LOW–FRACTIONAL OXYGEN CONCENTRATION CONTINUOUS POSITIVE AIRWAY PRESSURE IS EFFECTIVE IN THE PREHOSPITAL SETTING

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ABSTRACT

Objective. The objective of this study was to determine the effects of low–fractional concentration of inspired oxygen (FiO2) continuous positive airway pressure (CPAP) in prehospital noninvasive ventilation (NIV). With increasing concerns about the detrimental effects of hyperoxia, we sought to determine whether CPAP using a low FiO2 (28%–30%) was effective in the prehospital setting. Methods. The study was a six-month prospective, nonblinded observational study conducted in a large, busy urban emergency medical services (EMS) system (Las Vegas, NV). Results. A total of 340 patients participated in the study. Most patients presented with symptoms consistent with a diagnosis of congestive heart failure/acute pulmonary edema (47.4%), followed by chronic obstructive pulmonary disease (COPD) (40.9%), asthma (22.7%), and pneumonia (15.9%). Improvements were seen in respiratory rate (p = 0.00) and oxygen saturation (p = 0.00). The overall CPAP discontinuation rate was 16.5%. The most common reason for CPAP discontinuation was anxiety/claustrophobia. The total number of patients requiring prehospital intubation was 5.6%. Subjective paramedic assessment of patient status at hospital delivery found that 71.5% of patients’ conditions were improved, 15.1% remained unchanged, and 13.4% were worse. Conclusions. CPAP using a low FiO2 (28%–30%) was highly effective in the treatment of commonly encountered prehospital respiratory emergencies. Keywords: prehospital CPAP; noninvasive ventilation; EMS; continuous positive airway pressure

PREHOSPITAL EMERGENCY CARE 2012;Early Online:1–5

INTRODUCTION

The use of continuous positive airway pressure (CPAP) devices for noninvasive ventilation (NIV) have become common in the prehospital setting.1,2 These devices have proven effective in acute pulmonary edema and other respiratory conditions.3–5 They have also been demonstrated to be cost-effective and can reduce the subsequent need for intubation.5–8 Increasing concerns about the untoward effects of hyperoxia and oxidative stress have led to more restrictive prehospital oxygen administration protocols.9 Hyperoxia has been shown to decrease coronary blood flow and induce free-radical formation with resultant oxidative stress.10–12 It has been associated with worsened outcomes in several conditions, including stroke, chronic obstructive pulmonary disease (COPD), and cardiac arrest.13–16 Most CPAP devices used in the prehospital setting are oxygen-driven and deliver a variable concentration of supplemental inspired oxygen. The purpose of this study was to determine whether NIV with fixed low–fractional supplemental oxygen delivery CPAP was effective in the prehospital setting, thus lessening the possibility of hyperoxia.

METHODS

This study was a prospective, nonblinded observational study of prehospital CPAP usage in a large urban emergency medical services (EMS) system. The study was conducted at American Medical Response (AMR) and MedicWest Ambulance (MWA) in Clark County (Las Vegas), Nevada. Both AMR and MWA are advanced life support (ALS) 9-1-1 providers for Clark County and transport over 175,000 patients annually. They work cooperatively with area fire departments in providing prehospital care. Las Vegas is located in the high Mojave Desert with an altitude between 2,000 and 3,000 feet above sea level.

The inclusion criteria for this study were adults greater than 18 years of age who exhibited respiratory distress. Respiratory distress was defined as two or more of the following conditions: sternal retractions or accessory muscle usage, a respiratory rate greater than or equal to 25 breaths per minute, and/or a saturation of peripheral oxygen (SpO2) reading less than or equal to 94%. The exclusion criteria were age less than 18 years, inability to follow commands, apnea, vomiting or active gastrointestinal hemorrhage (increased risk of aspiration), major trauma, pneumothorax, and/or protected subject status (e.g., prisoner, pregnant). Patients with the following conditions were included in the study: asthma, COPD, congestive heart failure (CHF),...
and/or pneumonia. Paramedics made a presumptive diagnosis on scene and determined whether the patient met the inclusion criteria. The enrollment criteria and process are detailed in Figure 1.

The CPAP device selected for this study was the Pulmodyne O2-RESQ (Pulmodyne, Inc., Indianapolis, IN). The device is a single-use, disposable oxygen-driven product that delivers a fixed fractional concentration of inspired oxygen ($\text{FiO}_2$) of 28%–30%. The CPAP pressure was preset at 10 cmH2O for all patients in the study group. The device was left with the patient upon delivery to the hospital. Oxygen cylinder depletion with the device, based on standard 72-inch tubing and a pressure setting of 10 cmH2O, was 44 minutes for an E cylinder and 184 minutes for an M cylinder. The devices were standard production products purchased by AMR and MWA.

Institutional review board (IRB) approval was granted by the University Medical Center of Southern Nevada. The consent requirement was waived. A video education program on CPAP application and the research protocol was conducted for all providers prior to study initiation. The study began on February 21, 2011, and was terminated on August 30, 2011. Baseline and treatment data were collected for every patient. Initial demographic and physiologic data were

![Figure 1](https://example.com/figure1.png)

**Figure 1.** The enrollment criteria and process. CPAP = continuous positive airway pressure; $\text{SpO}_2$ = saturation of peripheral oxygen.
obtained. Repeat physiologic data were gathered at 5, 10, and 15 minutes of treatment. All EMS units used the Philips MRX patient monitor (Philips Electronics, Amsterdam, The Netherlands) for physiologic monitoring. Summary data were collected after hospital delivery. Patient data sheets were forwarded to a site coordinator for collection and data entry into a Microsoft Excel spreadsheet (Microsoft Corp., Redmond, WA). Subsequent data and statistical analysis were conducted using statistical features in Microsoft Excel. The significance of measured physiologic changes was determined using the paired t-test. Significance (α) was set at 0.05.

**RESULTS**

A total of 340 patients were enrolled. Of these, 183 (54%) were male and 157 (46%) were female. The average age was 67.7 years (95% confidence interval [CI]: 66.2–69.2). Of the inclusion criteria, 324 (95.3%) patients had a respiratory rate greater than 25 breaths per minute, 314 (92.4%) demonstrated accessory muscle usage, and 312 (91.8%) had an SpO2 value less than or equal to 94%. The presumptive medical conditions encountered included the following: 161 (47.4%) had CHF/acute pulmonary edema, 139 (40.9%) had COPD, 77 (22.7%) had asthma, and 54 (15.9%) had pneumonia. Some patients were assigned more than one prehospital diagnosis.

Physiologic data findings with 95% CIs and overall changes are detailed in Table 1. CPAP was discontinued in 56 (16.5%) patients. The most common reasons for CPAP discontinuation were anxiety/collapse, 22 (39%); need for intubation, 19 (34%); apnea and bag–valve–mask ventilation, four (7%); mask problems, four (7%); patient improved and removed mask, three (5%); and other, five (9%). Final subjective determination of patient condition by the treating paramedic was as follows: 241 (71.5%) improved, 51 (15.1%) stayed the same, and 45 (13.4%) worsened. Overall, 19 patients (5.6%) in the study group required field intubation.

**DISCUSSION**

Continuous positive airway pressure improves both ventilation and oxygenation in patients with respiratory distress. This appears to result from improved gas exchange, decreased work of breathing, and supple-
mentary oxygenation. It has been somewhat unclear whether the benefits of CPAP are more related to improved ventilation, improved oxygenation, or both. This study demonstrated improvement in respiratory rate (p = 0.00) and pulse oximetry readings (p = 0.00) when CPAP was applied. Despite an FiO2 of 28%–30%, the SpO2 in most patients was improved by 5 minutes and continued to improve throughout treatment. With increasing concerns about the detrimental effects of hyperoxia and oxidative stress, CPAP using a low FiO2 may be beneficial in the prehospital setting.

Overall, most of our patients improved following application of CPAP. Our findings were consistent with those of other similar studies of prehospital CPAP usage. Kallio et al. studied 121 prehospital patients in Helsinki with presumed severe pulmonary edema who received CPAP with a device that provided an FiO2 of 30%–35% and a positive-end expiratory pressure (PEEP) of 1 cmH2O/10 kg body weight. They found improvement in SpO2, respiratory rate, systolic blood pressure, and heart rate. Templier et al., in a study of 46 prehospital patients, found improvement in heart rate, blood pressure (systolic and diastolic), respiratory rate, and transcutaneous oxygen saturation using the Boussignac CPAP system. The Boussignac system uses an FiO2 between 70% and 100% with a reported PEEP of 10 cmH2O. Kosowsky et al., in an Ohio study of 19 prehospital patients with presumed pulmonary edema, found improvement in mean respiratory rate and SpO2. The FiO2 used in their study varied from a minimum of 35% up to 95% with the PEEP set at 10 cmH2O. Our overall intubation rate for the study group was 5.6%. Hubble et al. reported a decrease in the field intubation rate from 29.3% to 8.9% with CPAP usage. Ducros et al. reported a decrease in the field intubation rate from 14% to 4% with prehospital CPAP in patients with cardiogenic pulmonary edema. Dib et al. showed a decrease in prehospital intubations from 4.6% to 2.6% with CPAP usage in a cohort with severe CHF.

Despite using a lower FiO2 than other similar prehospital CPAP studies, we were able to demonstrate a similar and satisfactory improvement in SpO2 and respiratory rate.

**LIMITATIONS**

There are several limitations to our study. First, it was a nonrandomized, observational trial. Second, the determination to enroll patients in the study was based on subjective paramedic determination based on the inclusion and exclusion criteria. The accuracy of paramedic field diagnosis was not verified with subsequent hospital records. There was discordance in patient enrollment between the two participating EMS operations despite similar total system transports. AMR enrolled 137 (40%) patients, whereas MWA enrolled 203 (60%) patients. The reasons for this discordance were unclear. Furthermore, there was a decrease in overall patient data in the 10- and 15-minute physiologic measures because of the relatively short EMS transport times in Las Vegas. Patients who received prehospital CPAP may have exhibited further improvement with longer CPAP treatment. The improvements in blood pressure and heart rate seen in
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BP = blood pressure; CI = confidence interval; CO₂ = carbon dioxide; NS = not significant.
other prehospital CPAP studies, and not in ours, may have been related to longer EMS transports and associated increased CPAP treatment times. In addition, the altitude in Las Vegas (>2,000 feet above sea level) is significantly higher than that in other communities where the referenced prehospital CPAP studies were conducted (Cincinnati, Helsinki, and Paris) and may have accounted for some of the differences seen.

There were some issues with the CPAP device. Initially, the CPAP devices on participating EMS units were supplied with a single-size mask. A few patients were initially encountered who required a smaller mask. A smaller mask was added early in the study period and this issue was corrected. Several patients complained of anxiety. Some of these tolerated continued CPAP usage, whereas others did not. We did not add an anxiolytic during the study period. Anxious patients improving with CPAP might have benefited from an anxiolytic. Capnography readings were generally suboptimal. These were obtained with a nasal sensor placed under the CPAP mask. In some cases this affected CPAP mask seal and made end-tidal carbon dioxide (ETCO2) readings difficult to obtain. Using an inline CO2 sensor might have improved the quality of the capnography data.

There are additional limitations related to CPAP usage and our experimental protocol. The paramedics were not allowed to modify the CPAP (FiO2 and PEEP) settings during the study. While a setting of 10 cmH2O of PEEP is common, some patients might have benefited from a lower or higher PEEP setting. Also, there may have been a subset of patients who might have benefited from increased or decreased FiO2 levels.

CONCLUSIONS

Prehospital CPAP with low–fractional oxygen delivery (28%–30%) CPAP is highly effective. Improvements in respiratory rate and SpO2 were demonstrated. Overall, subjective improvements in symptoms were seen in 71.5% of the patients treated. The device was easy to use and inexpensive.

References