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Non-invasive respiratory support in the management of COVID-19: Report of a series using a nasal CPAP mask☆

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ABSTRACT

Background: During peak pandemic period of COVID-19, our hospital required rapid reorganization of resources and staff during between mid-March and early April 2020. Within this interval, the hospital responded to an overwhelming rate of admissions of patients in respiratory failure, rapidly reaching over 95% of its usual inpatient bed capacity and requiring 70 extra critical care beds and at least 40 intermediate care unit beds. This created a significant shortage of materials including ventilation equipment, requiring improvised use of available resources.
Aims: To describe our use of non-invasive ventilation (NIV) with the continuous positive nasal airway pressure (CPAP) device SuperNO_2VA™ (Vyaire Medical, Mettawa, IL) with hospitalized patients in acute respiratory failure due to presumed COVID-19.
Methods: We performed a retrospective analysis of 14 inpatients receiving NIV CPAP at the Hospital Ramón y Cajal in Madrid, Spain. These were inpatients presenting in respiratory failure during the peak pandemic period based on defined respiratory health, oxygenation, and comorbidity status criteria. Patient data were retrospectively acquired from patient medical records.
Results: All 14 patients were reviewed. Our series consisted of 11 males and three females with an average age of 61.5 years. Ten of 14 patients (71.4%) NIV CPAP patients did not require intubation or reintubation. Of the four unsuccessful cases, one required intubation, two required reintubation, and one expired.
Conclusions: In a time of crisis, anesthesiologists and respiratory specialists implemented the use of NIV CPAP with SuperNO_2VA to help meet the high care demand of patients in respiratory distress. Although the SuperNO_2VA was not originally developed for the management of patients in respiratory failure or distress related to COVID-19, this case series demonstrates it can be used with mostly favorable results during a time of limited resources to improve the clinical situation in patients. Advantages and disadvantages are explored.

1. Introduction

On March 11, 2020, the World Health Organization (WHO) declared an infection caused by SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus-2) as a pandemic [1]. The WHO reported the first case in Spain on February 1, 2020, and Madrid, with almost 7 million inhabitants, reported its first case on February 25, 2020 [2,3]. As of September 18, 2020, Spain had 625,651 cases and 30,405 deaths, including over 108,000 cases in Madrid [4].

Up to 15% of people infected with SARS-CoV-2 (COVID-19) require hospitalization for clinical care, including oxygen therapy; of those, approximately 5% require intensive care units (ICU) [5]. Acute respiratory failure (ARF) is the leading cause of death [6].

COVID-19 is a respiratory infection that can quickly progress to dyspnea, tachypnea, and oxygen desaturation [7]. Hypoxemic and hypercapnic distress can follow, resulting from a diffuse interstitial lung process with severe alteration of the ventilation-perfusion relationship and inhibition of the compensatory mechanism of hypoxic pulmonary vasoconstriction, further deepening hypoxemia and resulting in acute respiratory distress syndrome (ARDS) [8].

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For respiratory management of patients in respiratory distress, treatments range from conventional oxygen therapy to advanced support with extracorporeal membrane oxygenation (ECMO). Intermediate modes of ventilatory assistance include both invasive mechanical ventilation (IMV) and non-invasive ventilation (NIV) [9]. When maximum fraction of inspired oxygen (FiO_2) is achieved, the only alternative to improve oxygenation is to increase the mean pressure in the airway through positive end-expiratory pressure (PEEP) or continuous positive airway pressure (CPAP) devices [10].

During the peak pandemic period, over about 3–4 weeks from mid-March to early April 2020, our institution, the Hospital Ramón y Cajal in Madrid, Spain, required a rapid reorganization of facilities and staff in response due to overwhelming admissions in a short period of time of patients in ARF. The hospital reached >95% of our usual capacity of 901 inpatients and required 70 extra critical care beds and at least 40 intermediate care unit beds. This situation caused a significant shortage of high-flow oxygen and ventilation equipment and necessitated improvised use of available resources.

The use of NIV during the pandemic had not been universally adopted, in part because of concerns that health personnel might acquire infection given the high probability of such devices generating aerosols [11]. However, due to the lack of mechanical ventilators and the large numbers of patients in need of ventilatory support, the benefits of implementing NIV for ARF were greater than the potential risk of transmission of infection to healthcare workers with appropriate personal protective equipment (PPE).

We report here our use and evaluation of a newer nasal CPAP device for non-invasive ventilation of hospitalized patients with ARDS/ARF due to presumed COVID-19. The device we used is a positive nasal airway pressure (PAP) ventilation device originally designed for short periods of time (<24 h) in adult patients (>30 kg) during the process of sedation or anesthesia [12] and has not been specifically compared to traditional high-flow CPAP in the treatment of respiratory failure. The SuperNO_2VA system operates using wall oxygen rather than high-flow oxygen devices. Its low-flow mechanics allowed us to provide ventilatory support using available resources without significant capital investment in equipment.

2. Methods

We encountered a series of consecutive patients in respiratory failure at a time when no other ventilation devices, such as HFNC, masks for NIV, or Mapleson type C circuits were available. To meet the ventilation demands of our patients in the context of pandemic-related equipment shortages, we adapted and used the SuperNO2VA™ device (Vyaire Medical, Mettawa, IL) to temporarily provide NIV support to these patients. The SuperNO_2VA mask has a nasal bridge membrane and creates an airtight seal when placed over the patient's nose, directing the flow of gas to the upper airways, allowing the airway to remain open and preventing its collapse. The goal of the device is to improve oxygenation and ventilation by keeping the airway patent, providing positive pressure to the lower airways, and minimizing the shunt effect and alteration of the ventilation-perfusion ratio typical of respiratory distress [13,14]. (Figs. 1 and 2) If the patient did not tolerate or respond to the nasal CPAP device, other devices were selected for support including NIV with total face mask, other high-flow nasal CPAP device, or endotracheal intubation.

The Ethics Committee of the Hospital Ramón y Cajal, Ctra. de Colmenar Viejo waived the need for ethics approval and the need to obtain consent for the collection, analysis, and publication of the retrospectively obtained and anonymized data for this non-interventional study. The research was completed in compliance with the Declaration of Helsinki [15].

Given the small size of this convenience sample of patients, we did not attempt statistical interpretation other than descriptive statistics of means and percentages.

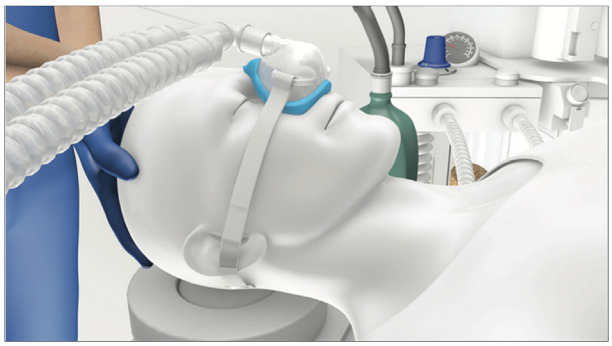

Fig. 1. SuperNO_2VA nasal CPAP device. This image is © 2020 Vyaire Medical, Inc.; Used with permission.

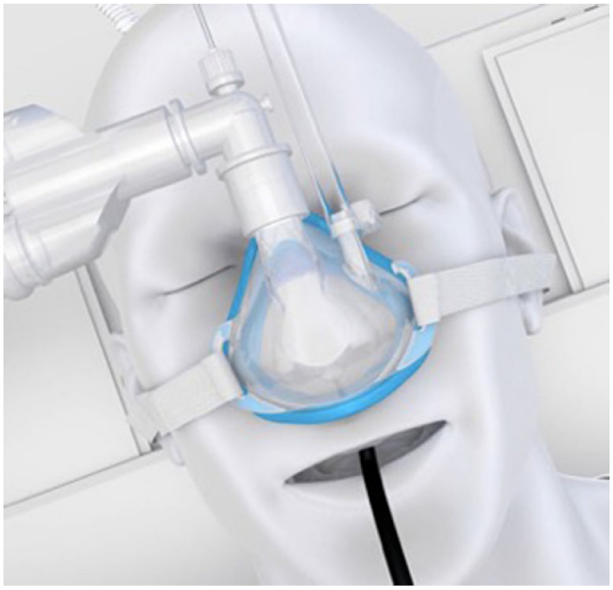

Fig. 2. SuperNO_2VA nasal CPAP device in a patient with an orogastric tube in place. This image is © 2020 Vyaire Medical, Inc.; Used with permission.

3. Results

During three weeks, the SuperNO2VA device was used on 15 patients including five in the ward, seven in the ICU, and three post-extubation ICU. In two cases, we used the device combined with the prone position as recommended in the literature for awake and cooperative patients [16,17].

The results of the device use in the 14 patients are reported in Table 1. In our cohort, 11 were males and three were females. The average age was 61.5 years for both sexes, with ages ranging from 43 to 87 years. Cases were broadly classified as patients in moderate respiratory failure with persistent hypoxia despite Venturi mask or reservoir (three patients); patients who did not meet ICU admission criteria due to advanced age and/or multiple comorbidities (two patients); patients in the intermediate respiratory care unit, before or after an ICU stay (seven patients); and patients who had been extubated in an effort to avoid reintubation (two patients).

The goal of the use of the nasal CPAP system was to avoid intubation or reintubation in this cohort of patients with respiratory insufficiency at a time of resource shortages. In total, 10 of the

Table 1
Criteria, Patient Experiences and Outcomes with NIV CPAP Device Use to treat Acute Respiratory Failure or Respiratory Insufficiency Related to COVID-19.

Case #	Clinical category	Age/ Sex	Synopsis	Outcome
1	Moderate respiratory failure, persistent hypoxia despite Venturi mask or reservoir	67/ M	COVID-19 positive. HTN, DM. SuperNO$_2$VA is applied after 3 days of hypoxia and tachypnea not improving with Venturi mask. Oxygenation improved after 3 days using SuperNO$_2$VA mask. Patient discharged home.	Successful
2		59/F	COVID-19 positive. Persistent hypoxia that improved with 24 h SuperNO$_2$VA mask	Successful
3		61/ M	COVID-19 positive. Asthma and dyslipidemia. After 3 days with Venturi mask followed by SuperNO$_2$VA for 12 h, no improvement in respiratory or clinical status; transferred to ICU for intubation.	Intubated
4	Did not meet ICU admission criteria due to age and/ or comorbidities	83/ M	COVID-19 positive. Multiple comorbidities Developed respiratory failure, pH 7.27, pCO2 81. Weaned off mask to nasal cannula after 72 h.	Successful
5		87/ M	COVID-19 positive. Congestive heart failure, acute renal failure. Persistent hypoxia; SuperNO$_2$VA was applied with initial improvement, subsequently deteriorated and expired.	Expired
6	Intermediate respiratory care unit, before or after ICU stay	43/ M	COVID -19 positive. ICU patient. Prone position was combined with SuperNO$_2$VA mask for 5 days. Weaned to nasal cannula.	Successful
7		49/ M	COVID-19 positive. ICU patient; asthma and obesity. Did not tolerate high-flow cannula. SuperNO$_2$VA applied combined with prone position. Weaned to nasal cannula.	Successful
8		60/F	COVID-19 positive. ICU patient. After 15 days with mechanical ventilator, she was transferred to intermediate care unit. SuperNO$_2$VA was applied and oxygenation and comfort improved	Successful
9		49/ M	COVID-19 positive. ICU patient. Asthma, temporal arteritis. SuperNO$_2$VA mask was applied for 3 days (12 h/day) with positive outcome	Successful
10		57/F	COVID-19 positive. ICU patient. Alternated high-flow cannula with SuperNO$_2$VA mask. The result was effective, ultimately weaned to nasal cannula.	Successful
11		62/ M	COVID-19 positive. ICU patient with COPD. Extubated, became agitated. pH 7.32, pCO2 65. Initially responded, but deteriorated and required reintubation. Found to have pneumonia secondary to bacterial superinfection.	Unsuccessful
12		58/ M	COVID-19 positive. ICU patient. Despite noninvasive ventilation and CPAP with SuperNO$_2$VA, ultimately required endotracheal intubation.	Unsuccessful
13	Post-extubation to avoid reintubation	66/ M	COVID-19 positive. Intubated for 16 days. Developed tachypnea and hypoxia after extubation. SuperNO$_2$VA was applied and oxygenation was better.	Successful
14		51/ M	COVID-19 positive. Pleural effusion and dyspnea after extubation; hypoxia despite Ventura mask. SuperNO$_2$VA mask rescue used for 3 days.	Successful

14 patients (71.4%) did not require tracheal intubation, including seven of the males and all three females. Four patients deteriorated during treatment with SuperNO$_2$VA, with two requiring intubation, one requiring reintubation, and one expiring. In two of the patients with successful use of NIV CPAP, the prone position was utilized. One patient experienced pain over the bridge of the nose related to the mask, requiring a different method of ventilation.

4. Discussion

In the wake of the COVID-19 pandemic, our hospital, like many others, faced a crisis of space, equipment, and manpower. The number of patients in respiratory failure who needed ICU beds, ventilators, and high-flow oxygen exceeded our capacity. We were forced to improvise, so we used a nasal CPAP system that relied on wall oxygen for NIV to provide respiratory support for some of these patients. This was easy to implement using available equipment and staffing. We found that the SuperNO$_2$VA system allowed us to provide ventilation sufficient to keep some patients out of the ICU and off invasive mechanical ventilation.

In our series of patients, the nasal CPAP device was used in cases with early respiratory failure or with significant comorbidities and poor prognosis. These were patients who failed with other noninvasive measures such as non-rebreather masks, Venturi masks, or high flow nasal cannula. Indications for escalation of care to noninvasive ventilation/invasive mechanical ventilation were respiratory distress, poor gas exchange, other organ dysfunction, and the rate of change in their clinical condition. We also used SuperNO$_2$VA in post-intubation and post-operative patients during recovery in order to free up ICU beds.

The use of this device as an interim therapy for acute respiratory failure has not been described. We theorized that low-flow nasal CPAP would provide better respiratory support that standard oxygen therapy in a setting where high-flow oxygen and equipment were not available. Positive experiences with high-flow CPAP have been published by Sartini [18] and Sivaloganathan [19]. In the latter study, 103 patients who would have required endotracheal intubation and mechanical ventilation were treated with NIV. Over half were able to avoid intervention with invasive ventilation. A study by Thompson et al. [20] evaluated out-of-hospital patients treated

emergently for acute respiratory distress and impending respiratory failure. CPAP applied in the field was associated with intubation in only 20% of patients compared with 50% in oxygen therapy alone. Even without more detailed physiologic data on these patients, the results with our small series are promising. This is a low-flow system that runs with wall oxygen only, avoiding the high-flow oxygen systems with their associated costs and challenges. While we were not certain that oxygenation would be adequate, we were impressed with its effectiveness and ease of use. As would be expected for a nasal CPAP device, the SuperNO_2VA device has known concerns of leak [21], patient tolerance, and nasal bridge pain. Nonetheless, of our 14 patients with respiratory failure, NIV using the SuperNO_2VA was successful in 10.

The authors are aware that the patients in this study are clinically disparate and generally do not fall within a group demographic (differing levels of acuity, comorbidities, stages of disease, etc.), making interpretation of results quite difficult. Proper evaluation of the efficacy/utility of this tool would require grouping like-patients into distinct cohorts and comparing them to known other techniques (conventional CPAP, HFNC, mechanical ventilation, etc.). However, our case series is thought-provoking and should spur interest in identifying these key clinical characteristics that are best helped with such a tool. Our paper reports on a small number of patients, limiting its generalizability. The report is retrospective in nature and would benefit from an age- and acuity-matched control intervention group. More detailed clinical data is not available to these authors at the time of this writing due to patient confidentiality laws. Such information describing criteria for intubation or avoidance of intubation would be helpful to establish objective statements about treatment success or failure using the SuperNO_2VA. Given these limitations, we did not attempt statistical interpretation other than descriptive statistics of means and percentages (Box 1, 2 and 3).

Text box 1

The current SARS-Cov-2 pandemic has created a dramatic influx of patients in respiratory failure, overwhelming the capacity of our intensive care unit to provide intubation services and critical care beds. Our medical team had to improvise to provide ventilatory support for these critically ill patients. We used the SuperNO_2VA, a positive nasal airway pressure (PAP) ventilation device originally designed for short periods of use (<24 h) in adult patients (>30 kg) during the process of sedation or anesthesia, to provide noninvasive ventilation for 14 patients who met criteria for respiratory failure.

Text box 2

In our series of 14 patients, 71% were able to be successfully managed without requiring invasive tracheal intubation by using the SuperNO_2VA device. Of the remaining patients, three required intubation and one expired. Ten patients did not require use of an intensive care unit bed.

Text box 3

Outstanding questions:

1. Which patients are acceptable candidates for the use of SuperNO_2VA noninvasive ventilation?
2. Does the use of the SuperNO_2VA noninvasive ventilation improve outcomes including costs?
3. Are there other continuous positive airway pressure devices that might be more or less successful compared to SuperNO_2VA for noninvasive ventilation in suitable candidates?

5. Conclusions

In times of crisis when facing overwhelming needs of critically ill patients, adaptability and improvisation require exploring the use of all tools available to achieve the best possible results. The SuperNO_2VA device does not need specialized equipment or personnel and is inexpensive compared to other ventilation devices, which saves resources. Although the SuperNO_2VA was not originally developed for the management of ARDS/ARF related to COVID-19, its mechanism allowed us, during a time of precarious resources, to improve the oxygenation and clinical situation in some patients with favorable results without the use of ICU beds.

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Declaration of competing interest

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References

[1] Centers for Disease Control and Prevention, Information for Healthcare Professionals about Coronavirus (COVID-19), 2020 August 25, p. 2020.
[2] Telemadrid, Confirmado el primer caso de coronavirus en Madrid, 2020 [Available from: http://www.telemadrid.es/noticias/madrid/Confirmado-primer-caso-coronavirus-Madrid-0-2207779217–20200225111539.html.
[3] World Health Organization, Novel Coronavirus(2019-nCoV) Situation Report - 12, 2020, 2/1/2020.
[4] Johns Hopkins University of Medicine, COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU): Coronavirus Resource Center, 2020 [updated 8/31/2020. Available from: https://coronavirus.jhu.edu/map.html.
[5] S. Murthy, C.D. Gomersall, R.A. Fowler, Care for critically ill patients with COVID-19, J. Am. Med. Assoc. 323 (15) (2020) 1499–1500, https://doi.org/10.1001/jama.2020.3633.
[6] Q. Ruan, K. Yang, W. Wang, L. Jiang, J. Song, Clinical predictors of mortality due to COVID-19 based on an analysis of data of 150 patients from Wuhan, China, Intensive Care Med. 46 (5) (2020) 846–848.
[7] S. Asadi, N. Bouvier, A.S. Wexler, W.D. Ristenpart, The Coronavirus Pandemic and Aerosols: Does COVID-19 Transmit via Expiratory Particles? Taylor & Francis, 2020.
[8] F. Zhou, T. Yu, R. Du, G. Fan, Y. Liu, Z. Liu, et al., Clinical course and risk factors

for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study, Lancet 395 (10229) (2020) 1054–1062, https://doi.org/10.1016/S0140-6736(20)30566-3.
[9] L. Gattinoni, D. Chiumello, P. Caironi, M. Busana, F. Romitti, L. Brazzi, et al., COVID-19 Pneumonia: Different Respiratory Treatments for Different Phenotypes? Springer, 2020.
[10] L. Gattinoni, M. Quintel, J.J. Marini, "Less is More" in mechanical ventilation, Intensive Care Med. (2020) 1–3.
[11] C.A. O'Neil, J. Li, A. Leavey, Y. Wang, M. Hink, M. Wallace, et al., Characterization of aerosols generated during patient care activities, Clin. Infect. Dis. 65 (8) (2017) 1335–1341, https://doi.org/10.1093/cid/cix535.
[12] Vyaire Medical. SuperNO2VA™ Nasal PAP Ventilation System 2020 [Available from:: https://www.vyaire.com/products/superno2va-nasal-pap-ventilation-system.
[13] F. Dimou, S. Huynh, G. Dakin, A. Pomp, Z. Turnbull, J.D. Samuels, et al., Nasal positive pressure with the SuperNO 2 VA™ device decreases sedation-related hypoxemia during pre-bariatric surgery EGD, Surg. Endosc. 33 (11) (2019) 3828–3832.
[14] S.P. Patil, I.A. Ayappa, S.M. Caples, R.J. Kimoff, S.R. Patel, C.G. Harrod, Treatment of adult obstructive sleep apnea with positive airway pressure: an American academy of sleep medicine systematic review, meta-analysis, and GRADE Assessment, J Clin Sleep Med 15 (2) (2019) 301–334, https://doi.org/10.5664/jcsm.7638.
[15] World Health Organization, WMA Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects, 2013 [Available from: https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/.
[16] O.R. Perez-Nieto, M.A. Guerrero-Gutierrez, E. Deloya-Tomas, S.A. Namendys-Silva, Prone positioning combined with high-flow nasal cannula in severe noninfectious ARDS, Crit. Care 24 (1) (2020) 114, https://doi.org/10.1186/s13054-020-2821-y.
[17] V. Scaravilli, G. Grasselli, L. Castagna, A. Zanella, S. Isgro, A. Lucchini, et al., Prone positioning improves oxygenation in spontaneously breathing nonintubated patients with hypoxemic acute respiratory failure: a retrospective study, J. Crit. Care 30 (6) (2015) 1390–1394, https://doi.org/10.1016/j.jcrc.2015.07.008.
[18] C. Sartini, M. Tresoldi, P. Scarpellini, A. Tettamanti, F. Carcò, G. Landoni, et al., Respiratory parameters in patients with COVID-19 after using noninvasive ventilation in the prone position outside the intensive care unit, Jama Jun 9 323 (22) (2020) 2338–2340, https://doi.org/10.1001/jama.2020.7861.
[19] A.A. Sivaloganathan, M. Nasim-Mohi, M.M. Brown, N. Abdul, A. Jackson, S.V. Fletcher, et al., Noninvasive ventilation for COVID-19-associated acute hypoxaemic respiratory failure: experience from a single centre, Br. J. Anaesth. Oct;125 (4) (2020) e368–e371, https://doi.org/10.1016/j.bja.2020.07.008. Epub 2020 Jul 21.
[20] J. Thompson, D.A. Petrie, S. Ackroyd-Stolarz, D.J. Bardua, Out-of-hospital continuous positive airway pressure ventilation versus usual care in acute respiratory failure: a randomized controlled trial, Ann. Emerg. Med. 52 (3) (2008) 232–241, https://doi.org/10.1016/j.annemergmed.2008.01.006, 41 e1.
[21] M.J. Pedro, S.H. Cataldo, Validation of novel completely sealed nasal positivboe airway pressure device: SuperNO2VA™ EtCO2 measurement and pressure test performance, Open J. Anesthesiol. 10 (10) (2020) 337–348.