

Suction mitigation of airborne particulate generated during sinonasal drilling and cautery

Alan D. Workman, MD, MTR^{1,2}, Roy Xiao, MD, MS^{1,2}, Allen Feng, MD^{1,2} , Shekhar K. Gadkaree, MD^{1,2}, Alicia M. Quesnel, MD^{1,2}, Benjamin S. Bleier, MD^{1,2}  and George A. Scangas, MD^{1,2}

Background: Coronavirus disease 2019 (COVID-19) has significantly impacted endonasal surgery, and recent experimentation has demonstrated that sinonasal drilling and cautery have significant propensity for airborne particulate generation immediately adjacent to the surgical field. In the present investigation, we assessed nasopharyngeal suctioning as a mitigation strategy to decrease particulate spread during simulated endonasal surgical activity.

Methods: Airborne particulate generation in the 1- μ m to 10- μ m range was quantified with an optical particle sizer in real-time during cadaveric-simulated anterior and posterior endonasal drilling and cautery conditions. To test suction mitigation, experiments were performed both with and without a rigid suction placed in the contralateral nostril, terminating in the nasopharynx.

Results: Both anterior (medial maxillary wall and nasal septum) and posterior (sphenoid rostrum) drilling produced significant particulate generation in the 1- μ m to 10- μ m range throughout the duration of drilling ($p < 0.001$) without the use of suction, whereas nasopharyngeal suction use eliminated the detection of generated airborne particulate. A

similar effect was seen with nasal cautery, with significant particle generation ($p < 0.001$) that was reduced to undetectable levels with the use of nasopharyngeal suction.

Conclusion: The use of nasopharyngeal suctioning via the contralateral nostril minimizes airborne particulate spread during simulated sinonasal drilling and cautery. In the era of COVID-19, this technique offers an immediately available measure that may increase surgical safety. © 2020 ARS-AAOA, LLC.

Key Words:

nasopharyngeal suctioning; airborne particulate mitigation; endonasal surgery; sinonasal drilling; sinonasal cautery; COVID-19

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In December 2019, coronavirus disease 2019 (COVID-19) developed in patient zero in Wuhan, China.¹⁻³ As the disease spread across the United States, health policy shifted from containment to mitigation.⁴ Although these measures are believed to have limited cases and casualties of

COVID-19, there have been widespread delayed and cancelled surgeries.⁵ As the country begins its reopening phase, hospital systems are working to adapt to balance the medical needs of the patient population, supplies of personal protective equipment (PPE), and available hospital beds for anticipated surges in demand.

Rhinologic procedures are particularly risky given the significant airborne particulate that can be produced from endoscopy, drilling, and cautery.^{6,7} However, continued delays in endoscopic nasal surgery negatively impacts patient care, as delays can worsen outcomes⁸ and increase costs.⁹ Although the risks of airborne particulate exposure can be mitigated through the use of PPE, these risks could be further minimized by directly controlling the source of airborne particulate itself. Thus, it is critical to explore methods that could limit particle generation during sinonasal surgery to not only minimize exposure risks, but also potentially decrease PPE requirements when supply is limited.¹⁰

¹Department of Otolaryngology, Massachusetts Eye and Ear Infirmary, Boston, MA; ²Harvard Medical School, Boston, MA

Correspondence to: George A. Scangas, MD, Division of Rhinology, Department of Otolaryngology, Massachusetts Eye and Ear Infirmary, 243 Charles St, Boston, MA 02215; e-mail: George_Scangas@meei.harvard.edu

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In the present study, we sought to assess nasopharyngeal suctioning as a mitigating approach to minimize, or potentially eliminate, airborne particulate spread during sinonasal surgery. Although it may not be possible to eliminate the production of airborne particulate during airway surgery, nasopharyngeal suctioning can alter airflow within the aerodigestive tract and potentially prevent airborne particles from escaping the surgical field. We hypothesized that airborne particle generation during endoscopic nasal surgery is significantly decreased when performed with simultaneous suctioning of the nasopharynx via the contralateral nostril.

Materials and methods

Study design

Simulation of otolaryngologic surgical drilling and electrocautery was Institutional Review Board (IRB)-approved with a formal excess tissue protocol. Cadaver experiments were performed using 2 fresh-frozen cadaver head specimens thawed to room temperature, and all simulation was performed in a surgical laboratory with an air exchanger operating at a rate of 6 total air changes per hour (726 total square feet), and an ambient room temperature of 21°C to 22°C throughout the duration of experimentation. An optical particle sizer (OPS 3330; TSI Inc, Shoreview, MN) was used to measure particle number, size, and concentration using single-particle counting technology, ranging from 0.3 µm to 10 µm. The OPS 3330 does not address aerodynamic properties, rate of desiccation, or settling rates of the particles analyzed. Flow rate through the OPS 3330 is a constant 1.0 L/min. All particle counts were measured in intervals of 10 seconds and expressed as particle concentration over that duration.

Surgical simulation

The cadaver head was placed in a supine position with the nostril situated 15 cm from the OPS intake port as described for surgical drilling simulation.⁶ A high-definition endoscopic camera was affixed to a 4-mm 0-degree endoscope (Karl Storz, Tuttlingen, Germany). Prior to each simulation event, background sampling was obtained for a period of 1 minute. At least 5 minutes passed between each experiment, and baseline airborne particulate concentrations were reached and measured prior to each new simulation. Suction was used to evacuate any retained intranasal particulates following all drilling and cautery conditions.

Experiments were performed in 10-second samples performed for a total duration of 5 minutes of drilling or 1 minute of cautery. Drilling conditions were either posterior (powered high-speed drilling of the sphenoid rostrum) or anterior (powered high-speed drilling of the anterior septum and medial maxillary wall) using a Midas Rex Legend Stylus (Medtronic, Minneapolis, MN) with a 4-mm cutting burr. Irrigation was not used during any drilling condition. Cautery conditions consisted of the use of battery-

powered endonasal cautery of the anterior septum and inferior turbinate (Acu-Tip; Practicon, Greenville, NC) without a cautery-specific suction. To test the intranasal mitigation capabilities of continuous suctioning of airborne particulate, all drilling and cautery experiments were performed with a 3-mm Killian suction tube placed in the contralateral nostril, terminating in the nasopharynx and providing continuous posterior suction throughout. All drilling and cautery conditions were performed (1) with suction off and (2) with suction on at an air flow rate of 32 L/minute (measured by a variable area flowmeter; Cole-Parmer, Vernon Hills, IL). Each condition was performed in duplicate utilizing 2 separate cadaver heads.

Statistical analysis

Stata version 13 (StataCorp, College Station, TX) software was used for statistical analysis to assess differences between specific pre-replicate baseline background particle concentrations and particles generated during simulated drilling and cautery with or without suction. Nonparametric statistical techniques were used because of small sample sizes, with Bonferroni correction for multiple comparisons. Prism Version 8 (GraphPad Software, La Jolla, CA) was used for visualization of data. All values are reported as means with standard error.

Results

Surgical simulation

Airborne particle generation during drilling conditions with and without suction

With the cadaver head in surgical position, drilling conditions were performed with airborne particulate sampling 15 cm inferolateral to the left nare. Six sampling replicates (10 seconds each) were collected prior to each simulation, with minimal variability in background observed between conditions. Conditions were performed in duplicate with 2 cadaver heads. A suction was placed in the contralateral nostril and positioned in the nasopharynx (Fig. 1). While the suction was turned off, significant particulate generation in the 1-µm to 10-µm range was observed during powered high-speed drilling of both the sphenoid rostrum ($p < 0.001$, $U = 56$, difference between medians = 120.5 particles/L, Fig. 2A) and anterior nasal septum/anterior medial maxillary wall ($p < 0.001$, $U = 26$, difference between medians = 403.6 particles/L, Mann-Whitney U test, Fig. 2B) over a 5-minute drilling period (30 sampling periods of 10 seconds each). Peaks in particulate generation were observed during this 5-minute period, and particle generation was consistently above baseline levels. Conversely, with the suction turned on throughout the drilling period, significant 1-µm to 10-µm airborne particulate generation over baseline concentrations was not observed in either posterior or anterior drilling conditions.

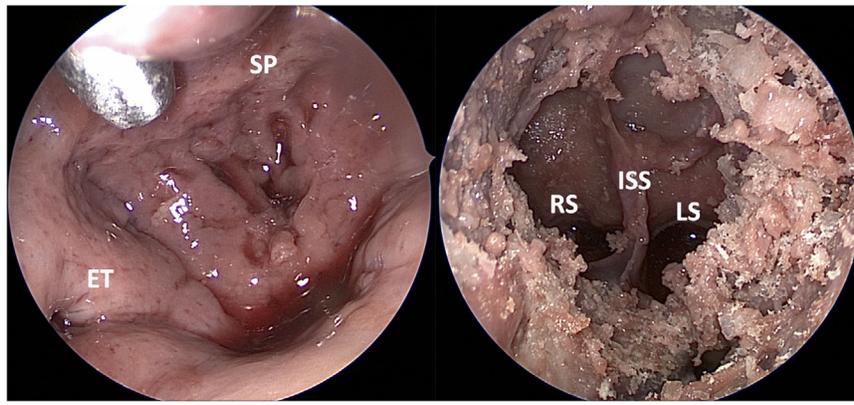


FIGURE 1. (Left) Positioning of suctioning in the nasopharynx, placed through contralateral nostril. (Right) Image of posterior nasal cavity following 5 minutes of drill use. ET = Eustachian tube; ISS = intersinus septum; LS = left sphenoid; RS = right sphenoid; SP = soft palate.

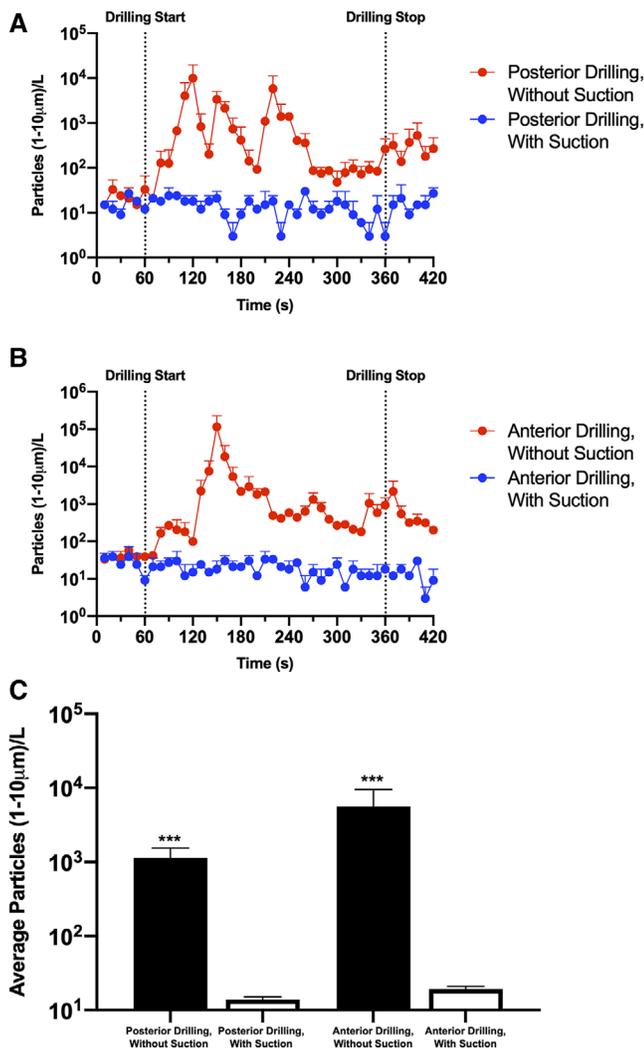


FIGURE 2. Airborne particulate generation (1 to 10 μm) during anterior (A) and posterior drilling (B) with or without suction performed on 2 separate cadaver heads. (C) Significant increases in airborne particulate over background are observed in the conditions without suction ($p < 0.001$, Mann-Whitney U test, Bonferroni correction for multiple comparisons).

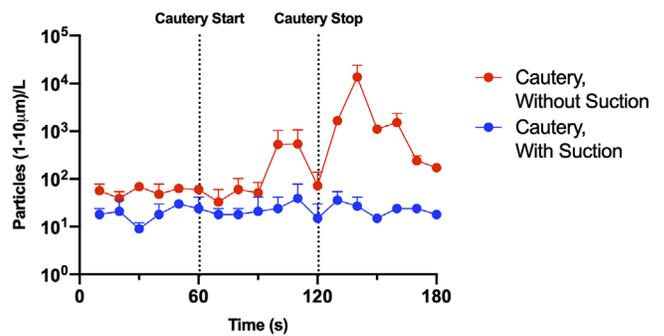


FIGURE 3. Airborne particulate generation (1 to 10 μm) during anterior nasal cautery with or without suction performed on 2 separate cadaver heads. Significant increases in airborne particulate over background are observed without suction in the minute following cautery ($p < 0.001$, Mann-Whitney U test).

Airborne particle generation during cautery with and without suction

Cautery conditions were performed with the cadaver head in standard surgical position with airborne particulate sampling again 15 cm inferolateral to the left nare. Six sampling replicates (10 seconds each) were collected prior to each simulation, and again immediately following completion of cautery. Conditions were performed in duplicate with 2 cadaver heads. With suction off, significant airborne particulate generation in the 1-μm to 10-μm range was observed in the 60-second period following cautery ($p < 0.001$, $U = 0$, difference between medians = 120.5 particles/L, Fig. 3), compared to matched-condition background levels. With suction on, particulate generation in this range did not significantly differ from matched background levels during or following cautery. Particle size generated across the 1-μm to 10-μm range for all non-suction conditions is depicted in Figure 4; cautery shows a skew toward smaller particulates generated, consistent with prior reports.⁶

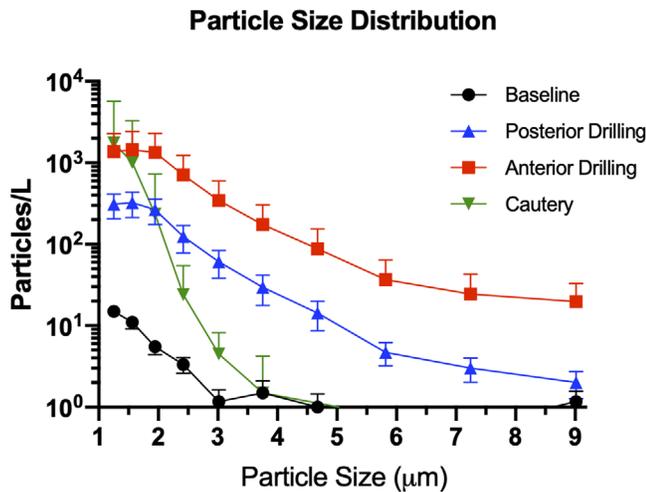


FIGURE 4. Particles per liter separated by size (1 to 10 µm) at baseline (averaged across all trials), during anterior and posterior drilling without suction, and immediately following anterior nasal cautery.

Discussion

In the absence of substantial clinical evidence during the COVID-19 pandemic, otolaryngologists have struggled to balance providing care to patients in need against the risk of exposure to members of the patient care team, especially during procedures prone to particulate generation.⁵ Prior research has demonstrated that aerosol-generating procedures can produce particles <10 µm in size.¹¹ Moreover, our group has recently reported data that common otolaryngologic procedures generate significant airborne particulate adjacent to the surgical activity.^{6,7,12} As otolaryngologists prepare to resume clinical operations and procedures, the present study shows a mitigation measure that improves the safety of airway surgery by controlling the source of particulate generation. Specifically, although sinonasal drilling and cautery both produce significant airborne particulate in the operative field, nasopharyngeal suctioning via the contralateral nostril decreases particulate detection in the operative field to the same level of transient background particulate matter. Although we cannot eliminate the production of airborne particulate, our data suggest that nasopharyngeal suctioning can alter airflow within the nasal cavities and potentially confine airborne particles to the aerodigestive tract.

The present findings may serve to guide clinical practice across several scenarios. Most notably, in situations where timely endoscopic surgery is required for COVID-19-positive patients, or even patients with unknown COVID-19 status, such as life-threatening epistaxis, every measure must be taken to minimize risk to the surgeon and all operating room staff. Accordingly, beyond appropriate use of PPE for barrier protection, nasopharyngeal suctioning represents a straightforward and widely available approach to potentially decrease exposure risk through near-complete elimination of airborne particulate adjacent to the nose. Our findings on airborne particulate supplement

those from a recent study suggesting that larger particle (droplet) spread in endonasal drilling could also be potentially mitigated by suction use.¹³ Moreover, the safety of sinonasal surgery in resource-poor regions that either lack sufficient COVID-19 testing capabilities or have limited access to adequate PPE stands to improve with more easily accessible nasopharyngeal suctioning. Additionally, nasopharyngeal suctioning may be especially useful as an adjunct to suctioning attached to the tip of the drill, or in cases with significant anticipated drilling components, in the event that such suctioning becomes occluded.

Although the present data are promising to inform ongoing decisions to maximize safety during sinonasal surgery, and perhaps airway surgery more generally, it is essential to proceed with caution and validate these findings in live patients. Rather than prematurely applying these findings to concrete recommendations, these results should instead serve as the first of many studies before establishing new safety procedures. Although not encountered during the conducted experiments, we anticipate numerous potential technical challenges that could be encountered with this intervention. Nasopharyngeal suction tips can be clogged by blood or adjacent tissue of the nasopharynx or soft palate, and in the latter scenario potentially cause pressure ulceration if not recognized by the surgeon. This risk can be mitigated with careful suspension above the nasal floor and use of large bore suction. Moreover, positioning the suction in the nasopharynx allows for direct visualization for the trained endoscopic surgeon. Last, contralateral instrumentation of the nose to allow for nasopharyngeal suctioning can restrict the range of motion for the surgeon, though we anticipate surgeons would adapt with increased experience in this operative arrangement. Alternatively, a flexible suction could be placed intraorally, but this will also pose additional difficulties.

It is important to note that this study specifically measured optical particle size and did not use an aerodynamic particle sizer or alternative instrument to measure the aerodynamic nature of these particles, material makeup, particle volume, shape, density, or rate of settling. Particulate observed in any condition is known to be present only at the distance measured from the source of generation and was measured in real time; by measuring from a single fixed point for brief intervals, there could be undersampling of particulate that is generated. For this reason, our results are best understood from a qualitative, rather than purely quantitative, perspective. Our findings do not capture information on particulate desiccation or morphological changes that may occur over time, or settling rates of these particles. Future studies should investigate the aerodynamic properties of these particles to determine their likelihood of being deposited within the upper respiratory tract. Moreover, it must be emphasized that our experiments were specifically focused on smaller airborne particulate in the 1-µm to 10-µm range, rather than larger particles such as droplets; thus, we cannot make any conclusions on the effect of nasopharyngeal suctioning on droplet

exposure during sinonasal surgery, which continues to be recognized as a significant potential means for severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2) transmission.¹⁴ Accordingly, we believe it remains important to continue comprehensive adherence to the “standard precautions” as defined by the Centers for Disease Control and Prevention (CDC),¹⁵ including judicious use of barrier PPE.

The present study includes several limitations that warrant discussion. These experiments were performed in cadaveric specimens and thus these results may not be generalizable to human surgery. Increased bleeding and physiologic mucus secretion may alter the propensity for airborne particulate production that exceeds the capabilities for evacuation via nasopharyngeal suctioning. Irrigation was also not used during the drilling conditions, which could have an effect on particle generation and spread. Additionally, as mentioned in the previous paragraph, it must be emphasized that the methodologies of the present study

were sensitive only to the airborne particles in the 1- μ m to 10- μ m range. Beyond not measuring droplet particles, we are unable to detect the presence of virus within particulate nor its infectious transmissibility. However, as a proof-of-concept method to control airborne particulate generation at the source, we believe our findings should inform future human studies to confirm the utility of nasopharyngeal suction to minimize airborne particulate spread.

Conclusion

Sinonasal drilling and cautery produce significant airborne particulate. The present study shows the efficacy of nasopharyngeal suctioning to minimize airborne particulate spread during simulated sinonasal surgery. These results suggest that beyond donning PPE such as N95 masks, nasopharyngeal suctioning during sinonasal surgery is an immediately available measure that can increase surgical safety. 

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