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Aerosol and Droplet Particles Contained by Inexpensive Barrier Tent During Mastoidectomy: A COVID-19 Innovation

ABSTRACT

Objective: To investigate the distribution and aerosolized particle counts generated during mastoidectomy, we utilized low-cost and locally available material and developed a plastic tent creating a barrier between the health care workers (HCW) and patient.

Methods: The barrier tent is a clear plastic bag attached to the microscope lens. The tent is draped and tucked underneath the patient's head and upper torso with surgeon's arms also passed underneath and secured with clamps. We demonstrated the area of greater contamination by spread of droplet particles and bone dust after drilling using fluorescent dye. Particle counts inside and outside the barrier was determined and then comparison with and without the tent after drilling of cadaveric temporal bone were also done.

Results: The area with highest concentration of contamination ("hot zone") was noted opposite the surgeon's hand drill which is dependent on the operator's handedness. Other hot zones noted were opposite the operator and on the operator's side. Particle determination of aerosol size 0.3 and 2.5µm inside the barrier tent were at peak levels after bone drilling procedure. Then a significant drop of particle counts was noted at 2 minutes after drilling was stopped with flattening observed at 8 minutes.

Conclusion: Our experimental results suggest that the improvised barrier tent can be effective in mitigating aerosols generated during mastoid surgery and may serve as an added protection for the operating room team.

Keywords: *SARS-CoV-2; Otologic surgery, Barrier tent, aerosol generating procedure; mastoid; COVID-19*

The recent report of isolated SARS-CoV-2 virus from the mastoid and middle ear by a team of experts from Johns Hopkins School of Medicine has significant implications on otolaryngologic practice including heightened precautions during otologic surgery; viral colonization in these two otologic structures confirmed previous knowledge on the theoretical risk on which management decisions and protocols against SARS-CoV-2 are grounded.[1]

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During otologic surgery, high-speed drilling of bone coupled with continuous irrigation generates aerosols and bone dust increasing exposure risk of the surgical team.[2,3] The high rate of asymptomatic and pre-symptomatic COVID-19 cases warrants precautions which include personal protective equipment (PPE) including eye protection and fit-tested N95 level mask at a minimum.[4] With the critical shortage of PPE, clinicians are compelled to seek alternative solutions to protect themselves. A recent review of best available evidence for COVID-19 practice of ENTs recommends the use of barrier methods to reduce risk of droplet transmission and infection.[5] Mitigation strategies and methods during otologic surgery utilize a Steri-Drape™ [2,3,6] and a second microscope cover that act as a physical barrier for containment of droplets generated by irrigated high-speed drilling of bone.[7] However, due to limited resources and availability of these materials in our setting, we resorted to alternatives found in the local market.

We describe our locally-developed version of protection barrier tent utilizing a low-cost, accessible, and easy to install plastic material which functions both as a physical barrier and a containment system to isolate the surgical field. Our objective is for the barrier to contain the droplet particles and aerosols during otologic surgery.

METHODS

Protection Barrier Tent Assembly

The protection barrier tent used an inexpensive 40 x 60 inch clear plastic bag (PE 002, Sun Ace Polymer Manufacturing Corp, Valenzuela, Metro Manila) which costs only P20 per piece and is available from local plastic suppliers. A 12cm diameter hole was cut at the middle of the base of the plastic bag which served as a port for attachment of the drape to the outer perimeter of the microscope lens secured by a rubber band. The prepared barrier plastic was sterilized using Pure 50 Low Temperature H2O2 Plasma Sterilizer (Zeronitec Co. Ltd, Gyeonggi-do, Korea). During the procedure, the barrier tent was draped over the surgical field and secured by sterile clamps. *(Figure 1)* The surgeon's hands including those of the assistant were inserted underneath the tent through controlled access ports, and these were made airtight by securing the edges of the plastic barrier and the plastic edge around the surgeon's wrists with sterile clamps. Instruments were passed under the barrier to access the surgical field. *(Figure 2)*

Simulated Mastoid Surgery, Particle Dispersion and Clearance

Using an S100 OPMI® pico operating microscope (Carl Zeiss Meditec AG, Jena, Germany) with an objective focal distance of 250 mm, surgical simulation was performed on cadaveric temporal bone specimens, thawed in fluorescent dye. Two surgeons with separate dominant handedness (left and right-handedness) performed the drilling of the mastoid cavity independently. With the specimen in standard otologic position they performed the mastoid cavity drilling using 6 mm cutting burr and a Volvere i7 drill (NSK-Nakanishi, Tochigi, Japan) at 70,000 rpm.

After the surgical procedure, the spread of droplet particles, bone dust and splatter were evaluated using UV light illumination in a darkened room. The fluorescent dye fluoresces bright yellow if illuminated with UV light. This is used to visualize the contamination in four (4) cardinal directions (surgeon side, opposite the surgeon, left side and right side of the surgeon) generated by high-speed drilling.

Two HT-9600 High Sensitivity PM2.5 Detector Particle counters (Dongguan Xintai Instrument Co. Ltd, GuangDong, China) with flow rate of 1.0 liters/minute were used to measure changes in particle number in the 0.3 µm and 2.5 µm size distribution. Particle counts were determined inside and outside the barrier tent prior to high-speed drilling which served as baseline particle count.

Measurement of particle counts after high-speed drilling was performed across three scenarios. The total particle counts for particles sizes 0.3 µm and 2.5 µm were collected after one minute of continuous irrigated high-speed drilling of mastoid bone, then at two-minute intervals until baseline was reached.

For the first scenario, one particle counter was placed inside and another was placed outside the plastic barrier. For the second drill scenario, both particle counters were placed beside each other inside the plastic barrier tent. For the third drill scenario, the plastic barrier tent was removed and drilling was performed with the particle counter in the same position as the first two scenarios.

Data Analysis

Electronic photographs were taken to record the data from the particle counter at specific time of measurement. Data was tabulated in MS Excel 2019 (Microsoft Corporation, Redmond, WA, USA) to generate descriptive statistics.

RESULTS

Protection Barrier Tent Assembly

The protection barrier tent was easy to set up once the temporal bone was positioned on the operating table with the operating microscope. The application and assembly of the tent took less than 5 minutes. There was no difficulty encountered in positioning the tent, in inserting the hands of the surgeon and assist underneath the tent through access ports, or in securing the edges of the plastic barrier around their wrists with clamps. There was also no difficulty encountered in passing instruments under the barrier to access the surgical field.

Fluorescein Distribution

Greater fluorescein concentration was observed during simulated cortical mastoidectomy on the surgeon's non dominant hand which held the suction tip during mastoid drilling. Less fluorescein was noted on the surgeon's dominant hand which was holding the drill handpiece. *(Figure 3A, B)*

Fluorescein was also demonstrated in greater concentration on the internal surface of the barrier tent opposite of the hand holding the mastoid drill. *(Figure 4A, B)* The internal surface of the tent on the same side of the hand holding the drill had minimal fluorescein staining. *(Figure 4C, D)* Minimal fluorescein staining was also found on the internal surface of the barrier tent on the surgeon's side and the side opposite of the surgeon.

Particle Counts

The particle counts for sizes of 0.3 µm and 2.5 µm across time were recorded across three set-ups. *Figure 5* shows the comparison of particle counts inside and outside the barrier tent after a 1-minute drill. The peak particle counts were detected one minute after the drilling procedure. This was followed by a significant drop after 2 minutes in both particle sizes 0.3 µm and 2.5 µm. At the eight-minute mark, particle counts reached baseline and were stable with no significant changes in the succeeding two-minute mark recordings. *Figure 6* shows comparison of particle counts of two counters (PC1 and PC2) inside the barrier tent. Particle counts with barrier tent removed are depicted in *Figure 7*.

DISCUSSION

During this COVID-19 pandemic, there is a general belief that all health care workers in the operating theatre during mastoidectomy are at risk.[8] The landmark findings by Frazier et al.[1] on the presence of SARS-CoV-2 virus in the mastoid and middle ear demonstrated the risk for exposure in the manipulation of these anatomic sites. These findings demonstrate empiric evidence on the need for precautions to mitigate risks for droplet and aerosol viral transmission during otologic surgery where several aerosol-generating steps are needed such as high-speed drilling with irrigation and diathermy.

For this aerosol generating procedure (similar to procedures on the nose, mouth and airway), the appropriate PPE includes an N95 mask, googles, and face shield with strong preference for a powered air-purifying respirator (PAPR). Furthermore, a negative pressure atmosphere is also recommended.[4]

The results of the mastoid surgery simulation emphasized the crucial role of physical barriers in protecting the surgeon and the surgical team. In our simulation, the direction where the drill head is pointing is an important factor in identifying areas of greater contamination during high-speed, irrigated drilling of bone as demonstrated by degree of fluorescein concentration. Our results demonstrate greater fluorescein concentration in the surgeon's non-dominant hand *(Figure 3A, B)* as well as the inner surface of the barrier tent opposite the drill head *(Figure 4A, B)* which were the areas the drill head was directly pointing at. These areas of high contamination corresponds to the "hot zone" (term coined by Matava *et al*.[9]) where most of the particulates are deposited and concentrated during the drilling procedure. By contrast, the least contamination was observed in the surgeon's dominant hand holding the drill *(Figure 3A, B)* and inner surface of the barrier tent on the same side *(Figure 4C, D)* which were away from direction the drill head was pointing. These patterns of distribution are explained by the direction of the rotation of the drill head according to the study by Sharma *et al.*[10] on otologic simulation using cadaver heads. These findings that map out the "hot zones" of droplet contamination show the utility of the barrier tent in minimizing exposure of the surgical team who are in close proximity to the surgeon.

The SARS-CoV-2 particle size identified in hospitalized patients in Wuhan, China varied from about 0.06 to 0.14 µm[11] and studies have shown that most viral particles are carried by infectious aerosols measuring <5 µm, while droplet spread is transmitted by particles >5-10 µm in size.[12] Using high powered instrumentation in mastoidectomy is a highly aerosol generating procedure with the potential to disperse particles smaller than 10µm.[3] We investigated the particle size and counts generated during mastoid bone drilling using a particle counter with detection size 0.3 and 2.5µm. Our findings showed that within the barrier tent, large quantities of particle size 0.3 µm and 2.5 µm were generated after 1 minute of high-speed drilling on cadaveric mastoid bone. A significant decrease in particle counts in both 0.3 µm and 2.5 µm was noted at 2 minutes after drilling was stopped with flattening of the particle counts at 8 minutes. *(Figure 5, 6)* This was also observed in previous studies by Chari *et al.*[3] and Sharma *et al.*[10] on cadaveric simulations. Our results suggest a period of 8 minutes for the aerosolized particles to significantly decrease inside the barrier tent, which serves as the basis for the timing of safe removal of the barrier tent after mastoid drilling.

The comparison of particle counts inside and outside the barrier tent *(Figure 5)* and those with or without the barrier tent *(Figure 7)* demonstrated the efficacy of the barrier strategy in mitigating or trapping aerosols. Particle counts detected outside the barrier tent and without using the barrier tent showed no increase in the number of particles generated during the drilling which may suggest the rapid dispersion of aerosolized particles during high-speed drilling. The study of Rohit *et al.*[13] on the mechanics of respiratory droplet size, dispersion, and displacement explained that the small particles move according to the law of Brownian motion wherein the diffusive forces transport particles in random motion. They showed that smaller particles spread throughout the room faster and remain suspended longer than larger particles.

Our experience demonstrates that the inexpensive locally acquired clear plastic barrier is practical for clinical use and is effective in

Figure 1. Barrier tent assembly: **A.** Barrier tent mounted on operating microscope; **B.** Elastic band used to secure plastic barrier on microscope lens; and **C.** Surgical clamps used to keep plastic barrier in place.

Figure 2. Arm access of surgeon secured with the use of blunt surgical clamps (bold arrows) to maintain an air-tight environment.

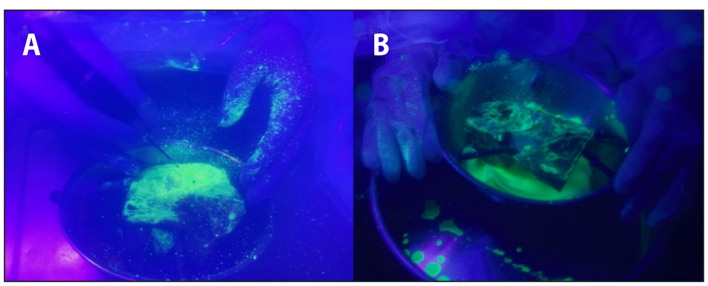

Figure 3. UV fluorescence of surgeons' hands after simulated mastoid surgery: A. right-handed surgeon; B. left-handed surgeon.

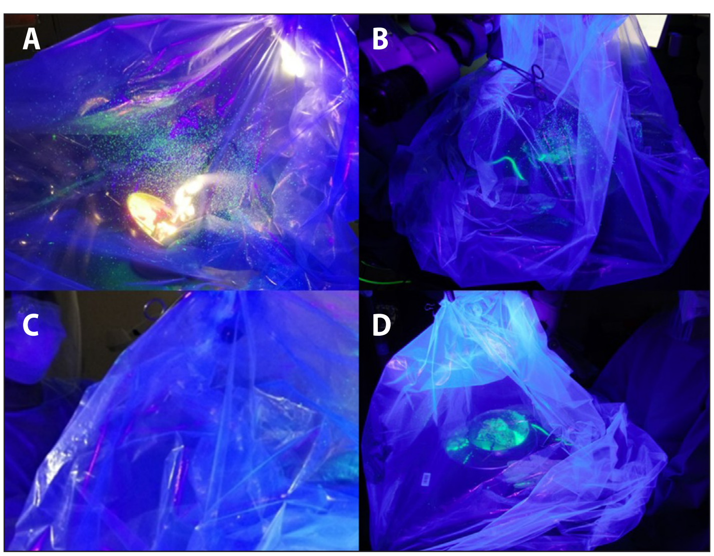

Figure 4. UV fluorescence of barrier tent after simulated mastoid surgery: **A.** and **B.** showing opposite side of the hand holding the high-speed drill; **C.** and **D.** showing the same side of the hand holding the high-speed drill.

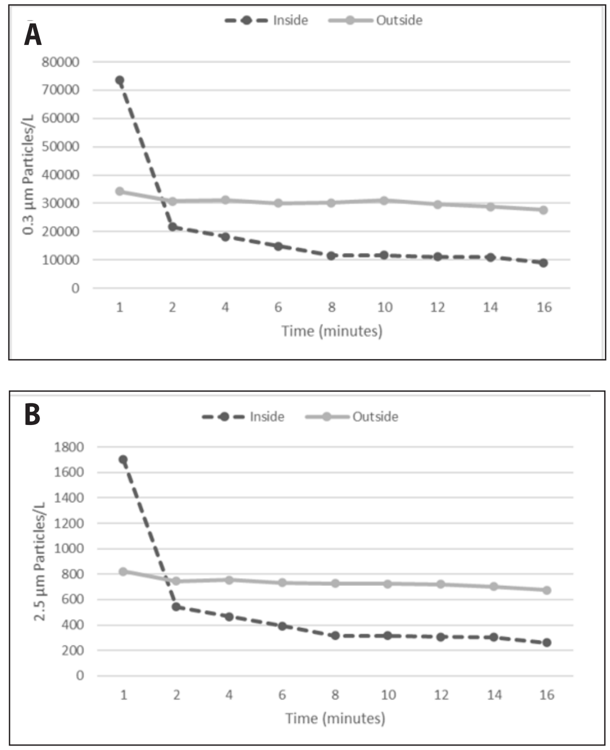

Figure 5. Particle counts inside and outside the plastic barrier tent: **A.** 0.3 µm; and **B.** 2.5 µm.

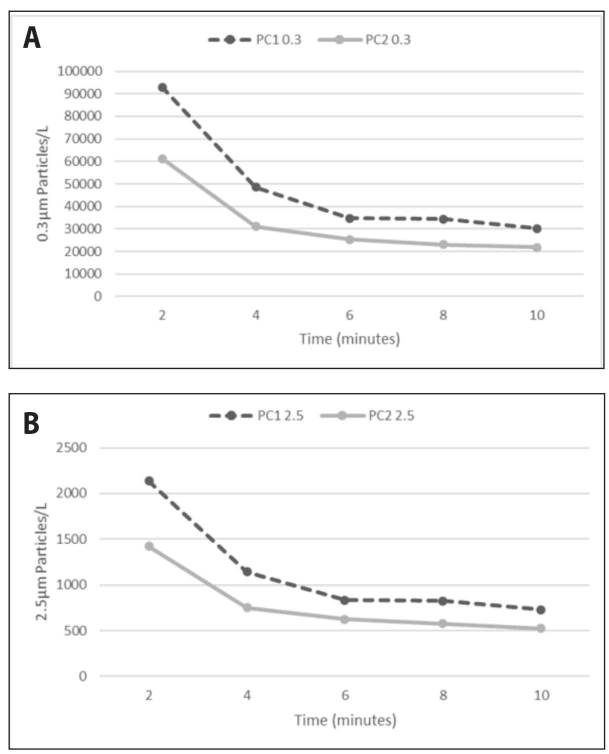

Figure 6. Comparison of two particle counters (PC1 and PC2) inside the barrier tent over 10 minutes: **A.** 0.3µm and **B.** 2.5µm.

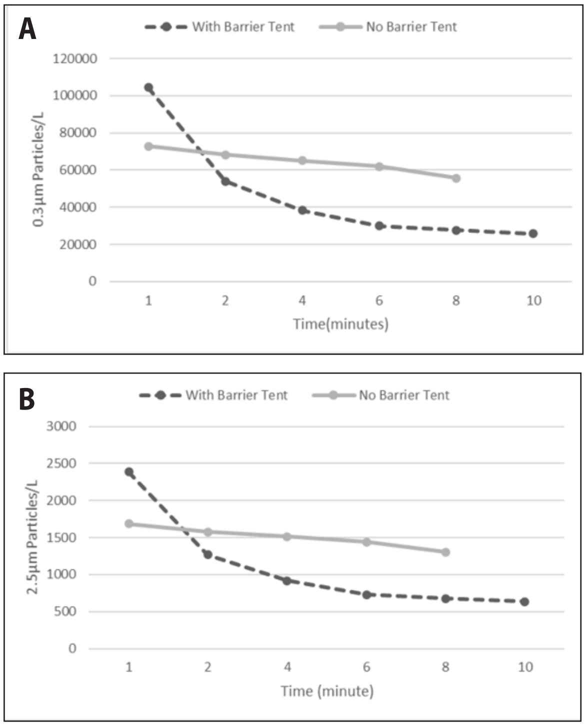

Figure 7. Comparison of particle count with and without barrier tent over 10 minutes: **A.** 0.3µm; and **B.** 2.5µm.

mitigating droplet spread during mastoid bone drilling. This plastic barrier method is akin to that described and used as an aerosol barrier for intubation/extubation which is effective in limiting aerosolization and droplet spray.[8] In our experience, the barrier tent is easy to install on a microscope using clips or clamps, allowing maneuverability of both operator's and assist's hands through the port access without impeding surgery especially during movement and adjustment of the microscope. Our simulation model using fluorescence raises important concerns that the use of minimum PPE alone will not provide adequate protection against bone particle droplets and aerosols generated by drilling. However, our protection barrier plastic bag does not replace adequate PPE use.

There are several limitations of our study. First, we only tested the barrier tent on a mastoidectomy model, and can only infer its use in mastoidectomy and similar otologic procedures. Future studies may model more complicated neurotologic procedures. We also did not formally assess the ease of setting up by nurses, or ease of use by surgeons, and these should be evaluated appropriately from the perspective of end-users. Second, the cortical mastoidectomies performed in this study utilized cadaveric temporal bones which are incomparable to live patients; future studies involving actual patients may confirm our initial findings. Third, the method of particle count determination in this study is limited to optoelectronic particle size measurement during simulation otologic surgery; we therefore recommend the use of aerosol spectrometers (aerodynamic measurement or optical aerosol spectrometers) and condensation particle counters for further studies. Our study did not evaluate aerosol dispersion at access ports during passing of instruments, and further studies may consider addressing this. Future innovations can also explore other means to secure the plastic tent to the microscope lens and avoid collapse of the plastic tent that may hamper the surgeon's visual field, and the addition of a high-volume suction system for evacuation of aerosol-generated particles. Meanwhile, extra precautions should be observed in properly removing and discarding the plastic barrier to contain particles that adhere to the internal surface of the barrier tent during the aerosol generating procedure.

In conclusion, our experimental results suggest that the improvised barrier tent can be effective in mitigating aerosol and droplet particles generated during selected mastoid surgeries and may serve as an added protection for the operating room team.

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