Deleterious Effects on Fio2 Using Common Airway Suction Devices During Intubation Utilizing the SALAD Park/NO DESAT Technique

Authors: Emanuele Lagazzi MD[1], David R. King MD COL USAR[1]

Affiliations:
1. Massachusetts General Hospital, Division of Trauma, Emergency Surgery & Surgical Critical Care and Harvard Medical School

Introduction

Oro-tracheal intubation remains a cornerstone in the advanced airway management of critically ill or injured patients in the prehospital setting or emergency department. Rapid sequence intubation (RSI) is the most used approach to achieve a definitive airway in rapidly deteriorating patients.[1] However, in contrast with elective intubation, emergent airway management outside of the operating room poses unique challenges, including anatomical factors, logistical issues, and physiological challenges such as hypoxia, hemodynamic instability, regurgitation of gastric content, and aspiration risk. [2–4] In this framework, airway contamination from blood, emesis, or secretions can impede the clinician's ability to ventilate or oxygenate the patient and to visualize the anatomical landmarks needed to perform a successful intubation, either via direct or video laryngoscopy. Additionally, the presence of airway contaminants increases the chance of failing first-pass intubation and of performing repeated attempts,[5–9] which has been shown to be a significant risk factor for airway or hemodynamic adverse events such as hypoxia, aspiration of gastric contents, and cardiac arrest. [10–12]

The increased risk of aspiration, and the higher incidence of oro-pharyngeal fluids such as blood and emesis during emergent airway management led to the advent of the Suction-Assisted Laryngoscopy Airway Decontamination (SALAD) technique, whose principles involve utilizing a rigid suction catheter to evacuate airway contaminants during basic and advanced airway management.[13] The SALAD technique offers a method to maintain continuous hypopharyngeal decontamination during laryngoscopy with a technique described as the "SALAD Park" maneuver, in which the rigid suction catheter tip is placed at the upper esophagus and repositioned to the left of the laryngoscope blade, thus allowing for continuous airway suctioning without impeding the visualization of the glottic opening.

Apneic oxygenation has been shown to be beneficial in patients at risk of rapid desaturation or those with a difficult airway and can be implemented via the use of humidified high-flow nasal oxygenation systems,[14–18] or standard nasal cannulae.[19,20] However, there is a growing concern that continuous airway suctioning during emergent airway management might have a detrimental impact on preoxygenation or apneic oxygenation due to the evacuation of the supplemental oxygen provided to the patient. While the benefit of apneic oxygenation is well documented in the literature and has become increasingly adopted as a technique in the past decade,[21–24] the impact of continuous oropharyngeal suctioning during emergency airway management on airway oxygen levels remains unknown.

The present study aims to define the degree to which a large bore rigid suction catheter connected to five separate suction sources will evacuate supplemental oxygen from the hypopharynx of a task trainer mannequin undergoing apneic oxygenation as described by the

NODESAT (no desaturation) technique.[19] Additionally, we evaluated a novel suction system that utilizes a self-priming fluid pump mechanism that allows for airway suction only in the presence of a contaminant, with the underlying hypothesis that intermittent suction might reduce the degree to which supplemental oxygen is removed from the hypopharynx during the SALAD Park maneuver.

Methods

Experimental Set-Up

A 7-Sigma Modular Partial Airway Trainer (7-SIGMA Simulation Systems, Minneapolis MN) was instrumented with an SSCOR DuCanto large bore rigid suction catheter (SSCOR Inc., Sun Valley, CA) under video laryngoscopy to position its tip immediately proximal the larynx of the mannequin and secured in place with a Thomas endotracheal tube holder (Laerdal, Stavinger Norway) throughout the tests. A 3-meter gas sampling line (Smiths Medical, Minneapolis, MN) was threaded through the mannequin from the distal trachea into a position immediately beneath the vocal cords. A Carescape B450 Monitor (GE Medical, Helsinki, Finland) with a gas analyzer module was connected to the gas sampling line and the data was recorded with a Sony A640 video camera (Sony Group Corporation, Minato, Tokyo) alongside a simple timing device to collect the data in real-time from the gas analyzer (**Figure 1**). Apneic oxygenation was provided via an Airlife Nasal Oxygen Cannula (Vyaire Medical, Mettawa, IL) and connected to a Precision Medical Dial Flowmeter (Precision Medical, Northhampton, PA) connected to the central hospital oxygen supply. At the start of each test, the oxygen flowmeter was set to 15 liters per minute and allowed to reach a steady state on the gas analyzer over 2 minutes.

Measurement of the airflow for each suction unit

      Five portable suction units which represent widely available commercial devices in the United States were utilized in this study. We tested each suction unit for their maximum gas flow rates generated by their vacuum pumps through a TSI 5400 series flow meter (TSI, Minneapolis MN) and was measured in liters per minute (LPM). The suction units evaluated were the SSCOR Duet Suction unit (SSCOR, Inc., Sun Valley, CA), the Laerdal LSU Suction unit, and the Laerdal LCSU 4 Laerdal Compact Suction unit (Laerdal, Stvinger, Norway). In addition to these units, we tested suction obtained from a hospital's central vacuum system (Aurora Medical Center at Summit, Wisconsin) as well as the prototype of a novel suction unit, the AIRO Suction Unit (CRO Medical, Missoula, Montana).

Impact of the individual suction sources on hypopharyngeal oxygen concentration (HOC):

We measured the oxygen concentration as a fraction of the oxygen present in the airway in the gas mixture (FiO2).[25] Hypopharyngeal oxygen concentrations (HOC) were defined as the FiO2 present at the hypopharyngeal level as measured by the Carescape B450 monitor. Each suction system was tested in the mannequin for a period of 60 seconds after allowing the oxygen concentration to reach a steady state (HOC 97%). All measurements for each suction unit were repeated a total of 7 times. Utilizing the video recorded during each test run, the HOC was recorded every 10 seconds from the beginning of the activation of each suction unit for a total elapsed duration of 60 seconds.

Results

<u>Suction Units Flow Rate</u>

The suction unit with the highest flow was the central hospital vacuum system (38.4 LPM), closely followed by the SSCOR Duet Suction unit (38.3 LPM). The Laerdal LSU Suction unit and the LCSU 4 Laerdal Compact Suction Unit generated a flow of 32 and 23 LPM, respectively). The novel AIRO portable suction device prototype had an airflow of 0.75 LPM. This extremely low flow rate was likely due to the fact that this device utilizes a self-priming fluid pump as its core technology in lieu of a vacuum pump, which is utilized in the other suction units (**Figure 2**).

<u>Hypopharyngeal oxygen concentration variations while utilizing the five suction systems:</u>

In our experimental setup, when no suction system was used, the HOC reached a steady state of 97%. The utilization of the central hospital suction system led to a reduction in HOC from 97% to 42 % at 10 seconds, and to 38% from 20 seconds after activation up to the end of the experiment. The SSCOR Duet suction unit caused a similar change in HOC compared to the central hospital suction system, with a reduction in hypopharyngeal oxygen concentration (HOC) from 97% to 45% at 10 seconds, 40% at 20 seconds, and 38% throughout the remainder of the test (30 seconds to 60 seconds). At 10 seconds, the Laerdal suction units (LSU and LCUS4) reduced the HOC to 51% and 63% at 10 seconds, 59% and 49% at 20 seconds, 58% and 47% at 30 seconds, and to 45% and 46% at 60 seconds, respectively. In contrast, the AIRO unit did not

register a change in the HOC following activation, with the HOC maintained at 97% throughout the experiment. While the rate in the decrease of HOC varied according to the suction system used, all vacuum-based suctioning systems caused a similar decrease in HOC at 60 seconds from activation, ranging from 38% to 46%, compared to when no suction systems were used (97%) (**Figure 3**).

Discussion

In the present study, continuous oropharyngeal suctioning in an experimental setup replicating apneic oxygenation during emergent airway management resulted in a significant reduction in hypopharyngeal oxygen concentration. In contrast with vacuum-based suctioning systems, the use of an experimental self-priming fluid pump was not associated with a reduction in airway oxygen levels.

Preoxygenation during induction and airway management has been integrated into the current standard of care and is associated with prolonged safe apnea time.[26–29] Apneic oxygenation further prolongs the time to desaturation and has been shown to be particularly useful during rapid sequence intubation and for the management of difficult airways. [20–24,30] The increase in patient's oxygen reserves has been shown to reduce the risk of prolonged oxyhemoglobin desaturation, which is associated with complications such as dysrhythmias, hypoxic brain injury, cardiac arrest, and death,[31] and to increase the operator's confidence and performance.[32] However, especially during emergent airway management in the prehospital or emergency department setting, healthcare providers may need to integrate multiple techniques such as preoxygenation and oropharyngeal suctioning to ensure optimal outcomes. Namely,

during the management of a severely contaminated airway, prolonged suction of the hypopharynx may become necessary due to the accumulation of airway contaminants (e.g., blood, emesis) which can defeat direct or video laryngoscopy and increase the risk of complications such as aspiration.[33–35] Nonetheless, continuous hypopharyngeal suctioning during airway management can result in a significant loss of airway gas volume which may exceed the delivery capacity of the nasal cannula, thus decreasing the oxygen delivered to a patient. To address this issue, possible strategies include increasing the delivery of oxygen, performing intermittent suctioning, or reducing the time to intubation. In this framework, the use of high-flow nasal oxygenation at 50 or 60 liters per minute could potentially overcome the volume depletion caused by the oropharyngeal suctioning. [36–38] Additionally, intermittent suctioning could yield a lower loss of oxygen in the airway and could be implemented via the clamping and unclamping of the suction line according to the presence of airway contaminants. Lastly, an expeditious intubation could limit the need for prolonged and continuous suctioning, thus limiting the loss of oxygen in the patients' airways. However, all of these approaches require either equipment, additional personnel, or conditions that may not be easily found in the emergent setting, especially in the prehospital environment.

The result of this study demonstrates that the use of a continuous suction technique (the SALAD Park maneuver) during supplemental oxygen administration may reduce the effectiveness of passive oxygenation utilizing a nasal cannula set to 15 liters per minute, as is common and current practice. Depletion of supplemental oxygen in the hypopharynx occurs due to the entrainment of ambient air into the hypopharynx through the mouth and nose due to the flow of the vacuum pump, which, in our experimental setup, exceeded the supplemental oxygen

supply rate. The degree to which oxygen concentration depletion occurred with each suction system tested was directly related to the gas flow generated by each individual suctioning system. The SSCOR Duet suction unit depleted the HOC at a rate similar to the hospital central vacuum system, whereas the Laerdal suction units depleted the HOC at a slower rate, attributable to their lower gas flow than the SSCOR Duet unit and the hospital central suction system. The AIRO unit demonstrated a negligible level of hypopharyngeal oxygen depletion in our tests, which is attributable to its novel mechanism, a self-priming fluid pump—which moved a negligible amount of gas when tested prior to the experiment in the instrumented mannequin. While future clinical trials are needed to assess the variation in HOC during RSI and the role of different suction devices, this study shows that the use of the SALAD Park maneuver might affect the efficacy of apneic oxygenation during emergent airway management.

To the best of our knowledge, this descriptive study is the first to investigate the impact of oropharyngeal suctioning and suction device type on airway oxygenation level. However, there are several limitations that must be acknowledged. The study was conducted on a mannequin under ideal and static conditions, without the presence of any airway contaminants. It is likely that in the clinical setting, the impact of suction on oxygen concentrations might vary significantly according to changes in suction cannula positioning, presence and amount of airway contaminants, and anatomical variations. Furthermore, during rapid sequence intubation in urgent or emergent settings, airway oxygenation can be further influenced by the duration of the preoxygenation, the patient's breathing, prior bag-valve-mask ventilation, and factors such as the type and positioning of the nasal cannulae. Lastly, we conducted our analysis using standard nasal cannulae at an oxygen flow rate of 15 liters per minute. However, high-flow nasal cannulae

can deliver up to 60 liters per minute.[37,38] While the set-up we chose may enhance the generalizability of our findings, as the resources needed for apneic oxygenation via standard nasal cannulae and low-flow oxygenation are available in most healthcare settings, future experimental setups using high-flow nasal cannulas are needed.

Conclusion

Hypopharyngeal oxygen concentrations during apneic oxygenation are inversely proportional to the gas flow rate generated by suction units. Consequently, the use of continuous oropharyngeal suctioning during emergent airway management might have a detrimental impact on oxygen concentrations in the patient's airways. The utilization of a self-priming fluid pump was associated with a reduced gas flow rate and a minimal impact on airway oxygen concentration. Future clinical studies investigating the implications of suctioning during definitive airway management are warranted.

References

1. Brown CA, Bair AE, Pallin DJ, Walls RM. Techniques, Success, and Adverse Events of Emergency Department Adult Intubations. *Ann Emerg Med*. 2015;65(4):363-370.e1. doi:10.1016/j.annemergmed.2014.10.036

2. Mort TC. Complications of Emergency Tracheal Intubation: Immediate Airway-related Consequences: Part II. *J Intensive Care Med*. 2007;22(4):208-215. doi:10.1177/0885066607301359

3.   Jarzebowski M, Estime S, Russotto V, Karamchandani K. Challenges and outcomes in airway management outside the operating room. *Curr Opin Anaesthesiol*. 2022;35(2):109-114. doi:10.1097/ACO.0000000000001100

4.   Higgs A, McGrath BA, Goddard C, et al. Guidelines for the management of tracheal intubation in critically ill adults. *Br J Anaesth*. 2018;120(2):323-352. doi:10.1016/j.bja.2017.10.021

5.   Prekker ME, Kwok H, Shin J, Carlbom D, Grabinsky A, Rea TD. The Process of Prehospital Airway Management. *Crit Care Med*. 2014;42(6):1372-1378. doi:10.1097/CCM.0000000000000213

6.   Joshi R, Hypes CD, Greenberg J, et al. Difficult Airway Characteristics Associated with First-Attempt Failure at Intubation Using Video Laryngoscopy in the Intensive Care Unit. *Ann Am Thorac Soc*. 2017;14(3):368-375. doi:10.1513/AnnalsATS.201606-472OC

7.   Burns B, Habig K, Eason H, Ware S. Difficult Intubation Factors in Prehospital Rapid Sequence Intubation by an Australian Helicopter Emergency Medical Service. *Air Med J*. 2016;35(1):28-32. doi:10.1016/j.amj.2015.10.002

8.   Gaither JB, Spaite DW, Stolz U, Ennis J, Mosier J, Sakles JJ. Prevalence of Difficult Airway Predictors in Cases of Failed Prehospital Endotracheal Intubation. *J Emerg Med*. 2014;47(3):294-300. doi:10.1016/j.jemermed.2014.04.021

9.   Mihara R, Komasawa N, Matsunami S, Minami T. Comparison of Direct and Indirect Laryngoscopes in Vomitus and Hematemesis Settings: A Randomized Simulation Trial. *Biomed Res Int*. 2015;2015:1-6. doi:10.1155/2015/806243

10.   Mort TC. Emergency Tracheal Intubation: Complications Associated with Repeated Laryngoscopic Attempts. *Anesth Analg*. Published online August 2004:607-613. doi:10.1213/01.ANE.0000122825.04923.15

11. Bernhard M, Becker TK, Gries A, Knapp J, Wenzel V. The First Shot Is Often the Best Shot. *Anesth Analg*. 2015;121(5):1389-1393. doi:10.1213/ANE.0000000000000891

12. Sakles JC, Chiu S, Mosier J, Walker C, Stolz U. The Importance of First Pass Success When Performing Orotracheal Intubation in the Emergency Department. *Academic Emergency Medicine*. 2013;20(1):71-78. doi:10.1111/acem.12055

13. Root CW, Mitchell OJL, Brown R, et al. Suction Assisted Laryngoscopy and Airway Decontamination (SALAD): A technique for improved emergency airway management. *Resusc Plus*. 2020;1-2:100005. doi:10.1016/j.resplu.2020.100005

14. Hua Z, Liu Z, Li Y, Zhang H, Yang M, Zuo M. Transnasal humidified rapid insufflation ventilatory exchange vs. facemask oxygenation in elderly patients undergoing general anaesthesia: a randomized controlled trial. *Sci Rep*. 2020;10(1):5745. doi:10.1038/s41598-020-62716-2

15. Sjöblom A, Broms J, Hedberg M, et al. Pre-oxygenation using high-flow nasal oxygen vs. tight facemask during rapid sequence induction. *Anaesthesia*. 2021;76(9):1176-1183. doi:10.1111/anae.15426

16. Wong DT, Dallaire A, Singh KP, et al. High-Flow Nasal Oxygen Improves Safe Apnea Time in Morbidly Obese Patients Undergoing General Anesthesia: A Randomized Controlled Trial. *Anesth Analg*. 2019;129(4):1130-1136. doi:10.1213/ANE.0000000000003966

17. Lodenius Å, Piehl J, Östlund A, Ullman J, Jonsson Fagerlund M. Transnasal humidified rapid-insufflation ventilatory exchange (THRIVE) vs. facemask breathing pre-oxygenation for rapid sequence induction in adults: a prospective randomised non-blinded clinical trial. *Anaesthesia*. 2018;73(5):564-571. doi:10.1111/anae.14215

18. Mir F, Patel A, Iqbal R, Cecconi M, Nouraei SAR. A randomised controlled trial comparing transnasal humidified rapid insufflation ventilatory exchange (THRIVE) pre-oxygenation with facemask pre-oxygenation in patients undergoing rapid sequence induction of anaesthesia. *Anaesthesia*. 2017;72(4):439-443. doi:10.1111/anae.13799

19. Weingart SD, Levitan RM. Preoxygenation and Prevention of Desaturation During Emergency Airway Management. *Ann Emerg Med*. 2012;59(3):165-175.e1. doi:10.1016/j.annemergmed.2011.10.002

20. Ramachandran SK, Cosnowski A, Shanks A, Turner CR. Apneic oxygenation during prolonged laryngoscopy in obese patients: a randomized, controlled trial of nasal oxygen administration. *J Clin Anesth*. 2010;22(3):164-168. doi:10.1016/j.jclinane.2009.05.006

21. Pavlov I, Medrano S, Weingart S. Apneic oxygenation reduces the incidence of hypoxemia during emergency intubation: A systematic review and meta-analysis. *Am J Emerg Med*. 2017;35(8):1184-1189. doi:10.1016/j.ajem.2017.06.029

22. Oliveira J E Silva L, Cabrera D, Barrionuevo P, et al. Effectiveness of Apneic Oxygenation During Intubation: A Systematic Review and Meta-Analysis. *Ann Emerg Med*. 2017;70(4):483-494.e11. doi:10.1016/j.annemergmed.2017.05.001

23. Sakles JC, Mosier JM, Patanwala AE, Arcaris B, Dicken JM. First Pass Success Without Hypoxemia Is Increased With the Use of Apneic Oxygenation During Rapid Sequence Intubation in the Emergency Department. *Acad Emerg Med*. 2016;23(6):703-710. doi:10.1111/acem.12931

24. Wimalasena Y, Burns B, Reid C, Ware S, Habig K. Apneic oxygenation was associated with decreased desaturation rates during rapid sequence intubation by an Australian helicopter

emergency medicine service. *Ann Emerg Med*. 2015;65(4):371-376. doi:10.1016/j.annemergmed.2014.11.014

25.   Fuentes S, Chowdhury YS. *Fraction of Inspired Oxygen*.; 2023.

26.   Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth*. 2015;115(6):827-848. doi:10.1093/bja/aev371

27.   Difficult Airway Society Extubation Guidelines Group, Popat M, Mitchell V, et al. Difficult Airway Society Guidelines for the management of tracheal extubation. *Anaesthesia*. 2012;67(3):318-340. doi:10.1111/j.1365-2044.2012.07075.x

28.   Baraka A. Routine pre-oxygenation. *Anaesthesia*. 2006;61(6):612-613. doi:10.1111/j.1365-2044.2006.04669.x

29.   American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. *Anesthesiology*. 2003;98(5):1269-1277. doi:10.1097/00000542-200305000-00032

30.   Gleason J, Christian B, Barton E. Nasal Cannula Apneic Oxygenation Prevents Desaturation During Endotracheal Intubation: An Integrative Literature Review. *Western Journal of Emergency Medicine*. 2018;19(2):403-411. doi:10.5811/westjem.2017.12.34699

31.   Mort TC. The incidence and risk factors for cardiac arrest during emergency tracheal intubation: a justification for incorporating the ASA Guidelines in the remote location. *J Clin Anesth*. 2004;16(7):508-516. doi:10.1016/j.jclinane.2004.01.007

32.   Schulz CM, Endsley MR, Kochs EF, Gelb AW, Wagner KJ. Situation awareness in anesthesia: concept and research. *Anesthesiology*. 2013;118(3):729-742. doi:10.1097/ALN.0b013e318280a40f

33.   Tafoya LA, McGee JC, Kaisler S, Gottula AL, Lauria MJ, Braude DA. Management of Acute Upper Gastrointestinal Bleeding in Critical Care Transport. *Air Med J*. 2023;42(2):110-118. doi:10.1016/j.amj.2022.12.006

34.   Choi I, Choi YW, Han SH, Lee JH. Successful Endotracheal Intubation Using Suction-Assisted Laryngoscopy Assisted Decontamination Technique and a Head-Down Tilt Position during Massive Regurgitation. *Soonchunhyang Medical Science*. 2020;26(2):75-79. doi:10.15746/sms.20.019

35.   Frantz E, Sarani N, Pirotte A, Jackson BS. Woman in respiratory distress. *J Am Coll Emerg Physicians Open*. 2021;2(1). doi:10.1002/emp2.12344

36.   Parke RL, Eccleston ML, McGuinness SP. The effects of flow on airway pressure during nasal high-flow oxygen therapy. *Respir Care*. 2011;56(8):1151-1155. doi:10.4187/respcare.01106

37.   Pillai A, Daga V, Lewis J, Mahmoud M, Mushambi M, Bogod D. High-flow humidified nasal oxygenation vs. standard face mask oxygenation. *Anaesthesia*. 2016;71(11):1280-1283. doi:10.1111/anae.13607

38.   Groves N, Tobin A. High flow nasal oxygen generates positive airway pressure in adult volunteers. *Aust Crit Care*. 2007;20(4):126-131. doi:10.1016/j.aucc.2007.08.001

Figure 1: Experimental set-up.

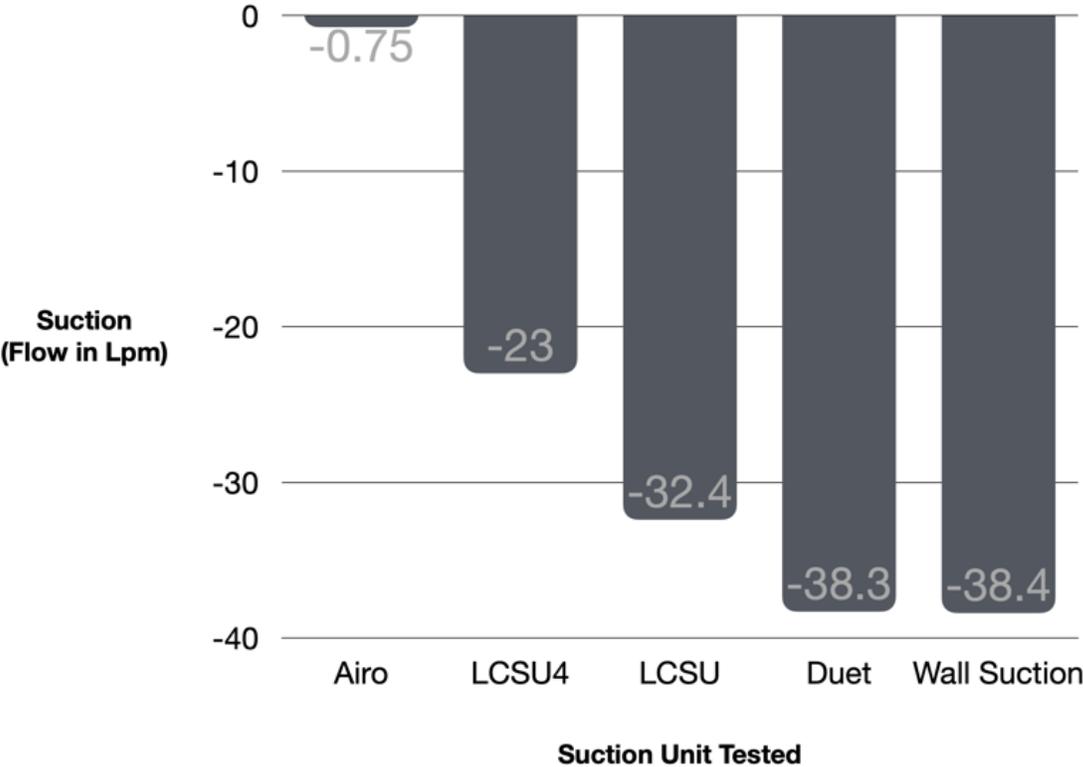**Figure 2**: Maximum Flow Rates of Suction Systems evaluated in study.

Figure 3: Reductions in mannequin hypopharyngeal oxygen concentration (HOC) over 10-second intervals according to suction source.

Methods:
- 15 Lpm of oxygen flowing through a standard Nasal Cannula was applied to a 7-Sigma Airway Manakin.
- A gas analyzer sampled FiO2 on the trachea side of the glottic opening through standard tubing.
- SSCOR DuCanto suction catheter was placed into the superior esophagus of the manakin.
- The suction catheter was held in place with an endotracheal tube securing device.
- FiO2 maxed at 97% while no suction was applied with oxygen through the nasal cannula flowing at a rate of 15 Lpm.
- Each suction unit was tested seven times for 60 seconds per test to evaluate the change in FiO2 at the trachea.
- The mean of those seven tests is noted in the chart above.
- Of note, the Airo is a self-priming fluid transfer pump, which draws significantly lower flows while not aspirating fluid.
- No modifications were made to the experimental model other than the section unit used between tests.

Wall Suction: Hospital Wall Suction
Duet: SSCOR Duet
LSU: Laerdal LSU
LCSU: Laerdal LCSU4
AIRO: AIRO Suction Unit