RESPIRATORY CARE Paper in Press. Published on August 20, 2013 as DOI: 10.4187/respcare.02499

Apnea testing: the effects of insufflation catheter size and flow rate on pressure and volume within a test lung

Author list:
Nicholas R. Henry, MSc, RRT-NPS, AE-C
Assistant Professor
Department of Respiratory Care
Texas State University-San Marcos

S. Gregory Marshall, Ph.D., RRT, RPSGT, RST
Chair/Associate Professor
Department of Respiratory Care
Texas State University-San Marcos

Corresponding author information:
Nicholas R. Henry, MSc, RRT-NPS, AE-C
Assistant Professor
Texas State University-San Marcos
Department of Respiratory Care
601 University Dr.
San Marcos, TX 78666
Phone: (512) 245-3491
Fax: (512) 245-7978
Email: NH14@txstate.edu

Conflict of interest statements:
Nicholas R. Henry, MSc, RRT-NPS, AE-C has no conflicts of interest in regards to this original research study.

S. Gregory Marshall, Ph.D., RRT, RPSGT, RST has no conflicts of interest in regards to this original research study.

Funding information: This study was supported by an internal institutional research enhancement grant provided by Texas State University-San Marcos.

Notation of prior abstract publication/presentation: A version of this manuscript was presented as a poster presentation at the American Association of Respiratory Care Open Forum in New Orleans, LA on November 10, 2012 by Nicholas R. Henry, MSc, RRT-NPS, AE-C. An abstract of this study was published in the October 2012 issue of *Respiratory Care*. (Henry NR, Marshall SG. The effects of insufflation catheter size on pressure and volume within a test lung when performing the apnea test. *Respir Care* 2012;57(10):1711.)

Abstract

Background: The apnea test (AT) is used to determine the absence of a respiratory drive when determining brain death. Current guidelines for performing the AT do not specify the size of insufflation catheter (IC) to use with each endotracheal tube (ETT) size despite previous case reports describing procedure-related complications with the use of varying IC sizes. The objective of this study is to identify an appropriate size of IC to use with each ETT size as a way to minimize the generated pressure and volume within the lungs when performing the AT. **Methods**: ETT sizes 6.0-10.0mm were inserted into an intubation manikin connected to a test lung sequentially. The peak pressures and volumes generated within the test lung were recorded when performing the AT using IC sizes 10-16 French and "cut oxygen supply tubing" at oxygen flow rates of 6-15 Lpm. The MANOVA and Tukey's HSD statistical methods were used to analyze data at an alpha level of 0.05. **Results**: The MANOVA method identified significant differences among pressures and volumes when performing the AT ($p<0.001$) and the Tukey's method identified significant differences among the pressures and volumes associated with IC:ETT ratios ≥0.7 and IC:ETT ratios <0.7 ($p<0.05$). **Conclusions**: Selection of an IC with an external diameter <70% of the ETT internal diameter at 6 Lpm may prevent increased pressures and volumes within the lungs while performing the AT. This recommendation coupled with current American Academy of Neurology guidelines for the determination of brain death may reduce the incidence of procedure related complications.

Key Words: CO_2 challenge, apnea test, brain death determination, IC:ETT ratio

RESPIRATORY CARE Paper in Press. Published on August 20, 2013 as DOI: 10.4187/respcare.02499

Introduction

The most accepted guideline for the determination of brain death (BD) outlined by the American Academy of Neurology (AAN) describes the necessary assessment elements, which includes a clinical evaluation (neurological assessment) and a CO_2 challenge or another ancillary test.[1-3] The CO_2 challenge, also known as apnea testing (AT), is an essential component in determining BD because it is utilized to establish the absence of a neurological stimulus for respiratory drive.[1]

According to the AAN guideline, the procedure for the AT involves disconnecting the patient from the ventilator for approximately eight minutes while maintaining oxygenation by advancing an insufflation catheter (IC) into the patient's endotracheal tube (ETT) to the level of the carina.[1] The IC is connected to 100% oxygen source and oxygen is delivered at 6 Liters per minute (Lpm) through the insufflation catheter.[1-2] However, the guideline does not specify the size of IC to use during the AT procedure.[1-2]

Complications of the AT have been well documented and include hypoxia, hypotension, cardiac arrhythmias, cardiac arrest, excessive hypercarbia and pneumothorax.[2,4-8] Interestingly, while the occurrence of pneumothoraces during the apnea test is believed to be rare,[9] several case reports have been published describing the occurrence of pneumothoraces within minutes of initiating the apnea test.[3,7-8,10] The case reports describe the utilization of varying oxygen flow rates, insufflation catheter sizes, and cut nasal cannula or oxygen supply tubing as an insufflation catheter when performing the AT.[3,7-8,10] Similar clinical accounts along with this literature finding led to the following research question. What pressures and volumes are generated within the lungs when performing the AT with varying insufflation catheter sizes and varying oxygen flow rates? The objective of this study is to identify an appropriate size of IC to use with each

ETT in order to minimize the pressure and volume within the lungs when performing the AT. The null hypothesis for this study is that there is no statistically significant difference in peak pressures or volumes within a test lung when performing the AT using varying insufflation catheter to ETT (IC:ETT) ratios with the AAN recommended oxygen flow rate of 6 Lpm.

Methods

This bench top Institutional Review Board approved exempt study involved the use of an anatomically correct intubatable manikin, the RespiTrainer Advance (IngMar Medical Ltd., Pittsburgh, PA), and the QuickLung test lung (IngMar Medical Ltd., Pittsburgh, PA). Together, these devices display a digital measurement of the pressure and volume within the test lung using a pressure transducer located within the RespiTrainer Advance. The volume measurement, provided by the RespiTrainer Advance, is a calculated volume from lung pressures using the formula (Ppeak-Pmin)/compliance. The test lung was set to a normal compliance setting of 50 ml/cmH_20 (0.05 Liter/cmH_2O) and a resistance of 5 cmH_2O/L/sec. Prior to data collection, the pressure transducer was calibrated following manufacturer recommendations.

The manikin was intubated with cuffed endotracheal tubes (SunMed, Largo, FL) sequentially with internal diameters (ID) from 6.0-10.0 millimeters (mm) with the tip of each ETT being advanced to exactly two centimeters above the carina in the manikin model. The ETT cuff was inflated to create a seal and IC sizes 10-16 French (Burak Healthcare, Costa Mesa, CA), as well as, a length of cut oxygen supply tubing (Hudson RCI, Research Triangle Park, NC) with an external diameter (ED) of 6.0 mm (18 French), were inserted one at a time into each ETT. The ED of the oxygen supply tubing was measured using a digital caliper (Kobalt, North Wilkesboro, NC). Each IC was advanced through the ETT and positioned precisely to the end of the ETT by matching the length markings on the IC to the length markings on the ETT. Because

RESPIRATORY CARE Paper in Press. Published on August 20, 2013 as DOI: 10.4187/respcare.02499

the oxygen supply tubing did not have length markings, a length marking was made on the tubing for consistency to ensure that it did not pass the end of the ETT.

For each IC and the oxygen supply tubing, 100% oxygen was delivered using a backpressure compensated Thorpe tube-type flow meter (Precision Medical, Northhampton, PA). Standard seven foot oxygen supply tubing (Hudson RCI, Research Triangle Park, NC) connected the flow meter to each IC. To reduce parallax error, the oxygen flow rate delivered was measured by aligning the middle of the Thorpe tube flow meter float at eye level with the correct flow marking on the Thorpe tube flow meter. The delivered oxygen flow rates were adjusted from 6-15 Liters per minute (Lpm) at one Lpm incremental increases. The delivered oxygen flow rates were validated using a thermal mass flow meter (TSI Inc., Shoreview, MN). Once the oxygen flow was delivered through the IC and to the test lung, the test lung inflated due to the flow of oxygen, until the test lung plateaued at a sustained pressure and volume. The sustained pressure and volume within the test lung was then observed and recorded.

The IC:ETT ratio for each IC and ETT combination was calculated by dividing the IC ED by the ETT ID. The IC:ETT ratios were arrayed in six groups as < 0.5, 0.5-0.54, 0.55-0.59 , 0.6-0.64, 0.65-0.69 and ≥ 0.7. The utilization of catheter to ETT ratios for selecting proper catheter size is well documented.[11-13] This study evaluated IC:ETT ratios because this strategy is repeatedly found in the literature as the common means for comparing catheter size to ETT size.[11-13] Table 1 displays the calculated IC:ETT ratios utilized for this study.

The MANOVA and Tukey's Honestly Significant Difference statistical methods were used to determine statistical significant differences among the measured pressures and calculated volumes associated with each IC:ETT ratio when using an oxygen flow rate of 6 Lpm while

RESPIRATORY CARE Paper in Press. Published on August 20, 2013 as DOI: 10.4187/respcare.02499

performing the AT procedure. An alpha level of 0.05 was used to determine statistical significant differences.

Results

Table 2 displays the mean peak pressures measured while performing the AT with the varying IC:ETT ratios and oxygen flow rates of 6-15 Lpm. Figure 1 graphically displays the descriptive statistics of the peak pressures for each IC:ETT ratio while performing the AT with an oxygen flow rate of 6 Lpm. When performing the AT with an oxygen flow rate of 6 Lpm, the MANOVA statistical method identified statistically significant differences among the pressures and volumes associated with the IC:ETT ratios ($p < 0.001$). The Tukey's Honestly Significant Difference indicated that pressures within the test lung associated with IC:ETT ratios greater than and equal to 0.7 were significantly different from the pressures associated with IC:ETT ratios less than 0.7 ($p < 0.05$).

Table 3 displays the mean volumes when performing the AT with the varying IC:ETT ratios and an oxygen flow rates of 6-15 Lpm. Figure 2 graphically displays the descriptive statistics of the calculated volumes for each IC:ETT ratio when performing the AT with an oxygen flow rate of 6 Lpm. Upon statistical analysis of the volumes within the test lung when performing the AT with an oxygen flow rate of 6 Lpm, the Tukey's Honestly Significant Difference statistical method identified that volumes within the test lung associated with IC:ETT ratios greater than and equal to 0.7 were significantly different from the volumes within the test lung associated with IC:ETT ratios less than 0.7 ($p < 0.05$).

Discussion

The 1995 Report of the Quality Standards Subcommittee of the AAN states to "place a cannula at the level of the carina."[2] The use of the word "cannula" is confusing in this context and may have led some health care professionals to mistakenly use nasal cannula tubing that had been cut and advanced into the ETT as the means to administer oxygen during the apnea test procedure.[7-8] Although the subsequent 2010 Report of the Quality Standards Subcommittee of the AAN revised the wording by stating "place an insufflation catheter through the endotracheal tube,"[1] the guideline fails to identify the size of insufflation catheter to be employed, even though the size of the IC has been purported to potentially contribute to the occurrence of pneumothoraces while performing the AT.[3,9]

Utilization of cut oxygen tubing was included in the research because the use of oxygen supply tubing in this manner is a common practice in the clinical setting for the AT in many locations. The use of cut oxygen tubing or cut nasal cannula tubing poses several concerns. First, oxygen tubing and nasal cannulas do not have graduated length markings similar to those found on the IC and the healthcare practitioner will not be able to accurately judge the depth to which the tubing is advanced down the ETT. The absence of these markings presents the risk of advancing the tubing past the end of the ETT and into a smaller airway, thus occluding the airway.[8,10] Furthermore, cut or severed nasal cannula tubing may have a sharp edge at the level of the cut and, if advanced past the end of the ETT, the edge has the potential to perforate or damage bronchial tissue leading to an air leak.[7]

When performing the AT with oxygen flow rates of 6-15 Lpm, IC:ETT ratios greater than 0.89 caused the test lung to continue inflation without reaching a plateau. Once the test lung was fully inflated (peak pressure greater than 22 cmH_2O and volume greater than 1100ml), the test lung was disconnected from the manikin to prevent damage to the test lung. As a result, sustained end-point pressures and volumes for these IC:ETT ratios were not obtained.

RESPIRATORY CARE Paper in Press. Published on August 20, 2013 as DOI: 10.4187/respcare.02499

Upon evaluation of the measured pressures and calculated volumes within the test lung using an oxygen flow rate of 6 Lpm, statistically significant differences among the mean pressures and volumes within the test lung were found for IC:ETT ratios greater than and equal to 0.7. Due to this finding, the null hypothesis was rejected. As a result, healthcare professionals performing the AT should be cautioned against the use of an IC when its ED exceeds 70% of the ID of the artificial airway. Therefore, healthcare practitioners should be cautioned against the utilization of an IC greater than 12 French when performing the AT with a 6.0 mm and 6.5 mm internal diameter ETT, greater than 14 French when performing the AT with a 7.0 mm and 7.5 mm internal diameter ETT, and greater than 16 French when performing the AT with an ETT that has and internal diameter ≥ 8.0 mm.

Increasing the delivered oxygen flow rate above the AAN recommend 6 Lpm resulted in increased pressures and volumes within the test lung, which could potentially lead to procedure-related complications. As seen in tables 2 and 3, the measured pressures and calculated volumes generated within the test lung while performing the AT were minimized when using 6 Lpm. Due to this finding, the AAN recommended guideline of 6 Lpm appears to be the most appropriate flow rate to minimize the measured pressure and calculated volume within the test lung.

The results of this study are different from the findings of a similar study performed by Olguner et al., in which a 2.3 Liter anesthesia bag was utilized as a lung model.[14] With Olguner's lung model, the apnea test was performed with size 7.0-8.0 ID ETTs, 8–14 French oxygen catheters, at six, eight, and ten Lpm oxygen flow rates.[14] Olguner et al. calculated ETT to oxygen catheter ratios by dividing the ETT internal diameter by the external diameter of the oxygen catheter,[14] inversely to tradition ratio calculations.[11-13] Olguner's study concluded that ETT to oxygen catheter ratios less than 1.75 were significantly different and were associated with higher pressures within their lung model from diameter-based ETT to oxygen catheter ratios greater than 1.75.[14] Although we utilized the traditional method for calculating IC:ETT ratios based on previous literature[11-13], we converted our ratios to compare our findings to those of Olguner et al.

The findings from our study may be different from Olguner's study for several reasons; first, Olguner utilized an anesthesia bag as a lung model in which the compliance of the anesthesia bag was not determined; second, Olguner utilized a pressure transducer calibrated for air but then used a 100% oxygen environment while performing the AT procedure; finally, Olguner utilized only three different sizes of ETTs, whereas we utilized nine different ETT sizes.[14]

The data from this study suggests that as the IC:ETT ratio increases, the measured pressures and calculated volumes within the test lung also increase. Lang and Heckmann stated that barotrauma may be prevented when performing the AT by limiting the insufflating oxygen flow rate, utilizing an appropriate sized IC relative to ETT size, and preventing excessive advancement of the IC through the ETT.[9] This study supports the statement by Lang and Heckmann and further recommends utilizing an IC with an ED less than 70% of the ETT ID as a means to prevent excessive pressure and volume within the lungs.

Limitations

This study utilized clean ETTs free of dried secretions within the lumen of the ETT. In the clinical setting, patients intubated for extended periods of time may have dried secretions within their ETT, which may decrease the ID. Health care professionals should consider using a smaller sized IC when performing the apnea test for patients known to have thick or tenacious pulmonary secretions.

RESPIRATORY CARE Paper in Press. Published on August 20, 2013 as DOI: 10.4187/respcare.02499

The test lung used for the study had a maximum volume of 1200 ml. Utilization of a larger test lung may facilitate the measurement of larger pressures and volumes for future studies. Due to the limitations of the test lung, the measured pressures and calculated volumes could not be measured for IC:ETT ratios greater than 0.89. Furthermore, the test lung was set to a predetermined compliance. Variations in patient lung compliance will result in varying pressures and volumes generated within the lungs.

This study specifically evaluated adult size 6.0-10.0 mm ETTs when performing the AT. The AT is also commonly performed for the determination of brain death in the pediatric population and further research should be conducted regarding size 3.0-5.5 mm ID ETTs.

Conclusions

The AT is outlined in the AAN guidelines for the determination of brain death but does not prescribe the size of IC to be used during the procedure.[1-2] As a result of this study, the most appropriate IC size to use when performing the apnea test is an IC that does not exceed 70% of the ETT ID. The findings of this study, coupled with the current AAN guidelines for the determination of brain death, may improve pulmonary outcomes and potentially reduce the risk of procedure-related complications and sequelae.

Acknowledgements

The authors would like to thank Christopher J. Russian M.Ed., RRT-NPS, RPSGT and Joshua F. Gonzales, MHA, RRT-NPS, RRT-SDS for their contributions in developing the research idea. The authors would also like to thank Lynda Harkins, Ph.D., RRT for assisting with the statistical analysis of the study's data.

References

1. Wijdicks, EFM, Varelas PN, Gronseth GS, Greer DM. Evidence-based guideline update: determining brain death in adults. Neurology 2010;74(23):1911-1918. doi: 10.1212/WNL.0b013e3181e242a8.
2. Report of the quality standards subcommittee of the American Academy of Neurology. Practice parameters for determining brain death in adults: summary statement. Neurology 1995;45(5):1012-1014.
3. Saposnik G, Rizzo G, Deluca JL. Pneumothorax and pneumoperitoneum during the apnea test: how safe is this procedure? Arq Neuropisquiatr 2000;58(3-B):905-908.
4. Saposnik G, Rizzo G, Vega A, Sabbatiello R, Deluca JL. Problems associated with the apnea test in the diagnosis of brain death. Neurol India 2004;52(3):342-345.
5. Xiao-liang WU, Qiang FANG, Li Li, Yun-qing QIU, Ben-yan LUO. Complications associated with the apnea test in the determination of brain death. Chin Med J 2008; 121(13):1169-1172.
6. Machado C, Perez J, Scherle C, Areu A, Pando A. Brain death diagnosis and apnea test safety. Ann Indian Acad Neurol 2009;12(3):197-200. doi: 10.4103/0972-2327.56326.
7. Burns JD, Russell JA. Tension Pneumothorax complicating apnea testing during brain death evaluation. J Clin Neurosci 2008;15(5):580-582. doi: 10.1016/j.jocn.2007.02.009.
8. Monterrubio-Villar J, Cordabo-Lopez A. Barotrauma during apnoea testing for brain death determination in a five-year-old boy. Anesth Intensive Care 2008;36(3):462-463.
9. Lang CJG, Heckmann JG. Apnea testing for the diagnosis of brain death. Acta Neurol Scand 2005;112(6):358-369.

10. Bar-Joseph G, Bar-Lavie Y, Zonis Z. Tension pneumothorax during apnea testing for the determination of brain death. Anesthesiology 1998;89(5):1250-1251.

11. Restrepo R, Brown J, Hughes J. AARC clinical practice guideline: endotracheal suctioning of mechanically ventilated patients with artificial airways 2010. Respir Care 2010;55(6):758-764.

12. Rossen M, Hillard E. The effects of negative pressure during tracheal suction. Anesth Analg 1962;41(1):50-57.

13. Tiffin NH, Keim MR, Frewen TC. The effects of variations in flow through an insufflating catheter and endotracheal-tube and suction-catheter on test-lung pressures. Respir Care 1990;35(9):889-897.

14. Olguner C, Koca U, Akan M, Karci A, Elar Z. The safe limits of mechanical factors in the apnea testing for the diagnosis of brain death. Tohoku J Exp Med 2007;211:115-120.

RESPIRATORY CARE Paper in Press. Published on August 20, 2013 as DOI: 10.4187/respcare.02499

Figure Legends

Figure 1. Descriptive statistics of the pressures generated in the test lung for each insufflation catheter to endotracheal tube (IC:ETT) ratio when using an oxygen flow rate of 6 Lpm when performing the apnea test.

Figure 2. Descriptive statistics of the volumes generated in the test lung for each insufflation catheter to endotracheal tube (IC:ETT) ratio when using an oxygen flow rate of 6 Lpm when performing the apnea test.

RESPIRATORY CARE Paper in Press. Published on August 20, 2013 as DOI: 10.4187/respcare.02499

Table 1. The calculated insufflation catheter (IC) to endotracheal tube (ETT) ratios based on the internal diameter of the ETT and the external diameter of IC.

	Insufflation Catheter Size (French)				
ETT Internal Diameter (mm)	10	12	14	16	18
6.0	0.55	0.67	0.78	0.89	1.00
6.5	0.51	0.62	0.72	0.82	0.92
7.0	0.48	0.57	0.67	0.76	0.86
7.5	0.44	0.53	0.62	0.71	0.80
8.0	0.42	0.50	0.58	0.67	0.75
8.5	0.39	0.47	0.55	0.63	0.71
9.0	0.37	0.44	0.52	0.59	0.67
9.5	0.35	0.42	0.49	0.56	0.63
10.0	0.33	0.40	0.47	0.43	0.60

RESPIRATORY CARE Paper in Press. Published on August 20, 2013 as DOI: 10.4187/respcare.02499

Table 2. The mean and standard deviations of the measured peak pressures (cmH_2O) within the test lung when performing the apnea test procedure.

IC:ETT Ratio		Flow Rate (Liters per minute)									
		6	7	8	9	10	11	12	13	14	15
< 0.5	Mean ±SD	0.41 ±0.19	0.56 ±0.30	0.80 ±0.31	0.90 ±0.38	1.09 ±0.43	1.37 ±0.64	1.58 ±0.66	1.73 ±0.65	2.11 ±0.85	2.52 ±1.51
	N	9	9	9	9	9	9	9	9	9	9
0.5-0.54	Mean ±SD	0.68 ±0.13	1.23 ±0.60	1.48 ±0.48	1.75 ±0.57	2.08 ±0.64	2.33 ±0.55	2.70 ±0.67	3.23 ±0.78	3.63 ±1.34	3.83 ±1.31
	N	4	4	4	4	4	4	4	4	4	4
0.55-0.59	Mean ±SD	0.97 ±0.44	1.25 ±0.64	1.60 ±0.81	2.12 ±1.37	2.25 ±1.23	2.77 ±1.67	3.17 ±1.72	4.13 ±2.94	4.28 ±2.81	4.9 ±3.19
	N	6	6	6	6	6	6	6	6	6	6
0.6-0.64	Mean ±SD	1.16 ±0.80	1.48 ±1.11	1.82 ±1.24	2.22 ±1.58	2.62 ±1.65	3.02 ±2.16	3.38 ±2.28	3.78 ±2.72	4.34 ±3.09	4.68 ±3.24
	N	5	5	5	5	5	5	5	5	5	5
0.65-0.69	Mean ±SD	1.93 ±0.87	2.28 ±1.06	3.13 ±1.66	4.0 ±2.50	4.88 ±2.93	5.95 ±4.08	5.38 ±2.51	7.48 ±5.31	8.63 ±5.88	8.53 ±5.13
	N	4	4	4	4	4	4	4	4	4	4
≥ 0.7	Mean ±SD	6.73 ±4.72	8.48 ±6.06	9.16 ±5.68	11.18 ±7.35	9.57 ±5.60	8.78 ±3.72	9.7 ±4.19	11.23 ±4.89	12.65 ±5.64	14.03 ±5.67
	N	10	10	10	9	7	6	6	6	6	6

RESPIRATORY CARE Paper in Press. Published on August 20, 2013 as DOI: 10.4187/respcare.02499

Table 3. The mean and standard deviations of the calculated peak volumes (mL) within the test lung when performing the apnea test procedure.

IC:ETT Ratio		Flow Rate (Liters per minute) 6	7	8	9	10	11	12	13	14	15
< 0.5	Mean ± SD	21.11 ±9.49	30.89 ±14.35	40.44 ±16.15	46 ±18.79	52 ±26.66	69.89 ±31.87	82.44 ±31.5	91.33 ±32.65	109.78 ±43.03	126.11 ±75.65
	N	9	9	9	9	9	9	9	9	9	9
0.5-0.54	Mean ± SD	35.25 ±5.74	62 ±30.40	75 ±26.38	89.25 ±27.54	105 ±34.27	117.5 ±28.07	138.25 ±31.81	165 ±39.15	185.25 ±67.18	193 ±65.31
	N	4	4	4	4	4	4	4	4	4	4
0.55-0.59	Mean ± SD	49.67 ±22.12	64.33 ± 31.83	80.67 ±40.27	106.17 ±67.94	114 ±61.64	141.17 ±83.49	164.33 ±86.34	211.17 ±147.59	218 ±137.57	245.17 ±159.16
	N	6	6	6	6	6	6	6	6	6	6
0.6-0.64	Mean ± SD	58.6 ±39.48	77 ±55.73	91.8 ±60.43	111.8 ±78.64	132.8 ±83.39	153.2 ±107.81	171.8 ±112.86	195.2 ±137.32	223.2 ±154.39	235.2 ±161.62
	N	5	5	5	5	5	5	5	5	5	5
0.65-0.69	Mean ± SD	98.25 ±44.06	115.5 ±51.72	157.5 ±82.28	201.5 ±123.10	245.25 ±147.56	298 ±206.19	271.25 ±122.22	378.25 ±267.38	437.5 ±294.05	428.25 ±259.82
	N	4	4	4	4	4	4	4	4	4	4
≥ 0.7	Mean ± SD	337.4 ±237.51	427.1 ±302.91	458.6 ±283.49	561.33 ±367.92	481.29 ±280.25	490 ±194.41	489.5 ±210.25	566.67 ±245.79	587.67 ±233.86	701.83 ±283.59
	N	10	10	10	9	7	6	6	6	6	6

RESPIRATORY CARE Paper in Press. Published on August 20, 2013 as DOI: 10.4187/respcare.02499

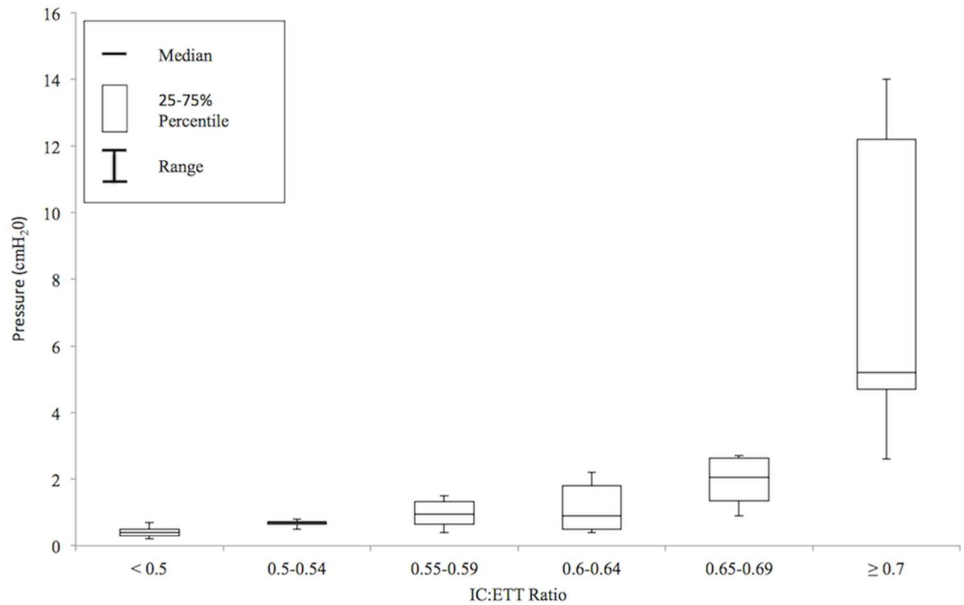

Figure 1. Descriptive statistics of the pressures generated in the test lung for each insufflation catheter to endotracheal tube (IC:ETT) ratio when using an oxygen flow rate of 6 Lpm when performing the apnea test.
422x277mm (72 x 72 DPI)

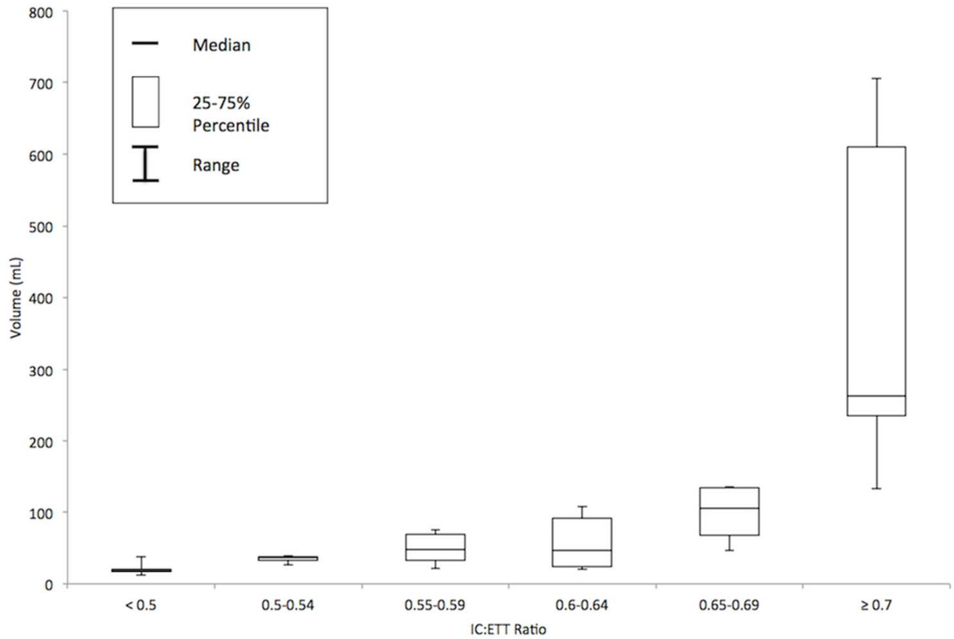

Figure 2. Descriptive statistics of the volumes generated in the test lung for each insufflation catheter to endotracheal tube (IC:ETT) ratio when using an oxygen flow rate of 6 Lpm when performing the apnea test.
394x274mm (72 x 72 DPI)