AMERICAN JOURNAL OF OTOLARYNGOLOGY–HEAD AND NECK MEDICINE AND SURGERY 37 (2016) 221–224

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The effect of high flow nasal cannula oxygen therapy on middle ear pressure☆,☆☆,★,★★

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ARTICLE INFO

Article history:
Received 4 August 2015

ABSTRACT

Objectives: To investigate the effect of high flow nasal cannula oxygen therapy (HFOT) on middle ear pressure.

Materials/methods: Ten patients (eight males and two females) with oxygen desaturations requiring HFOT were recruited with 19 ears available for our study. The study group was aged 29–90 years (mean 65.3 ± 16.5). All patients underwent a review of medical history, questioned about subjective hearing loss and underwent a standard otologic exam, with middle ear pressures measured with a GSI TympStar tympanometer.

Results: The middle ear peak pressures in our study group ranged from 25 to −200 daPa (mean −13.7 ± 56.3 daPa). Volume of HFOT was delivered at 20–40 L (mean 30.5 ± 9 L) and fraction of inspired oxygen required was 30–70% (mean 58 ± 13%). There was a positive correlation between liters of oxygen delivery and middle ear pressure with a Pearson coefficient (R) of 0.436, although lacking statistical significance (p = 0.06).

Conclusion: Previous studies have shown that HFOT delivered in the range of 35–40 L/min produces pharyngeal pressures at or above 5 cm H_2O. Since pharyngeal pressures of 5 cm H_2O produced via CPAP have shown to produce middle ear pressures above 40 daPa, we expected HFOT to result in similar middle ear pressures of 35–40 L/min. However, although our results show an increase in middle ear pressures with flow volume, HFOT did not produce significant increases in middle ear pressures. This may make HFOT an appropriate option of oxygen delivery to patients who require otologic procedures.

1. Introduction

High flow oxygen therapy (HFOT) has become a popular method of delivering high volumes of oxygen for respiratory support via nasal cannula. Continuous positive airway pressure (CPAP) has traditionally been the respiratory support of choice. Its ability to maintain patent alveoli and upper airways leads to improved respiratory function [1,2]. However, CPAP also has been shown to result in a number of complications. These include, but are not limited to, nasal stuffiness, dry mouth, nasal mucosal trauma, nasal deformity, and overall discomfort [3–5]. As a result of these unfavorable consequences of CPAP, HFOT is often considered as an alternative.

☆ There are no financial or conflicts of interest to disclose.
☆☆ This article was presented as a poster at 2015 Triological Combined Sections Meeting (Coronado Island, CA) January 22–24, 2015.
★ Level of Evidence: 4.
★★ Study Design: Prospective case-series study.
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http://dx.doi.org/10.1016/j.amjoto.2015.09.001
0196-0709/

HFOT allows for the delivery of humidified oxygen at flows that can reach 60 liters/minute (L/min) without many of the complications associated with CPAP. Previous studies have shown HFOT allows for easier application and reduced nasal trauma when compared to CPAP [6]. Additionally, HFOT is better tolerated than a conventional face-mask and results in better oxygenation in patients with acute respiratory failure [7].

The nasopharynx serves as a drainage pathway of the middle ear via the Eustachian tube. Therefore, high nasopharyngeal pressures have been linked to simultaneous high middle ear pressures [8,9]. This phenomenon has been described in physiologic processes including nose blowing and during valsalva. It has been shown that positive pressures are produced in the nasopharynx in patients using HFOT in both pediatric and adult populations [8,9]. However, to our knowledge, middle ear pressures have not been studied with respect to HFOT [10].

Evaluating the effects of HFOT on middle ear pressures is important, as it will allow for a better understanding of optimal oxygen volumes and inform whether or not HFOT can be safely used as an oxygen delivery device in patients undergoing otologic procedures. We hypothesize that HFOT will increase middle ear pressures proportionally to oxygen volumes due to increased nasopharyngeal pressures.

2. Materials and methods

Institutional review board permission was granted for our study. The study was performed prospectively at a tertiary medical center. Ten patients were recruited into our study after obtaining informed consent. All patients recruited were in an ICU setting, as high flow nasal cannula therapy can only be administered in a critical care unit at our facility. In the study group, data collected included patient demographics, indication for high flow nasal cannula therapy, fractional inspired oxygen (FiO_2), liters of oxygen delivered, pertinent medical history, subjective hearing loss, and previous otologic history. Patients with cerumen impaction, perforated tympanic membranes, previous ear surgery, or history of Eustachian tube dysfunction were excluded from our study. All patients underwent an otoscopic exam prior to tympanometry to ensure patency of the external auditory canal and visualization of an intact tympanic membrane. A disposable tympanometer probe sized to fit the external canal to provide a complete seal was placed in the left and right external auditory canals and tympanometry carried out with GSI Tympstar Tympanometer. The mean with standard deviation was generated for data points of interest. Pearson coefficients and p-values were obtained for percent FiO2 and liters of oxygen delivery and observed patient middle ear pressures. A p-value <0.05 was considered to be statistically significant. Metric data are presented as means ± standard deviation.

3. Results

Ten patients met inclusion criteria for our proposed study and were amenable to proceed after providing informed consent. Study participants included 8 males and 2 females. The age ranged from 29 to 90 years; the mean age in the study group was 65.3 ± 16.5 years.

The indication for high flow nasal cannula therapy in all patients was for documented oxygen desaturation. Otoscopic exam revealed one ear fully obstructed by cerumen, the remaining 19 ears were appropriate for further evaluation with tympanometry.

The middle ear peak pressures in our study group ranged from 25 to −200 daPa (mean −13.7 ± 56.3 daPa). Volume of high flow oxygen therapy was delivered at 20–40 L (mean 30.5 ± 9 L) and fraction of inspired oxygen required was 30–70% (mean 58 ± 13%). There was a positive correlation between liters of oxygen delivery and middle ear pressure with a Pearson coefficient (R) of 0.436, though lacking statistical significance ($p = 0.06$) (Fig. 1). There was a weak correlation between treatment levels of FiO_2 percent and middle ear pressure with a Pearson coefficient (R) of 0.158 and a p-value of 0.52 (Fig. 2).

4. Discussion

The middle ear is a gas pocket with a relatively constant gas volume. As a result, gas flux in or out of the middle ear space causes a measurable change in pressure. Due to the importance of appropriate middle ear pressures for proper middle ear function, these pressures are highly regulated. While not well understood, it is believed that several components are involved in this regulatory process including, but not limited to, the tympanic membrane (TM), the Eustachian tube (ET), and the mastoid. Displacement of the TM can compensate for small volume changes in the middle ear. The ET acts as a one-way valve, allowing air escape from the middle ear more readily than air intake from the nasopharynx. Several mechanisms have been proposed as to how the mastoid may contribute to middle ear pressure regulation, including intermittent gas exchange with the ET and continuous gas and fluid exchange with the mucosal venous network [11].

A retrospective review of 3066 tympanograms revealed that less than 0.03% of the sample had normal middle ear pressures that exceeded 40 daPa and that the mean normal middle ear pressure was 11 daPa in the same population [12]. This same group studied the effects of a range of continuous positive airway pressures and found that as little as 5 cm H_2O resulted in an average middle ear pressure of 46.75 daPa. These results show that the positive pressures produced by CPAP are transmitted to the middle ear. Other studies have shown that the positive pressures in the middle ear produced with CPAP can have clinical significance. One group was able to reinflate atelectatic tympanic membranes with 3 hours of CPAP at 10 cm H_2O [13]. There have also been reports of otologic consequences such as alternobaric vertigo secondary to CPAP therapy [14].

It has been demonstrated that, similar to CPAP, HFOT is associated with the generation of significant positive pharyngeal pressures when the mouth was closed (7.2 cm H_2O at 40 L/min) and that the positive airway pressure is largely determined by flow/liters of oxygen delivery [15]. A recent