Evaluation of Bronchial Pressures and Tidal Volume Using Three Different Adult High Flow Nasal Cannula (HFNC) Devices

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Introduction

There are many proposed mechanisms by which a High Flow Nasal Cannula (HFNC) works to help patients in respiratory distress. Kevin Dysart et al., have proposed five mechanisms by which they believe HFNC works. First, they believe that the HFNC washes out the dead space in the nasopharynx leading to improved fraction of alveolar gases. Second, HFNC provides enough flow to overcome the resistance of the nasopharynx reducing work of breathing (WOB). Third, humidified and warmed gas improves pulmonary compliance compared to dry, cool gas. Fourth, warm, humidified gas reduces the metabolic work associated in gas exchange. Lastly, they propose that the high flow through the nasal cannula can provide some positive distending pressure for lung recruitment.

Purpose

The use of High Flow Nasal Cannula (HFNC) has been used extensively in the neonatal population based on the effect of creating some unknown level of Continuous Positive Airway Pressure (CPAP) level for patients and reducing work of breathing which can help avoid re-intubation. The use of HFNC in adults has not been studied extensively, and current studies are limited. One study conducted by Groves and Tobin showed that when healthy adult volunteers were placed on a Fisher & Paykel high flow nasal interface at a flow of > 60L/min, measured pharyngeal pressures did create some CPAP. Another study conducted by Parke and McGuiness concluded that there was some low level nasopharyngeal pressure created with the use of HFNC. Both of these studies showed pressure being created, but the pressure was measured in the oropharynx or the nasopharynx. We do not know if these pressures were transmitted into the lungs and will actually create clinical benefits.

The aim of this study was to determine whether Positive End Pressure (PEP) or CPAP is created in the bronchi when using the HFNC, and also to see if there are any changes in tidal volumes.

Methods

We used a Puritan Bennett™ 7200 ventilator (Covidien, Boulder, CO) as our driver to simulate spontaneous breathing to one test lung of a dual test lung system (Dual Adult TTL® 1600, Michigan Instruments, Grand Rapids, MI.) The other test lung was attached via tubing to an intubation manikin's right main stem (Laedral® Airway Management Trainer, Wappingers Falls, NY). The left mainstem of the manikin was capped. Monitoring devices were placed in line at the right main stem. These included a 30INCH-D-4V pressure transducer (All Sensors, Morgan Hill, CA) and a flow sensor connected to a NICO® cardiopulmonary monitor (Philips Healthcare, Andover, MA). The driver was set on CMV, rate-15/min, sine flow waveform at tidal volumes (Vt) of 400, 600, 800, 1000 mL and peak flow rates of 30, 40, 60 and 80 LPM. The manikin was first open to room air with no positive pressure applied then configured with the mouth closed. We applied varying levels of CPAP and pressure support ventilation (PS): CPAP 5/PS 0 cmH_2O, CPAP 5/PS 5cmH_2O, and CPAP 0/PS 5cmH_2O to the manikin via NIPPV through a Draeger Evita XL ventilator. Finally we applied HFNC therapy through the following devices: Optiflow™ (Fisher & Paykel, Irvine, CA), Comfort Flo™ (Teleflex Medical, Durham, NC), and Precision Flow® (Vapotherm, Stevensville, MD). We administered HFNC at flows of 30, 40, 60, 70 LPM. Measurements administering HFNC were taken with the mouth open and closed.

Figures

Figure 1 Bronchial Inspiratory Pressures

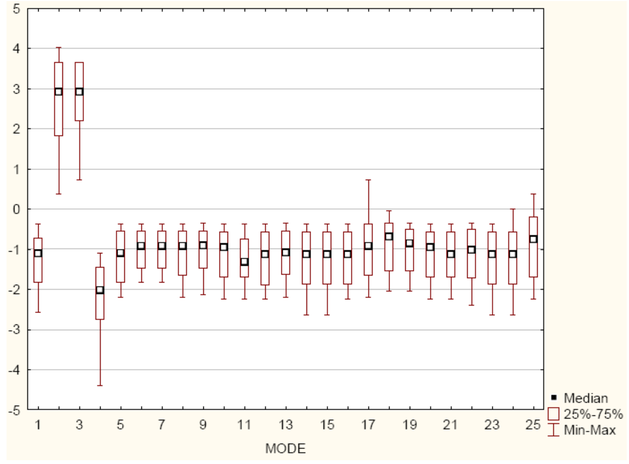
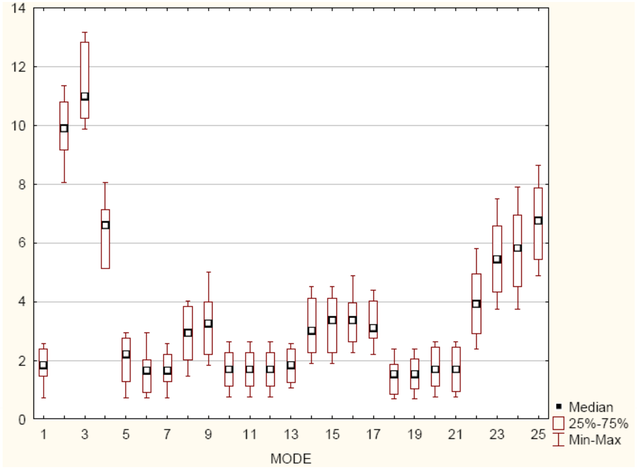


Figure 2: Bronchial Expiratory Pressures



Key

Number	Mode
1	Mouth Open
2	CPAP 5/ PS 0
3	CPAP 5/ PS 5
4	CPAP 0/ PS 5
5	Mouth Closed
6	Vapotherm 30 MO
7	Vapotherm 40 MO
8	Vapotherm 30 MC
9	Vapotherm 40 MC
10	Hudson 30 MO
11	Hudson 40 MO
12	Hudson 60 MO
13	Hudson 70 MO
14	Hudson 30 MC
15	Hudson 40 MC
16	Hudson 60 MC
17	Hudson 70 MC
18	FP 30 MO
19	FP 40 MO
20	FP 60 MO
21	FP 70 MO
22	FP 30 MC
23	FP 40 MC
24	FP 60 MC
25	FP 70 MC

Disclosures

Keith R. Hirst, MS, RRT-NPS and Ankeet Patel, MS, RRT have no disclosures.

David L. Vines, MHS, RRT-FAARC is a speaker for Teleflex Medical.

Data

	Spontaneous Breathing	Hudson HFNC (LPM)				Fisher & Paykel HFNC (LPM)				Vapotherm HFNC (LPM)	
		30	40	60	70	30	40	60	70	30	40
Bronchial Inspiratory Pressure cmH_2O (mean ± SD) Mouth Open	-1.19 ± 0.64	-1.15 ± 0.67	-1.24 ± 0.63	-1.19 ± 0.70	-1.11 ± 0.64	-1.0 ± 0.69	-1.02 ± 0.61	-1.17 ± 0.70	-1.19 ± 0.71	-1.00 ± 0.55	-1.00 ± 0.55
Bronchial Inspiratory Pressure cmH_2O (mean ± SD) Mouth Closed	-1.19 ± 0.71	-1.29 ± 0.85	-1.24 ± 0.78	-1.22 ± 0.74	-1.03 ± 0.82	-1.17 ± 0.77	-1.26 ± 0.81	-1.22 ± 0.88	-0.89 ± 0.92	-1.12 ± 0.68	-1.03 ± 0.62
Bronchial Expiratory Pressure cmH_2O (mean ± SD) Mouth Open	-1.76 ± 0.61	1.69 ± 0.70	1.69 ± 0.70	1.69 ± 0.70	1.82 ± 0.60	1.44 ± 0.60	1.53 ± 0.63	1.75 ± 0.73	1.71 ± 0.76	1.57 ± 0.65	1.66 ± 0.65
Bronchial Expiratory Pressure cmH_2O (mean ± SD) Mouth closed	-1.96 ± 0.76	3.14[c] ± 1.02	3.25[c] ± 1.01	3.37[c] ± 0.87	3.29[c] ± 0.81	3.96[c] ± 1.24	5.46[b] ± 1.32	5.76[b] ± 1.41	6.75[a] ± 1.41	2.85[c] ± 0.97	3.18[c] ± 1.01

a= significantly greater than all modes; b= significantly greater than all modes except FP- 40, 60, 70 with mouth closed; c= significantly great than all with mouth open

Conclusion

The goal of this study was to determine whether any PEP or CPAP would be created using three different HFNC devices and to see if the flows or pressures resulted in any increase in tidal volume. Results from the study showed that there were significant differences in PEEP, PIP, bronchial inspiratory and bronchial expiration pressures measured only with ventilator-applied CPAP and PS. None of the HFNC devices tested achieved any clinically significant level of CPAP. With the mouth closed all three HFNC devices created significantly higher PEP than when the mouth was open. With the mouth closed the Fisher & Paykel Optiflow™ created higher PEP at 40, 60, and 70 LPM than the other devices with the mouth closed. Although there was no significant change in tidal volume, the effect on work of breathing is unknown. In conclusion, the data from this study does not support the supposition that any CPAP is being created nor does it augment volumes in our adult model. Although a clinically significant level of PEP may occur in patients on high flows with their mouth closed.

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