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Suction catheter size: an assessment and comparison of three different calculation methods

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ABSTRACT

Background: Current AARC clinical practice guidelines (CPGs) recommend a suction catheter to endotracheal tube (SC:ETT) ratio based on a comparison between the external diameter of the suction catheter and the internal diameter (ID) of the ETT. A SC:ETT ratio of less than 50% is consistent with the current recommendation. We theorized that a more satisfactory assessment of SC:ETT ratio could be accomplished using volume or area formulas and expansion of diameter recommendations. Some respiratory care texts recommend a SC:ETT ratio that exceeds the CPG standard. **Methods:** This research project was granted exemption status by the institutional review board at Texas State University-San Marcos. The project involved calculating the internal volume and area of a variety of ETT sizes, calculating the external volume and area of a variety of SC sizes and comparing the ETT and SC calculations to achieve a final ratio. In addition, we assessed negative pressures using vacuum suction and a lung model during multiple suction maneuvers. **Results:** Our results indicate volume and area calculations provide an alternative method to determining SC:ETT ratio. We found that a volume or area ratio of 50% corresponds to a diameter ratio of 70%. We demonstrated that negative pressures during suctioning remain low at the new ratios. This indicates that use of a larger suction catheter than current clinical practice guidelines is possible while continuing to allow air entrainment between the suction catheter and endotracheal tube. **Conclusion:** Our investigation determined the ETT internal volume and area, SC external volume and area and SC:ETT ratios based on volume, area and diameter for a variety of ETTs and SCs. Our results support an alternative ratio when pairing suction catheters and endotracheal tubes.

Key Words: Suction catheter size, endotracheal tube size, suction catheter:endotracheal tube ratio, tube diameter, endotracheal suctioning, airway clearance

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Introduction

In 1960 Rosen and Hillard published an extensive paper on the use of suction during clinical practice with a follow-up article in 1962 focusing specifically on negative pressure during tracheal suctioning.[1,2] The authors introduced a formula to determine the negative pressure generated within the lungs during a suctioning maneuver. Based on their calculations the authors recommended the ideal suction catheter size is one that does not occlude more than half of the airway. This was the seminal publication on suction catheter:endotracheal (SC:ETT) ratios. Regardless of widespread acceptance for a SC:ETT ratio based on tube diameter there is evidence that clinicians and researchers use larger ratios than recommended.[3-6]

American Association for Respiratory Care (AARC) convened an expert panel to develop, and periodically update, clinical practice guidelines (CPG) for suctioning the artificial airway of the mechanically ventilated patient.[7,8] Section 2.0 of the AARC Endotracheal Suctioning CPG suggests selecting a suction catheter based on the internal diameter of the artificial airway.[8] The expert panel cited two studies[9,10] to support this recommendation. However, Tiffin et. al. suggested using a SC:ETT ratio based on tube area versus diameter.[9] Pedersen et. al., not cited in the AARC CPG, suggested, "the suction catheter should occlude less than half the internal lumen, rather than half the diameter of the ET-tube [sic]."[11pp23] The authors considered lumen synonymous with volume and provided a volume formula in their article.[11] Collectively there exist three different options for determining the relationship between SC and ETT size, i.e. diameter, volume, and area.

The purpose of this project is to: 1) calculate the internal volume and cross-sectional area of multiple ETTs, 2) calculate the external volume and cross-sectional area of multiple suction catheters, 3) record the negative pressures generated during a suction procedure using an airway model and 4) make comparisons between current AARC CPG diameter recommendations with the volume and area ratios.

Methods

The current research project was granted exemption status by the institutional review board at Texas State University-San Marcos. This project involved calculating the internal volume and the internal area of a variety of ETT sizes, calculating the external volume and external area of a variety of SC sizes, and comparing the ETT and SC measurements to achieve a final SC:ETT ratio. Standard geometry formulae for the volume and area calculations were used. ETT sizes 2.0 mm to 10.0 mm internal diameter (ID) and suction catheter sizes 4 to 16 French (Fr) were used for all calculations. The following millimeter and Fr conversions were used when necessary:[12]

1 mm = 3 Fr and 0.33 mm = 1 Fr.

Internal diameter and the length was used to calculate ETT volume relying on the manufacturer label for ETT internal diameter. The 15 mm ETT connector was not included in the measurements. Endotracheal tube length was measured from the distal end of the ETT 15 mm connector, while inserted in the ETT, to the proximal end of the Murphy eye. External diameter and length was used to calculate SC external volume. Length is crucial to volume measurements; therefore, SC and ETT length were matched for the calculations. Original ETT length per the manufacturer was not altered thus allowing ETT length to guide SC length and the resulting volumes. The SC external diameter was found using a digital caliper. Volume calculations were converted from cubic millimeter to milliliter. A ratio was created for the external volume of the SC to the internal volume of the endotracheal tube (SC:ETT volume ratio) for all measured sizes.

ETT internal diameter and SC external diameter was used to calculate cross sectional area. A ratio was created for the external area of the SC to the internal area of the endotracheal tube (SC:ETT area ratio) for all measured sizes.

Lastly, negative pressures generated were recorded during a suction maneuver using an airway model, i.e. corrugated tubing or oxygen tubing. Cuffed ETT sizes 6 mm to 10 mm ID (SunMed, Largo, FL) were inserted into 12 inches of large bore corrugated tubing (diameter = 21.0 mm). Cuffed ETT sizes 4.0 mm and 5.0 mm ID (SunMed, Largo, FL) were inserted into 12 inches of pediatric ventilator corrugated tubing (diameter = 16.0 mm). A cuffed ETT size 3.0 mm ID (Wai Medical, Viroqua, WI) was inserted into 9 inches of neonatal ventilator corrugated tubing (diameter = 10.6 mm). Finally, an uncuffed ETT size 2.0 mm ID (Sheridan/Teleflex, Research Triangle Park, NC) was inserted into 7.5 inches of oxygen tubing (diameter = 4.0 mm). Half-sized ETTs, e.g. 5.5mm ID, were not used for this portion of the study. A negative pressure manometer (Instrumentation Industries, Inc., Bethel Park, PA) was connected to the distal end of each lung model and opposite the ETT point of insertion. The use of cuffed ETTs created a seal between the ETT and the airway model. This seal was crucial to our experiments because it prevented air entrainment between the ETT and the airway model thus reducing pressure attenuation from this pathway. Since the 2.0 mm ID ETT does not have a cuff a 7.5-inch length of oxygen tubing served as the airway model. Insertion of the ETT to the hub created a seal between the ETT and the oxygen tubing. Similar to the corrugated tubing models a pressure manometer was attached to the distal end of the oxygen tubing to display our lung pressures during suctioning. Pressures were recorded with the 2.0 mm ID ETT fully inserted into the oxygen tubing to simulate a sealed ETT scenario. In-line suction catheters (Kimberly-Clark, Roswell, GA) were connected to each ETT with the suction line connected to a vacuum source.

The vacuum source was adjusted to adhere to AARC CPG specifications based on patient population.[8,13] Therefore, the following ETT size and suction pressure combinations were used, ETT ≥ 6 mm ID received -150 mmHg; ETT = 5.0 mm ID received -120 mmHg; ETT = 3.0 and 4.0 mm ID received -100 mmHg; and ETT = 2.0 mm ID received -80 mmHg. Each suction catheter was inserted into the ETT until reaching the tip of the tube. Suction was applied as the catheter was slowly withdrawn. The maximum negative pressure generated was recorded. The suction procedure was repeated to achieve two identical negative pressures. If the negative pressures differed by more than 2 cmH2O the procedure was repeated. The "ventilator connection" of the in-line suction catheter remained open during all suctioning maneuvers. Therefore, atmospheric air entrainment was possible between the ETT and SC depending on the ratio.

Results

Table 1 displays the external volume calculations for each SC included in this study. A 14Fr SC was compared to several ETTs of different lengths; therefore, SC volume for each length is reported. Table 2 displays the external area calculations for each suction catheter included in this study. Table 3 displays the internal volume and internal area calculations for all ETTs included in this study. Table 4 displays a suction catheter size comparison based on the AARC Endotracheal Suctioning CPG, the area calculations and the volume calculations. Due to current AARC CPG language table 4 has a column for *less than 50%* and a column for *less than or equal to 50%*. The area and volume recommendations are based on 50% of the ETT area and volume calculations, respectively. Our 50% area and volume calculations match the less than 70% diameter calculations. SC sizes on table 4 were limited to 14Fr. A larger suction catheter is possible with certain ETTs, e.g. 10 mm ID ETT. Table 5 displays the pressure results during

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bench-top evaluation from a suction maneuver using our airway model. A curvilinear change in negative pressure occurs based on the SC:ETT ratio.

Discussion

Our calculations allow comparison of SC:ETT area and volume ratios with diameter ratios per the current AARC CPG. Selection of a SC that is 50% of the internal area or 50% of the internal volume of an ETT equates to a SC that is 70% of the diameter of an ETT. This relationship applies to adult, pediatric and neonatal ETTs. Per the AARC CPG, only infants can be suctioned with a SC that is less than 70% of the ETT diameter. The calculations for area and volume require somewhat complicated formulae versus using diameter calculations. Equally, ETT diameter calculations require a conversion from millimeter to French to match SC sizing. However, there is a quick method available to determine SC:ETT ratios. Choosing a SC that is less than 70% of the ETT internal diameter only requires the clinician to double the millimeter diameter size of the ETT to get the size of the SC in Fr. For example, a 7.0 mm ETT can accept a 14 Fr SC. This method to determine SC size would apply for adult, pediatric and neonatal ETTs. Furthermore, using a SC:ETT ratio exceeding the current AARC CPG is supported by two nationally recognized respiratory care textbooks.[14,15] Table 4 demonstrates the comparison between all three methods.

It has been demonstrated that suction catheters that occlude half the area of the ETT continue to allow air to pass into the lungs during a suction procedure.[9] Figure 1 provides an illustrative comparison of a SC:ETT ratio based on 50% of the diameter and 70% of the diameter. Suction catheters that block 70% of the ETT internal diameter still allow half of the ETT internal area for air entrainment. A space for air entrainment is crucial to the negative pressure generated within the lungs and the air that enters the SC. Our bench-top experiment

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allowed the generation of negative pressures during a suction maneuver using an airway model. As expected, the pressure applied to the lungs became more negative as the SC size increased in comparison to the ETT. See Figure 2. High suction pressures do not appear to occur until beyond the 70% diameter recommendation.

Previous authors have calculated the negative pressure within the lungs when factoring in the applied suction pressure, the SC:ETT ratio and the SC-ID:SC-OD ratio.[1,2] As figure 3 demonstrates, a SC:ETT diameter ratio of 50% appears to generate a negative pressure on the flat or less steep portion of all three curves. Depending on the suction catheter characteristics, the steep portion of the curve does not occur until after a SC:ETT diameter ratio of 70% and -200 cmH2O. In addition, the suction pressure included in the original calculations, e.g. -20 in Hg (-500 mmHg), is beyond the negative pressures recommended in the AARC CPGs, e.g. adults < -150 mmHg (-6 in Hg).[8,13] The formula developed by these authors was used to recalculate and plot the relationship between suction pressure, SC size and ETT size.[1,2] Suction pressures were based on the current AARC CPG. Figure 4 demonstrates the curvilinear relationship of SC and ETT sizes. Triangles indicate the recommended SC and ETT combination based on volume/area ratio of 50% and a diameter ratio of less than 70%.

Limitations

The impact of larger SC:ETT ratios on lung volumes was not assessed in association with this project. However, there is literature to address this topic.[16-18] Additional research to determine the changes in lung volume when performing ETS with the identified suction catheter size is warranted. Suction catheter size was limited to 14 Fr despite results indicating a larger SC is possible. The reasons are based on the inability to locate literature supporting the use of a 16

Fr suction catheter with adult ETTs. In addition, there is literature suggesting a 14 Fr SC is acceptable for adult patients.[14]

ETTs that have pulmonary secretions along the walls of the ETT will decrease the ETT internal volume, area and diameter, as well as limit the amount of air entrainment during a suctioning maneuver. This may lead to greater negative pressure generation within the lungs when performing ETS. The impact of secretions on ETT internal size and negative pressure generation was not evaluated in this study.

Distal negative pressures with a completely closed system suction set-up was not evaluated in this study. The proximal end of the in-line suction catheter remained open to the atmosphere. The proximal end of the in-line suction catheter is a source for air entrainment during a suctioning maneuver. Adding positive pressure ventilation to the proximal end of the in-line suction catheter will impact the negative pressures generated during a suctioning maneuver.

Lastly, cuffed ETTs are not common practice for neonatal and some pediatric patients. Without the use of a cuff there is the chance for a leak between the ETT and the trachea. This leak will offer another location for air entrainment during a suctioning maneuver. Cuffed ETTs were deliberately used to determine the negative pressures due to the SC:ETT ratio. Therefore, our suctioning results do not reflect actual results that may occur when using uncuffed ETTs in the NICU or PICU.

Conclusion

Volume and area calculations were applied to a variety of SC and ETT sizes to determine the SC:ETT ratio. Volume and area calculations were compared to diameter calculations for all sizes. This study demonstrated that a calculated SC:ETT ratio based on 50% of ETT area or 50% of ETT volume is equivalent to 70% of the ETT diameter. Using a diameter ratio at 70% will allow the clinician to quickly determine the proper SC size by doubling the ETT size. This method for determining SC:ETT ratios allows for a larger suction catheter to be used than recommended by current AARC CPGs.[8] It needs to be stressed, our results establish the maximum SC size for each ETT. Bedside practitioners can select a SC that is smaller than the ratios provided above if the recommended size is unavailable or deemed inappropriate due to clinical outcomes.

References

1. Rosen M, Hillard EK. The use of suction in clinical medicine. Brit J Anaesth 1960;32(10):486-504.
2. Rosen M, Hillard EK. The effects of negative pressure during tracheal suction. Anesth Analg 1962;41(1):50-57.
3. Witmer MT, Hess D, Simmons M. An evaluation of the effectiveness of secretion removal with the ballard-circuit suction catheter. Respir Care 1991;36(8):844-848.
4. Fernandez M-d-M, Piacentini E, Blanch L, Fernandez R. Changes in lung volume with three systems of endotracheal suctioning with and without pre-oxygenation in patients with mild-to-moderate lung failure. Intensive Care Med 2004;30(12):2210-2215. doi: 10.1007/s00134-004-2458-3.
5. Frengley RW, Closey DN, Sleigh JW, Torrance JM. The effect of closed system suction on airway pressures when using the Servo 300 ventilator. Crit Care Resuscitation 2001;3(4):230-235.
6. Day T, Wainwright S, Wilson-Barnett J. An evaluation of a teaching intervention to improve the practice of endotracheal suctioning in intensive care units. J Clin Nurs 2001;10(5):682-696.
7. AARC clinical practice guideline: Endotracheal suctioning of mechanically ventilated adults and children with artificial airways. Respir Care 1993;38(5):500–504.
8. AARC clinical practice guideline: endotracheal suctioning of mechanically ventilated patients with artificial airways: 2010. Respir Care 2010;55(6):758-764.

9. Tiffin NH, Keim MR, Frewen TC. The effects of variations in flow through an insufflating catheter and endotracheal tube and suction catheter size on test lung pressures. Respir Care 1990;35(9):889-897.
10. Vanner NH, Bick E. Tracheal pressures during open suctioning. Anaesthesia 2008;63(3):313-315. doi: 10.1111/j.1365-2044.2007.05348.x
11. Pederson CM, Rosendahl-Nielsen M, Hjermind J, Egerod I. Endotracheal suctioning of the adult intubated patient-what is the evidence? Intensive Crit Care Nurs 2009:25(1);21-30. doi: 10.1016/j.iccn.2008.05.004
12. Iserson KV. J.-F.-B. Charriére: The man behind the "French" gauge. J Emerg Med 1987;5(6):545-548.
13. AARC clinical practice guideline. Nasotracheal suctioning – 2004 revision and update. Respir Care 2004;49(9):1080-1084.
14. Davies JD, May RA, Bortner PL. Airway Management. In: Hess, DR, MacIntyre NR, Mishoe SC, Galvin WF, Adams AB, editors. Respiratory Care: principles and practice, 2nd ed. Sudbury, MA: Jones & Bartlett Learning; 2012:376-418.
15. Altobelli N. Airway Management. In: Kacmarek RM, Stoller JK, Heuer AJ, editors. *Egan's Fundamentals of Respiratory Care*. 10th ed. St. Louis, MO: Elsevier; 2013:732-786.
16. Lindgren S, Almgren B, Hogman M, Lethvall S, Houltz E, Lundin S, Stenqvist O. Effectiveness and side effects of closed and open suctioning: an experimental evaluation. Inten Care Med 2004;30(8):1630-1637.
17. Morrow BM, Futter MJ, Argent AC. Endotracheal suctioning: from principles to practice. Inten Care Med 2004;30(6):1167-1174. doi: 10.1007/s00134-004-2238-0

18. Tingay DG, Copnell B, Grant CA, Dargaville PA, Dunster KR, Schibler A. The effect of endotracheal suction on regional tidal ventilation and end-expiratory lung volume. Inten Care Med 2010;36(5):888-896. doi: 10.1007/s00134-010-1849-x

Figure Legend

Fig. 1. Representation of SC:ETT ratio based on ETT diameter. Picture A: SC:ETT diameter ratio of 50%. Picture B: SC:ETT diameter ratio of 70%.

Fig. 2: Negative pressures generated using an airway model. Black triangles indicate the SC:ETT recommendation based on an area/volume ratio of 50% and a diameter ratio of 70%. Since half sizes for the ETTs were not used, a recommendation for the 7Fr and 5Fr suction catheters is not provided.

Figure 3: The calculated negative pressure developed in the lung is plotted against the ratio between the outside diameter of the suction catheter and the inside diameter of the airway. In this example the negative pressure applied to the suction is 20 in Hg. Each curve represents a catheter with a different wall thickness expressed as the ratio between the inside diameter (I.D.) and the outside diameter (O.D.) of the catheter. Copied from reference 1. British journal of Anaesthesia: BJA by OXFORD UNIVERSITY PRESS. Reproduced with permission of OXFORD UNIVERSITY PRESS in the format reuse in a journal/magazine via Copyright Clearance Center.

Fig. 4. Negative pressures calculated from Rosen and Hillard formula.[1,2] Triangles indicate the SC:ETT recommendation based on an area/volume ratio of 50% and a diameter ratio of 70%. The calculated location for each ETT is indicated on the suction catheter curves.

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Table 1. Suction catheter sizes and the external volume for each catheter. SC length is matched against ETT length.

Suction Catheter Size (Fr)	Suction Catheter Size (mm)	Volume of Suction Catheter (mL)
16.0*	5.3	6.7
16.0†		6.5
16.0‡		6.3
16.0§		6.0
14.0*	4.7	5.2
14.0†		5.0
14.0‡		4.8
14.0§		4.6
14.0¶		4.4
12.0*	4.0	3.8
12.0†		3.6
12.0‡		3.5
12.0§		3.4
12.0¶		3.3
12.0**		2.9
10.0§	3.3	2.4
10.0¶		2.3
10.0**		2.0
8.0‡	2.7	1.6
8.0§		1.5
8.0¶		1.5
8.0**		1.3
7.0**	2.3	1.0
6.0**	2.0	0.7
5.0**	1.7	0.5
4.0**	1.3	0.3

* Suction catheter length equals 302 mm
† Suction catheter length equals 290 mm
‡ Suction catheter length equals 280 mm
§ Suction catheter length equals 270 mm
¶ Suction catheter length equals 260 mm
** Suction catheter length equals 230 mm

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Table 2. Suction catheter sizes and the external area calculation for each catheter.

Suction Catheter Size (Fr)	Suction Catheter External Diameter (mm)	Area of Suction Catheter (mm^2)
16	5.3	21.9
14	4.7	16.8
12	4.0	12.3
10	3.3	8.5
8	2.7	5.5
7	2.3	4.2
6	2.0	3.1
5	1.7	2.1
4	1.3	1.4

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Table 3. Endotracheal Tube Internal Volume and Area calculations with maximum volume displacement and maximum area of encroachment. Tube lengths are provided in the legend.

ETT Internal Diameter (mm)	ETT French Size (Fr)	Volume of ETT (mL)	Max Vol Displacement (50% of Vol calc) (mL)	Area of ETT (mm^2)	Max Area of Encroachment (50% of Area calc) (mm^2)
10.0*	30.0	23.7	11.9	78.5	39.3
9.5*	28.5	21.4	10.7	70.8	35.4
9.0*	27.0	19.2	9.6	63.6	31.8
8.5*	25.5	17.1	8.6	56.7	28.4
8.0*	24.0	15.2	7.6	50.2	25.1
7.5*	22.5	13.3	6.7	44.2	22.1
7.0†	21.0	11.2	5.6	38.5	19.2
6.5‡	19.5	9.3	4.6	33.2	16.6
6.0§	18.0	7.6	3.8	28.3	14.1
5.5¶	16.5	6.2	3.1	23.7	11.9
5.0**	15.0	4.5	2.3	19.6	9.8
4.5**	13.5	3.7	1.8	15.9	7.9
4.0**	12.0	2.9	1.4	12.6	6.3
3.5**	10.5	2.2	1.1	9.6	4.8
3.0**	9.0	1.6	0.8	7.1	3.5
2.5**	7.5	1.1	0.6	4.9	2.5
2.0**	6.0	0.7	0.4	3.1	1.6

* ETT length equals 302 mm
† ETT length equals 290 mm
‡ ETT length equals 280 mm
§ ETT length equals 270 mm
¶ ETT length equals 260 mm
** ETT length equals 230 mm

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Table 4. Suction catheter size recommendations based on AARC CPG[2], area and volume calculations.

	Suction Catheter Size based on AARC CPG (Fr)				Suction Catheter Size based on Area calc (Fr)	Suction Catheter Size based on Vol calc (Fr)
ETT Internal Diameter (mm)	<0.5 of the ETT Internal Diameter	</=0.5 of the ETT Internal Diameter	</=0.66 of the ETT Internal Diameter	<0.7 of the ETT Internal Diameter	</=0.5 of ETT Area Calculation	</=0.5 of ETT Volume Calculation
10.0	14	14	14*	14*	14*	14*
9.5	14	14	14*	14*	14*	14*
9.0	12	12	14*	14*	14*	14*
8.5	12	12	14*	14*	14*	14*
8.0	10	12	14	14*	14*	14*
7.5	10	10	14	14	14	14
7.0	10	10	12	14	14	14
6.5	8	8	12	12	12	12
6.0	8	8	10	12	12	12
5.5	8	8	10	10	10	10
5.0	7	7	8	10	10	10
4.5	6	6	8	8	8	8
4.0	5	6	7	8	8	8
3.5	5	5	6	7	7	7
3.0	4	4	5	6	6	6
2.5	2	2	5	5	5	5
2.0	2	2	4	4	4	4

*suction catheter size limited to 14Fr. A larger size suction catheter is possible based on calculations.

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Table 5. Negative pressure measurements (cmH_2O) using vacuum suction and an airway model.

	Suction Catheter Size (Fr)								
	16	14	12	10	8	7	6	5	
ETT (mm)									Vacuum Pressure (mmHg)
10	2	1							150
9.5	4	3							150
9	4	3	1						150
8.5	8	4	1						150
8	13	6	2						150
7.5	28	10	3	1					150
7	40	13	4	1					150
6.5	98	22	4	1					150
6	120	52	12	4	1				150
5*	DNF	88	40	10	4	1			120
4*		DNF	DNF	88	20	14	2		100
3†				DNF	120	78	18	4	100
2‡					DNF	DNF	DNF	100	80

ETT 10-6 mm used large bore corrugated tubing for airway model
* = Pediatric ventilator circuit tubing used for airway model
† = Neonatal ventilator circuit tubing used for airway model
‡ = Oxygen tubing used for airway model
DNF = does not fit. Suction catheter does not fit into ETT

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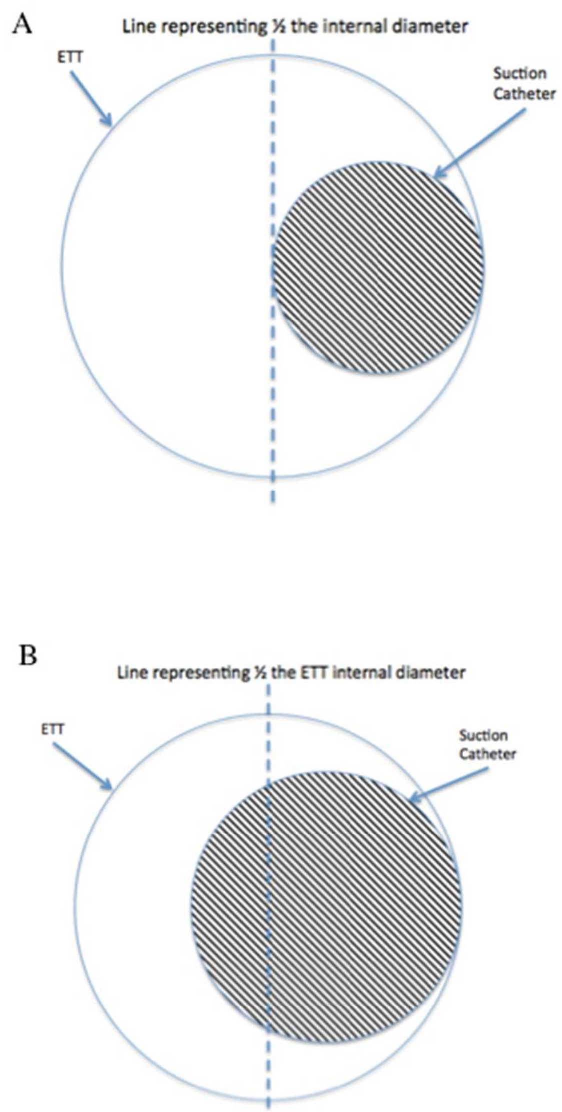

Fig. 1. Representation of SC:ETT ratio based on ETT diameter. Picture A: SC:ETT diameter ratio of 50%.
Picture B: SC:ETT diameter ratio of 70%.
126x245mm (72 x 72 DPI)

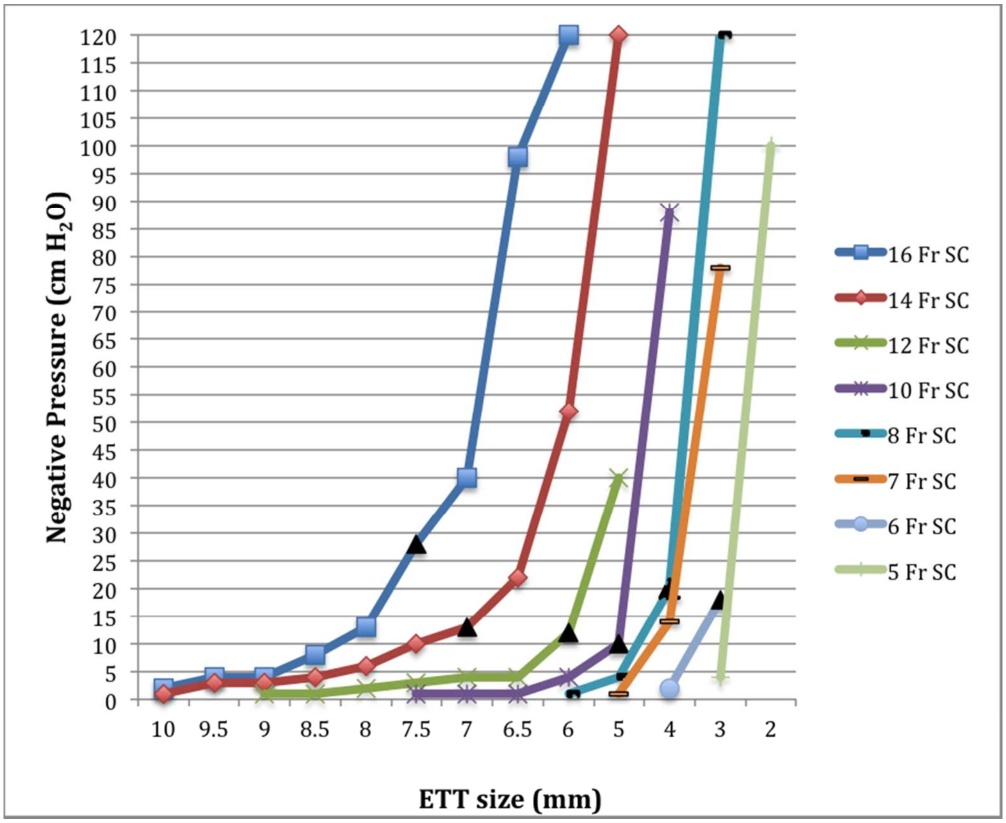

Fig. 2: Negative pressures generated using an airway model. Black triangles indicate the SC:ETT recommendation based on an area/volume ratio of 50% and a diameter ratio of 70%. Since half sizes for the ETTs were not used, we were not able to indicate the recommended ratio for the 7Fr and 5Fr suction catheters.
152x124mm (150 x 150 DPI)

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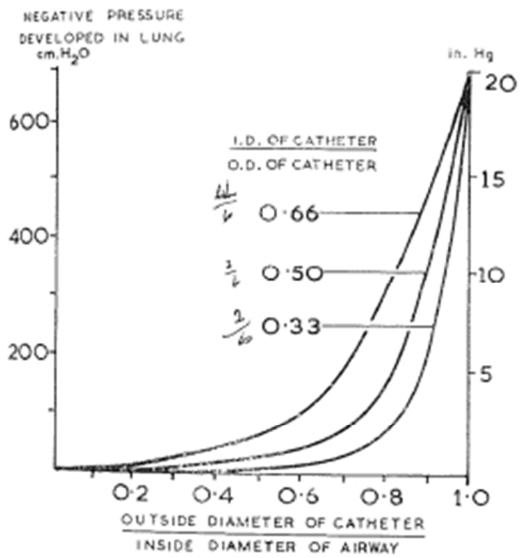

Figure 3: The calculated negative pressure developed in the lung is plotted against the ratio between the outside diameter of the suction catheter and the inside diameter of the airway. In this example the negative pressure applied to the suction is 20 in Hg. Each curve represents a catheter with a different wall thickness expressed as the ratio between the inside diameter (I.D.) and the outside diameter (O.D.) of the catheter. Copied from reference 1. British journal of Anaesthesia: BJA by OXFORD UNIVERSITY PRESS. Reproduced with permission of OXFORD UNIVERSITY PRESS in the format reuse in a journal/magazine via Copyright Clearance Center.
103x100mm (72 x 72 DPI)

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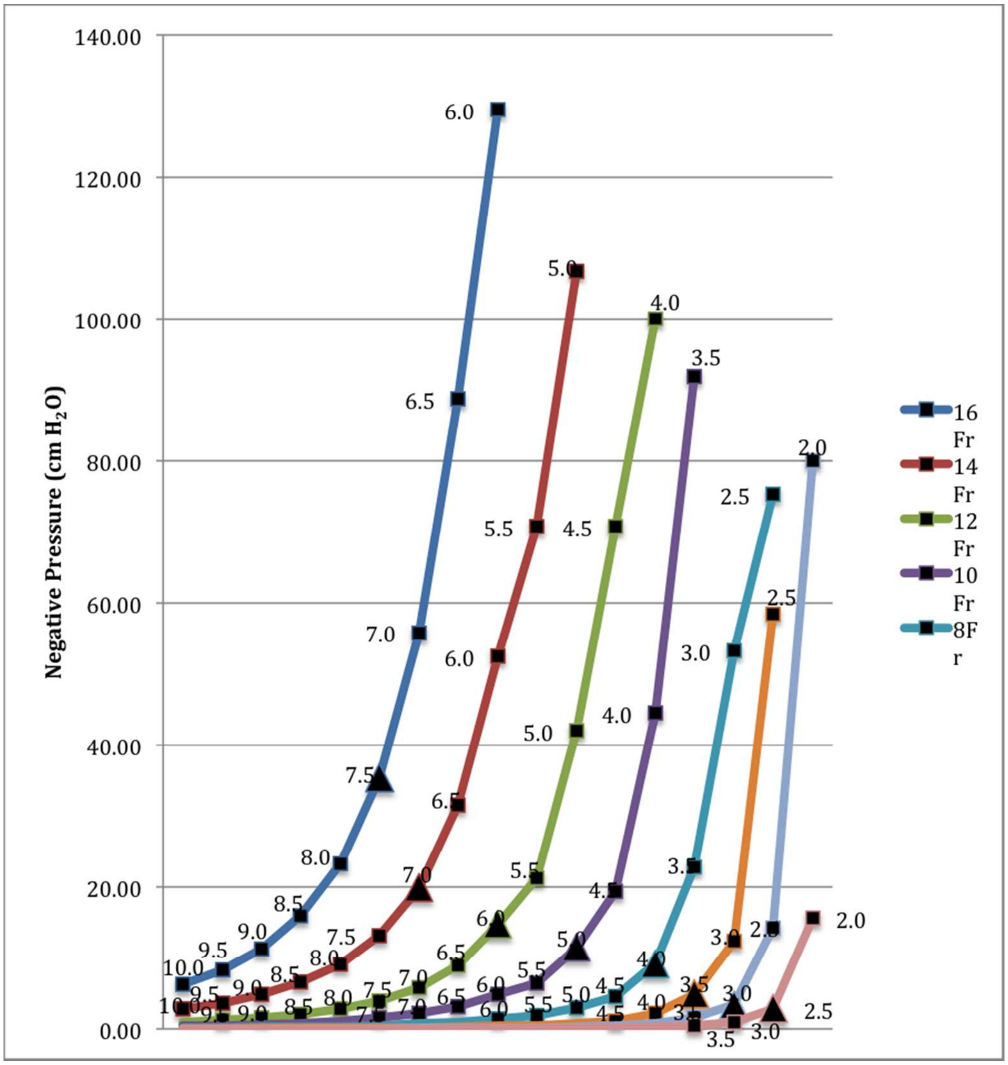

Fig. 4. Negative pressures calculated from Rosen and Hillard formula.1,2 Triangles indicate the SC:ETT recommendation based on an area/volume ratio of 50% and a diameter ratio of 70%. The calculated location for each ETT is indicated on the suction catheter curves.
152x161mm (150 x 150 DPI)