


Aerosol Generation in Ear Canal and Air-Fluid Interface Suction

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Abstract

Objective. The identification of aerosol-generating procedures (AGPs) is important during the current SARS-CoV-2 pandemic due to aerosol-mediated virus transmission. Aerosol measurement during clinical procedures using particle counting may be confounded by variable natural background aerosol levels or limited by partial volume sampling. The study objective was to quantify any significant aerosol generated from simulated suction clearance procedures.

Study Design. Prospective quantification of aerosol generation during clinical suction simulation.

Setting. Clean chamber.

Methods. We created a clean environment for particle counting in a transparent neutralized polypropylene chamber. Air was passed through a HEPA 14 class filter to maintain a constant chamber inlet pressure. An optical particle counter was connected in line to the chamber exhaust vent to measure all of the vented particles. The chamber background count was 1 particle $\geq 0.3 \mu\text{m}$ per 15 minutes at a flow rate of 1 chamber air change per minute. We used this system to quantify very low aerosol counts generated from suction clearance of a silicone ear canal and at an open air-fluid interface.

Results. No clinically significant aerosol generation was found by particle counting of the whole chamber air volume during simulated suction procedures.

Conclusion. Simulated ear suction clearance and air-fluid interface suction does not generate any significant aerosol. It appears likely that any aerosol potentially generated at the suction tube tip is entrained by incoming air flow. This is the first study to quantify aerosols generated by suction in a controlled environment; further research is required to determine its clinical implications.

Keywords

COVID-19, airborne, aerosolization, aerosol-generating procedure, AGP, ear suction, microsuction, suction

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Aerosol-generating procedures (AGPs) present a risk to health care workers around the world because of the airborne transmission of diseases such as SARS-CoV-2. Otolaryngologists are at particularly high risk of becoming infected, as many in-office procedures are considered to be AGPs.^{1,2} The SARS-CoV-2 virus has a predilection for infecting the mucosa of the upper and lower airways. Multiple viruses have been previously isolated from middle ear fluid.^{3–6} Health care guidance suggests considering otologic procedures, including suction clearance of the ear, as possible AGPs. Donning full personal protective equipment (PPE) has been recommended before undertaking microsuction.^{1,2} Public health guidance regarding the reuse of a room after an AGP varies by country. UK guidance (which has recently changed) currently suggests a recommended delay of 10 to 60 minutes before reusing a clinical room following an AGP depending on the number of air changes per hour and the amount of aerosol likely to be generated by the procedure.^{7,8} This has resulted in a reduction of clinical activity. There are now challenging decisions regarding how to safely allow elective patients back into clinics and operating theatres.

The potential for aerosol generation during ear suction clearance procedures has not been conclusively determined. An evidence-based determination of this potential is required, as this affects the status of ear suction clearance as an AGP with its attendant heightened requirements for PPE and environmental controls. There is existing evidence that suction of the nasal cavity does not generate significant aerosols.⁹ There is also evidence that suction of fluorescein tracer fluid from the cadaveric ear canal does not generate detectable fluorescein staining on a sampling filter.¹⁰

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Aerosol measurement during clinical procedures using particle counting or other techniques may be confounded by a number of factors including variable natural background aerosol levels and limitations from partial volume sampling. An ideal measurement technique would have a zero background particle count and would characterize the physical, chemical, and biological properties and fate of all particles arising from the AGP. This is difficult to achieve in practice, but it is possible to perform an AGP within a clean chamber. Most generated particles can then be counted by venting the chamber air through a particle counter with an adequate sampling flow rate and with an equivalent volume of clean air being admitted in replacement.

The purpose of this study was to quantify any significant aerosol generated from simulated ear suction clearance and suction at an open air-fluid interface in this controlled clean environment.

Methods

We created a clean procedure chamber by positively pressurizing a transparent isopropanol washed/neutralized polypropylene chamber with HEPA-filtered, particle-free air. We connected an optical particle counter to the chamber exhaust vent with 10-mm internal diameter PVC particle transport tubing to count and size all vented particles. A portable, clinical continuous positive airway pressure machine set to deliver air at 400 Pa with a clinical breathing circuit fitted with a terminal HEPA 14 filter was used as a clean air source for the chamber (**Figure 1**).

Particle counting was performed by a Particles Plus 8306 optical counter (6 size channels, ISO calibrated, 0.1 cfm [2.8 L/m] sample flow rate, 0.3- to 25- μm cumulative count range). Chamber background counts were an average of 1 particle per 15 minutes (approximately 30/ m^3 corrected for counter efficiency) equivalent to an ISO 3 class clean room. The use of an isopropanol wash to neutralize the chamber and tubing helped to reduce deposition from electrostatic effects.

A combined positive control and system particle counting performance calibration was performed by generating aerosol for chamber recovery tests (following ISO 14644-3 B 4.3)¹¹ with and without small and large tip suction active in the chamber by injecting air onto the surface/air/fluid junction of an open container of 10% saline. This allowed measurement of chamber aerosol elimination rate constants, equilibration time, system aerosol deposition rate, and calibration of chamber counting efficiency under the different suction/airflow conditions.

We used this system to quantify any aerosol generated during suction clearance of an anatomically realistic silicone ear canal/pinna (**Figure 2**). Each experiment was conducted by introducing a 2-mm internal diameter unfenestrated Zoellner sucker via a port (both with and without an 18G fine-end suction tip attached) with 40-kPa negative suction pressure in 10-second duration episodes with 5 replicates for each of the following:

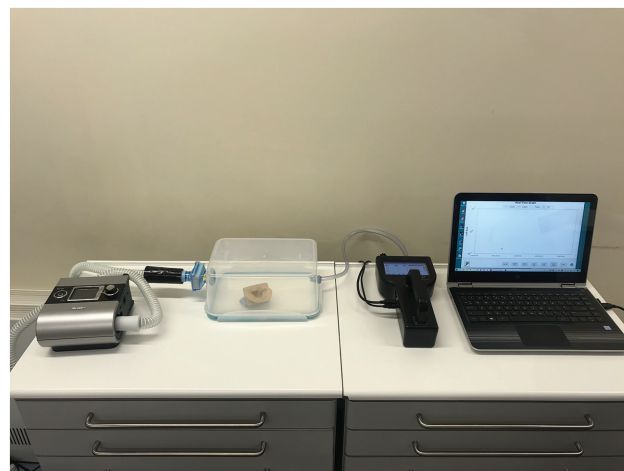


Figure 1. Clean chamber with continuous positive airway pressure machine connected to the left and optical particle counter connected to the right.



Figure 2. Suction performed through a port in the chamber.

1. Dry suction in the triangular fossa (as negative controls)
2. Suction of microbiology culture swab agar gel from the ear canal
3. Suction of 10% saline from the ear canal
4. Suction of 10% saline in an open tray at the air-fluid interface

A delay of 1 minute was allowed after each replicate with the suction machine turned off (which allowed the particle counter to sample 1 chamber volume of vented air). As per the Medical Research Council and Health Research Authority, NHS Research Ethics Committees review was not required for this research.

Results

We detected a total of 8 particles after performing five 10-second replicates of dry suction in the triangular fossa

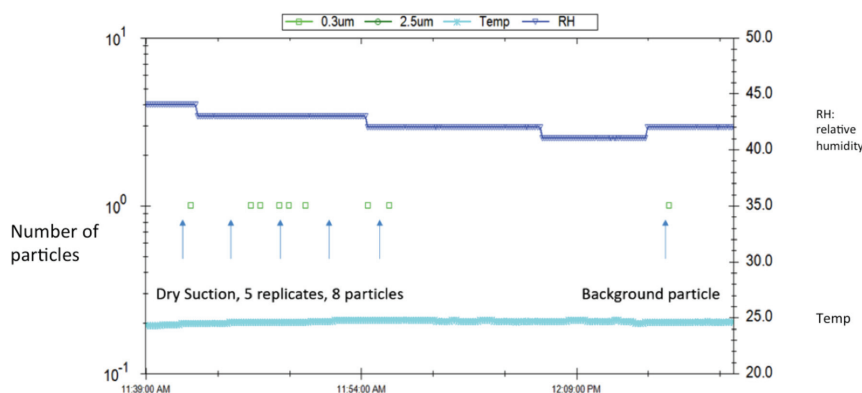


Figure 3. Live chart of particles generated during dry suction in the triangular fossa. RH, relative humidity in %; Temp, temperature in °C.

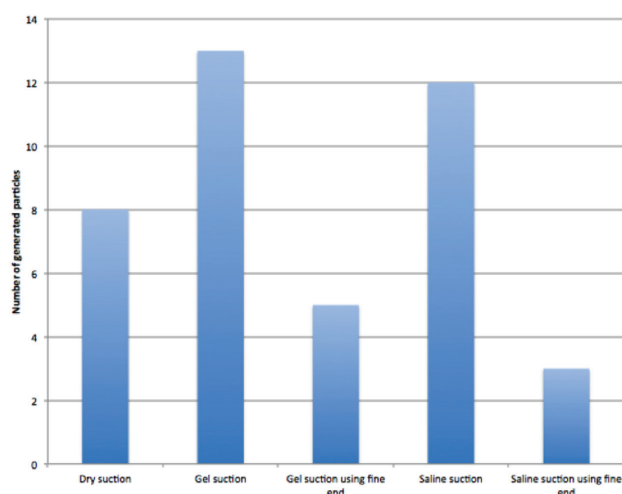


Figure 4. Amount of generated particles with different replicates of suction.

(**Figure 3**) over a 6-minute period. The particles were all in the 0.3- to 0.5- μm size range.

Five 10-second replicates of Zoellner ear canal suction of gel and 10% saline generated 13 and 12 particles, respectively, with 5 and 3 particles for gel and 10% saline, respectively, with the 18G fine suction tip (**Figure 4**). All detected particles were in the 0.3- to 0.5- μm size range, with the exception of 1 particle, which was in the 0.5- to 1- μm size range. Five replicates of 10-second Zoellner suction of saline at the air-fluid interface in an open container did not generate any particles at all.

The positive chamber pressure was designed to prevent external particles from entering the chamber at any of the ports or being released internally from the contact of the sucker with the edge of the port. No particles were detected during repeated manipulation of the suction tube in the chamber access port ruling this out as a source of particles.

The positive control chamber recovery test showed an effective chamber aerosol clearance rate of 3.13 L/min with a particle counter flow of 2.83 L/min giving a count efficiency of 90% (the rest of the particles were deposited in the chamber

or vent system). The measured total aerosol clearance rate was 6.5 L/min with the 18G fine tip suction operating and 13.0 L/min with the Zoellner sucker.

Discussion

The purpose of this study was to quantify the aerosol generated from ear canal suction clearance and suction at an open air-fluid interface. The use of suction simulation in a clean chamber with very low background particle levels between 0.3 and 25 μm enabled us to count the majority of all generated particles. We were able to confirm this by directly measuring and calibrating the counting performance of the chamber. The 0.3- to 25- μm range of sizes has been shown to include almost all coronavirus aerosols.¹² This is the first article to describe a calibrated total particle counting system with an ISO 3 equivalent particle background level.

We found that suction produced negligible and nonclinically significant numbers of particles with particle generation at least 3 orders of magnitude lower than those generated from an equivalent length of breathing and a mass of particles at least 5 orders of magnitude lower than that generated during an equivalent duration of breathing.^{9,13,14}

Most of the aerosol generated from ear canal suction appeared to arise from contact of the side of the sucker with the ear canal rather than the air-fluid interface, based on the production of similar numbers of particles from the dry suction control and lack of particle generation from suction at an open air-fluid interface. This corresponds to the well-known generation of aerosol by surface contact of clothing, footwear, and skin and other surfaces including furniture, walls, and flooring. The primary aerosol can be generated by this mechanism, or previously deposited particles can be resuspended into the air.¹⁵

Our results extend the findings of the previous ear suction simulation performed on a cadaveric temporal bone, in which droplet spread during suctioning of fluorescein-labeled middle ear fluid was measured and visualized with a blue-light filter. There was no fluorescein detected on the sampling filter after suction of the labeled fluid.¹⁰ This study, however, could not characterize the number and size of any generated particles.

Our results are also consistent with a previous study that carried out a simulation of myringotomy and tympanostomy tube insertion again using a cadaveric temporal bone with no spread of fluorescein marker onto a sampling filter during the simulation.¹⁰ This is also consistent with results of a simulation of nasal endoscopic procedures in which endonasal procedures (including nasal suctioning and use of microdebrider with suction tip) produce a low risk of aerosol generation.^{10,13,16,17} These findings were noted to be in marked contrast to speech, coughing, sneezing¹⁴ and the use of diathermy and drills (in the nasal cavity or mastoidectomy),¹⁷ which were significantly aerosol generating.^{10,13,16,17}

The use of a clean chamber method allowed for the detection and total count of very low levels of aerosol greater than 0.3 μm . This technique could, with minor modifications and appropriate safety precautions, allow an awake or anesthetized human subject to be partially enclosed for AGP assessment. We believe that the technique may be useful as part of the ongoing clinical risk assessment of AGPs, either as part of a live or simulated procedure.

Conclusion

Our experimental simulation demonstrated minimal aerosol generation during ear suction, suggesting that aerosols are likely entrained by incoming air flow when performing ear suctioning in clinical settings. These findings may inform clinical practice and future investigation. Our data also suggest that air-fluid interface suction does not generate significant aerosol. Further research is necessary to determine the clinical implications and reproducibility of these findings.

Author Contributions

Mohammed Bahgat, research design, data collection, writing the manuscript; **Leon Lindsey**, research design, data collection, writing the manuscript; **Paul Lindsey**, data collection, writing the manuscript, doing literature review; **Andrew Knight**, data analysis, writing the manuscript.

Disclosures

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