez M, Almirall J, Lorente L, Marqués A, Socias L, *et al.*; H1N1 GTEI/SEMICYUC Investigators. Early non-invasive ventilation treatment for severe influenza pneumonia. *Clin Microbiol Infect* 2013;19:249–256.

5. Ma X, Vervoort D. Critical care capacity during the COVID-19 pandemic: global availability of intensive care beds. *J Crit Care* 2020;58:96–97.

6. World Health Organization. COVID-19 Clinical management: living guidance. World Health Organization [accessed 2021 May 5]. Available from: https://apps.who.int/iris/bitstream/handle/10665/338882/WHO-2019-nCoV-clinical-2021.1-eng.pdf.

7. Mathers CD, Loncar D. Projections of global mortality and burden of disease from 2002 to 2030. *PLoS Med* 2006;3:e442.

8. Bragazzi NL, Zhong W, Shu J, Abu Much A, Lotan D, Grupper A, *et al.* Burden of heart failure and underlying causes in 195 countries and territories from 1990 to 2017. *Eur J Prev Cardiol* 2021; zwaa147.

9. British Thoracic Society Standards of Care Committee. Non-invasive ventilation in acute respiratory failure. *Thorax* 2002;57:192–211.

10. Bourke SC, Piraino T, Pisani L, Brochard L, Elliott MW. Beyond the guidelines for non-invasive ventilation in acute respiratory failure: implications for practice. *Lancet Respir Med* 2018; 6:935–947.

11. American Thoracic Society; Infectious Diseases Society of America. Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. *Am J Respir Crit Care Med* 2005;171:388–416.

12. Lemiale V, Mokart D, Resche-Rigon M, Pène F, Mayaux J, Faucher E, *et al.*; Groupe de Recherche en Réanimation Respiratoire du patient d'Onco-Hématologie (GRRR-OH). Effect of noninvasive ventilation vs oxygen therapy on mortality among immunocompromised patients with acute respiratory failure: a randomized clinical trial. *JAMA* 2015;314:1711–1719.

13. Mandelzweig K, Leligdowicz A, Murthy S, Lalitha R, Fowler RA, Adhikari NKJ. Non-invasive ventilation in children and adults in low- and low-middle income countries: a systematic review and meta-analysis. *J Crit Care* 2018;47:310–319.

14. Plant PK, Owen JL, Parrott S, Elliott MW. Cost effectiveness of ward based non-invasive ventilation for acute exacerbations of chronic obstructive pulmonary disease: economic analysis of randomised controlled trial. *BMJ* 2003;326:956–959.

15. Patel SP, Pena ME, Babcock CI. Cost-effectiveness of noninvasive ventilation for chronic obstructive pulmonary disease-related respiratory failure in Indian hospitals without ICU facilities. *Lung India* 2015;32:549–556.

16. Inglis R, Ayebale E, Schultz MJ. Optimizing respiratory management in resource-limited settings. *Curr Opin Crit Care* 2019;25:45–53.

17. Baker T, Lugazia E, Eriksen J, Mwafongo V, Irestedt L, Konrad D. Emergency and critical care services in Tanzania: a survey of ten hospitals. *BMC Health Serv Res* 2013;13:140.

18. Maheshwari V, Paioli D, Rothaar R, Hill NS. Utilization of noninvasive ventilation in acute care hospitals: a regional survey. *Chest* 2006;129:1226–1233.

19. Hess DR. How to initiate a noninvasive ventilation program: bringing the evidence to the bedside. *Respir Care* 2009;54:232–243. [Discussion, p. 243–245.]

20. Crimi C, Noto A, Princi P, Esquinas A, Nava S. A European survey of noninvasive ventilation practices. *Eur Respir J* 2010;36:362–369.

21. Lino JA, Gomes GC, Sousa NDSVC, Carvalho AK, Diniz ME, Viana Junior AB, *et al.* A critical review of mechanical ventilation virtual simulators: is it time to use them? *JMIR Med Educ* 2016;2:e8.

22. Spadaro S, Karbing DS, Fogagnolo A, Ragazzi R, Mojoli F, Astolfi L, *et al.* Simulation training for residents focused on mechanical ventilation: a randomized trial using mannequin-based versus computer-based simulation. *Simul Healthc* 2017;12:349–355.

23. Keller JM, Claar D, Ferreira JC, Chu DC, Hossain T, Carlos WG, *et al.* Mechanical ventilation training during graduate medical education: perspectives and review of the literature. *J Grad Med Educ* 2019;11:389–401.

24. Losonczy LI, Barnes SL, Liu S, Williams SR, McCurdy MT, Lemos V, *et al.*; Research and Education consortium for Acute Care in Haiti (REACH) Study Group. Critical care capacity in Haiti: a nationwide cross-sectional survey. *PLoS One* 2019;14:e0218141.

25. Allison M. Noninvasive ventilation masterclass. Medmastery; 2020 April 9 [accessed 2021 March 24]. Available from: https://www.medmastery.com/course/noninvasive-ventilation-masterclass.

26. Downey RG, King C. Missing data in Likert ratings: a comparison of replacement methods. *J Gen Psychol* 1998;125:175–191.

27. Seam N, Kriner E, Woods CJ, Shah NG, Acho M, McCurdy MT, *et al.* Impact of novel multiinstitutional curriculum on critical care fellow ventilator knowledge. *ATS Scholar* 2020;2:84–96.

28. Pean CA, Davis K, Merrill R, Marinelli B, Lockwood A, Mathews Z, *et al.* Near-peer emergency medicine for medical students in Port-au-Prince, Haiti: an example of rethinking global health interventions in developing countries. *Ann Glob Health* 2015;81:276–282.

29. Berkenstadt H, Ziv A, Gafni N, Sidi A. Incorporating simulation-based objective structured clinical examination into the Israeli National Board Examination in Anesthesiology. *Anesth Analg* 2006;102: 853–858.

30. Biccard BM, Miller M, Michell WL, Thomson D, Ademuyiwa A, Aniteyeet E, *et al.*; African COVID-19 Critical Care Outcomes Study Investigators Patient care and clinical outcomes for patients with COVID-19 infection admitted to African high-care or intensive care units (ACCCOS): a multicentre, prospective, observational cohort study. *Lancet* 2021;397:1885–1894.

31. Alexander C, Fort M, Cordoba Torres IM, Jackson Peter M. Collaboration in the time of COVID 19 noninvasive ventilation training in Haiti. Anesthesiology News [published 2021 May 4; accessed 2021 Jul 15]. Available from: https://www.anesthesiologynews.com/PRN-/Article/05-21/COVID-19-Noninvasive-Ventilation-Training-Haiti/63359.