

Role of the Boussignac Continuous Positive Pressure Mask in the Emergency Department

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Abstract

Objectives: (1) To determine whether noninvasive continuous positive airway pressure (CPAP) ventilation with the Boussignac face mask can reverse acute respiratory failure in patients with congestive heart failure (CHF) or chronic obstructive pulmonary disease (COPD) in the emergency department (ED); (2) To characterize patients who may benefit from this method.

Methods: Patients presenting to the ED in 2004 with respiratory distress, who were referred for mechanical ventilation, were first allocated to a treatment trial with Boussignac-CPAP. Success was defined as an improvement in respiratory parameters without subsequent need for endotracheal intubation. Data were collected on demographic and clinical features, diagnosis and respiratory parameters, door-to-treatment interval, and outcome.

Results: The sample included 86 patients of average age 74.3 years. The main indications for CPAP ventilation were CHF (78%), diagnosed mainly by chest x-ray, and COPD (54.6%), diagnosed mainly by physical examination. The large majority of patients were conscious (90.7%) and fully cooperative (83%). Average time from admission to ventilation was 16±22 minutes. Respiratory parameters improved in 80 patients (93%); the major improvement occurred within the first 30 minutes of treatment. Only 6 patients (7%) subsequently required full ventilation. Sixty-nine patients (91%) were admitted to general medical wards and 7 (9%) to the intensive care unit; the remainder were discharged home.

Conclusions: Noninvasive CPAP via the Boussignac face mask is a near-ideal means of ventilation in the ED, provided patients are carefully selected. It improves respiratory distress in most patients; is associated with very few side effects; and spares patients full mechanical ventilation.

MeSH Words: Respiratory distress; Chronic obstructive pulmonary disease; Congestive heart failure; Continuous positive airway; Boussignac

Introduction

Emergency Department (ED) physicians often encounter patients with respiratory failure requiring ventilatory support. The main cause is dysfunction or fatigue of the respiratory muscles or a neurological disorder. Traditionally,

ventilatory support was achieved by essentially invasive means involving full patient sedation, muscle relaxation and mandatory hospitalization in an intensive care area. The procedure was cumbersome, expensive and uncomfortable, and it was directly associated with relatively high morbidity and mortality rates. To overcome these

problems, clinicians introduced the use of noninvasive ventilation techniques, such as continuous positive airway pressure (CPAP) and bi-level positive airway pressure (BiPAP), which have none of these disadvantages. The development of the Venturi-type CPAP face-mask system by Boussignac made noninvasive ventilation even more attractive for ED use owing to its simple application, mobility and independence from an electricity source -- all prerequisites for efficient ED work.

The aims of the present study were threefold: to determine whether the Boussignac-CPAP system can serve as an efficient means of mechanical ventilation in the ED for patients with acute respiratory failure; to determine whether Boussignac-CPAP can eliminate the subsequent need for full mechanical ventilation in patients with secondary coronary obstructive pulmonary disease (COPD) or congestive heart failure (CHF), alone or overlapping; to characterize patients who would benefit most from noninvasive Boussignac-CPAP treatment in the ED.

Methods

Boussignac-CPAP System

The disposable Boussignac-CPAP device (Vygon®), first described by Boussignac in 1989], works according to the principle of the turbine jet engine. It consists of a lightweight plastic cylinder connected to a face mask. A jet effect is generated by insufflation of gas, either compressed air or oxygen, at high velocity through micro-channels along the narrow cylinder. The gas is deflected toward the central zone, creating a relative positive flow-dependent pressure at the patient's side and a relative depression at the ambient air side. Boussignac-CPAP is a permanent open system, totally independent of electricity or other source of energy except for a source of compressed air or oxygen. The device is adaptable to any conventional face mask, endotracheal probe or tracheotomy nozzle.

Study Design and Procedure

A prospective case-series design was used. Boussignac-CPAP was offered to all consecutive patients who presented to the ED in 2004 during the morning shift with signs and symptoms of

respiratory distress indicative of the need for mechanical ventilation (severe dyspnea, respiratory rate >30/minute, peripheral cyanosis, use of accessory muscles, lightheadedness, etc.), and who met the prerequisites for noninvasive ventilation (hemodynamically stable, lucid enough to understand and cooperate with the explanations of the staff). Patients with mental obtundation, impaired swallowing, active upper gastrointestinal bleeding, excessive secretions, or acute facial trauma, and patients who were unable to tolerate the mask because of discomfort or pain, were excluded. We recruited only morning-shift patients (08:00-16:00 AM), because the regular senior faculty of the ED are present at this time, whereas the evening and night shifts are usually covered by rotating residents from other departments. This practice lessened the risk of bias by various examiners. Oral consent was obtained from each patient before the intervention. Because the noninvasive Boussignac-CPAP system is a licensed therapeutic device approved by the Israel Ministry of Health for use in the treatment of respiratory failure, written consent was not required.

Before onset of the study, a short preparatory course was held for the participating staff members on patient indications and inclusion/exclusion criteria and proper use of the Boussignac-CPAP device.

To ensure full cooperation, patients were first given a short explanation of the purpose and workings of the Boussignac-CPAP system, and the mask was applied in two consecutive steps. Patients were first encouraged to attach the mask tightly to their face, by themselves, without the harness, and to leave it there for a few minutes. Thereafter, full harnessing was used for the rest of the ventilation time.

The appropriate pressure level was generated through a compressed oxygen or air source by plotting a precalculated airflow-pressure curve. The initial pressure used was 8 cm H₂O. Blood levels of partial pressure of oxygen (pO₂), partial pressure of carbon dioxide (pCO₂) and saturated oxygen (satO₂) were measured at 0, 30, 60, and 90 minutes of noninvasive ventilation.

The following data were collected for the study: demographic features, clinical and respiratory findings on presentation to the ED, diagnosis,

time from admission to CPAP, changes in blood gas levels after CPAP, need for pharmacologic treatment, and need for intensive treatment after noninvasive CPAP.

Statistical Analysis

The VassarStats Website for Statistical Computation[®] was used for statistical calculations. Student t-test and ANOVA, Z-ratio, chi-square test and Spearman correlation were used as necessary. We adopted the conventional standard of statistical significance ($p \leq 0.05$),

Results

A total of 86 patients were enrolled in the study: 62 men (72%) and 24 women (28%) of mean age 74.3 ± 11 years.

The main indications for CPAP ventilation were CHF (78%) and COPD (54.6%) ($p < 0.001$); some patients had both. The main co-morbidity was arterial hypertension. The diagnosis was based on physical examination and chest radiography. CHF was detected more often by chest x-ray (61% vs. 38%; $p = 0.02$, $\chi^2 = 4.5$) whereas COPD was detected more often by physical examination (78% vs. 22%; $p < 0.0001$, $\chi^2 = 30.26$).

The large majority of patients (90.7%) were conscious on admission. However, 40.7% were confused or agitated (95% CI 38%-63%) and 7.4% were stuporous. None was unconscious. Seventy-two patients (84.5%; 95% CI 75%-91%) fully understood the explanation given about noninvasive ventilation and provided oral consent to treatment. Of the remainder, 8.3% understood it partially and 7% not at all. Seventy-one patients (83%) were fully cooperative.

The average respiratory rate at arrival was 27 ± 5 /minutes [95% CI 1.29 (16-48)]. Most patients (77%) were using accessory respiratory muscles ($Z = 6.423$). About one-third of the patients (34.7%) were cyanotic ($p = 0.0001$).

In addition to noninvasive CPAP ventilation, 62 patients (72%) were treated with diuretics (furosemide), 39 (45.3%) with bronchodilators, and 15 (17.4%) with morphine. For 84% of the patients, this was the first time they had received ventilatory support.

The average time elapsed from ED admission to CPAP ventilation (door-to-treatment interval) was 16 ± 22 minutes (95% CI 0-95). The main improvement in blood gas levels was observed during the first 30 minutes of noninvasive treatment. Mean pO₂ rose from 109 ± 64.5 mmHg units at time 0 to 148 ± 66.5 mmHg at 30 minutes ($t = -2.16$ $p = 0.034$). There was some further decrease at 60 and 90 minutes, but it was not significant. Oxygen saturation (satO₂) showed a similar trend, but the difference from baseline did not achieve significance (from $91.7\% \pm 12.3$ at time 0 to 93.7 ± 11.7 at 30 minutes; $t = -0.825$ $p = 0.14$). There was no deterioration in pCO₂ during the entire treatment ($p = 0.455$).

Overall, noninvasive ventilation alleviated respiratory distress in 80 patients (93%). The other 6 patients (7%) subsequently required sedation, intubation and full ventilation (95% CI 75%-91%; $Z = 11.28$). Seventy-six patients were eventually hospitalized: 69 (91%) in a general medical ward and only 7 (9%) in the intensive care unit (95% CI 69%-88%; $Z = 10.058$). The others were discharged home from the ED.

Discussion

Almost a century has passed since Bunnell first described the application of positive pressure by face mask for intraoperative patient ventilation. Despite reports in the 1930s of the successful use of CPAP in the treatment of acute pulmonary edema, it was only in the last decade that noninvasive positive pressure ventilation became the standard of treatment of various respiratory problems. The main indications at present for CPAP are acute pulmonary edema and refractory hypoxemia [1,2]. However, the creation of positive airway pressure reduces inspiratory work [3] and this method is used, in practice, whenever an increase in intra-alveolar pressure is needed to achieve normoxemia. [4]. In studies of its application in the ED for patients with acute respiratory failure, no differences were observed between CPAP and BiPAP ventilation in treatment duration, complications, failure rate, disposition, or length of hospital stay [5].

In patients with acutely decompensated heart failure, the early application of CPAP has been found to reduce hospital mortality, length of stay and need for intubation and ventilation [6,7]. The

key to success is careful selection of candidates. The major contraindications are undrained pneumothorax, hypovolemia and hypotension (CPAP decreases the venous return), in addition to intracranial hypertension and pulmonary emphysema [4]. CPAP ventilation through a mask should be used only in conscious and cooperative patients, like in the present study, who are capable of withdrawing the device if necessary (for example in case of vomit or cough). [4]

COPD is another indication for noninvasive ventilation with CPAP [8]. COPD is the third major cause of death by disease in the Western world [9]. In advanced stages, COPD causes chronic respiratory failure with hypoxemia and frequent hypercapnia [9]. There is a strong evidence that noninvasive ventilation reduces the complications and mortality rate of acute and chronic hypercapnia [arterial carbon dioxide pressure (PaCO₂) >45 mmHg] [10]. It also decreases arterial blood gases and spares patients intubation in most episodes that do not respond to standard therapy [8,10,11]. Noninvasive ventilation prevents a higher proportion of intubations in hypercapnic than in normocapnic patients [12], and it may also be useful for treating asthma exacerbations [13].

The main finding of our study, i.e that CPAP can successfully alleviate respiratory distress in patients with CHF or COPD, is in agreement with the literature [3]. Our study is unique, however, in that it is the first to examine the use of Boussignac-CPAP ventilation in patients with CHF or COPD on a relatively large scale in the ED setting. We found substantial improvement in 93% of the patients. We were able to transfer most of the patients to a general ward instead of the ICU, saving hospital costs and sparing patients the potential complications associated with full mechanical ventilation.

Most of the improvement in blood gas levels occurred within the first 30 minutes of treatment. This improvement was sustained through 90 minutes of treatment, but there were no additional significant changes after this time point. A similar pattern has been reported by others [14,15].

In order to succeed with CPAP ventilation in the ED, the indications must be identified as early as

possible [6]. In our study, the mean door-to-ventilation time was 16±22 minutes. Most of the delays were due to delayed diagnosis or late deterioration of the primary condition.

Our study also showed that chest radiography is the most accurate tool for the diagnosis of pulmonary edema in the ED, whereas lung auscultation is more accurate for the diagnosis of COPD. Therefore, performing auscultation and chest radiography immediately on arrival of the patient could shorten the time to intervention. Since triage nurses are usually the first to meet the patient, attention needs to be addressed to developing methods to improve their diagnostic and decision-making skills in terms of early application of CPAP ventilation [6].

Complications of noninvasive ventilation are rare. In one study, facial scars were the most common complication, but they did not warrant withdrawing treatment [16]. Others reported, however, that patients with COPD who were treated with noninvasive ventilation were at high risk of readmission and life-threatening events [11]. Although early reports suggested an increased rate of acute myocardial infarction associated with noninvasive ventilation [17], this was not validated in our study or in other recent reports [17].

Regarding Boussignac-CPAP ventilation in particular, no side effects have been reported to date [17]. In our study, either, none of the patients had adverse treatment-related complications. Our failure rate for Boussignac-CPAP ventilation was 7% (6/86).

The Boussignac-CPAP system has several important advantages. It requires no generator or power source besides high-pressure oxygen or air, making it amenable to pre-hospital and outdoor settings as well as patient transport [15]. With an input of 100% oxygen, the system can deliver high fraction of inspired oxygen (FiO₂) levels and allows for the volume-per-minute measurements usually required in patients with pulmonary edema. Furthermore, the oxygen flow needed is lower than for other CPAP flow generators based on the Venturi effect [15]. The device is also disposable, which prevents cross-contamination and saves hospitals the expense of re-sterilization. We found it easy to handle and rapidly applicable, requiring only a short training period. The desired change in respiratory

parameters (respiratory rate, muscle activity, tidal activity and volume, and ratio of arterial oxygen tension to inspired oxygen concentration) was achieved already at 30 minutes in our study, in agreement with others [17].

We conclude that the noninvasive Boussignac face mask CPAP system is a near-ideal means of ventilation in the ED, provided patients are carefully selected. It improves respiratory distress in most patients; is associated with very few side effects; and spares patients full mechanical ventilation.

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