Negative Pressure Assisted Microenvironment Surgical Hood: A Novel Cost-Effective Device to Minimize Aerosol Contamination During Neurosurgical Procedures in Times of COVID-19

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■ OBJECTIVE: **Present guidelines on reducing aerosol generation during neurosurgical procedures are futile. The aim of this article was to describe a novel device to contain aerosol within a small localized environment around the operative field—the negative pressure assisted microenvironment surgical hood (NEPA-MESH).**

■ METHODS: **This device can be assembled using easily available materials—steel wires, image intensifier cover, surgical drape, and three-dimensional−printed self-locking copolyester double hoops. Large-bore pipes in continuity with a high-volume suction apparatus create a constant negative pressure microenvironment around the operative field. The CEM DT-9880 particle counter was used to estimate particle concentration inside the NEPA-MESH during various stages of a neurosurgical procedure as well as outside. The NEPA-MESH was tested in different craniotomies and endoscopic procedures.**

■ RESULTS: **Mean particle concentration inside the NEPA-MESH and outside during drilling in various procedures was calculated and compared using unpaired *t* test. Significant reduction in particle concentrations was recorded for particles sized 0.3 μm ($t = 17.55$, $P < 0.0001$), 0.5 μm ($t = 11.39$, $P < 0.0001$), 1 μm ($t = 6.36$, $P = 0.0002$), 2.5 μm ($t = 2.04$, $P = 0.074$), 5.0 μm ($t = 7.026$, $P = 0.0008$), and 10 μm ($t = 4.39$, $P = 0.0023$).**

■ CONCLUSIONS: **As definitive evidence demonstrating the presence of coronavirus disease 2019 (COVID-19) in aerosol particles is awaited, we describe a cost-effective strategy to reduce aerosol contamination. Significant reduction in particle concentrations was seen outside the NEPA-MESH compared with inside it during various stages of neurosurgical procedures.**

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has come as a bolt from the blue affecting the whole world, and no one was prepared to deal with this. Health care professionals are on the front lines of caring for patients with COVID-19 and are being subjected to alarmingly high risk of infection with no effective cure established yet. The current reality is that there is no reliable method of risk stratification of elective or emergency procedures. A large percentage (48.9%) of COVID-19−positive individuals may be asymptomatic, whereas 27.7% of individuals may have false-negative results on testing.[1]

The highest risk of aerosol generation in neurosurgery is during use of high-speed tools, diathermy, and ultrasound aspirators and while operating on the nasopharynx. Concentration of coronavirus in blood and cerebrospinal fluid has been demonstrated, and it has increasingly been detected in various body fluids, including peritoneal fluid and conjunctival fluid.[2] The current guidelines and literature provide nonspecific suggestions to "produce less aerosol" and to "be more careful" and are not helpful to surgeons working at ground zero.

Toward this goal and to minimize the spread of COVID-19 through aerosol-generating maneuvers, we have developed a simple and cost-effective plastic-covered canopy/screen, the negative pressure assisted microenvironment surgical hood (NEPA-MESH), which can be easily constructed using available

Key words
- Aerosol
- COVID-19
- Microenvironment
- Negative pressure
- Neurosurgery

Abbreviations and Acronyms
COVID-19: Coronavirus disease 2019
CSF: Cerebrospinal fluid
NEPA-MESH: Negative pressure assisted microenvironment surgical hood

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Figure 1. Basic requirements for assembling the negative pressure assisted microenvironment surgical hood: image intensifier covers, three-dimensional—printed copolyester double hoop and blue plastic surgical drape for glove access, and molded stainless steel wire.

materials and can be attached to the microscope and thus prevent the spread of aerosol. The NEPA-MESH can used for both cranial and spinal surgeries and can be modified for other specialties as well. We acknowledge the negative-pressure otolaryngology viral isolation drape described for endoscopic skull base and transoral surgeries, which is based on a similar concept and understanding of COVID disease spread.[3]

MATERIALS AND METHODS

Steel wire was fashioned into a cage resembling a pyramid (**Figure 1**). The cage was then draped with 2 opposing clear sterile polyethylene covers normally used for sterile draping of the image intensifier. The narrow upper cover was tied to the microscope objective while the base sat over the operative field using appropriate cuts on the lower cover, forming a skirt. Glove access was through a triple layer of plastic membrane stretched within a self-locking three-dimensional—printed double hoop of copolyester. The membranes were then cut in an opposing trifurcation (resembling a Mercedes-Benz sign). This allowed for free glove access while at the same time largely containing the inner atmosphere (**Figures 1—3**). The design allowed for flexibility in the placement of the glove access rings as well as addition of more access points if required for assistance. High-volume vacuum suction pipes were then placed within the enclosure to clear off the aerosol into the ventilation system (**Figure 2**).

RESULTS

To objectively assess the efficacy of the NEPA-MESH, we used the CEM DT-9880 air particle counter (CEM Instruments, Kolkata, India) during various stages of a neurosurgical procedure, frontotemporoparietal craniotomy and decompression of glioma (**Table 1** and **Figure 4**). The particle matter concentration outside the NEPA-MESH was significantly lower than inside (**Tables 2** and **3**). The highest count of 0.3 μm particle matter inside the NEPA-MESH was seen during drilling (130,414 ppm), followed by much lower counts during use of diathermy (2059 ppm), during suction after drill use (1102 ppm), while raising a subgaleal flap (600 ppm), and after intubation (252 ppm). The particle counter

Figure 2. High-volume wall-mounted suction with large-bore evacuation pipes dispensed to the surgical site.

Figure 3. (**A**) Negative pressure assisted microenvironment surgical hood fit to the objective of a neurosurgical microscope. Notice the triangulated cut made in the blue drape cloth for surgical access. (**B**) High-volume vacuum suction tubing (*arrow*) placed inside operating field and with the drapes to ensure sterility. (**C**) The portal of surgeon's hand entry (*arrow*) made with three-dimensional—printed interlocking rings and plastic membrane surgical drapes to ensure proper sealing and prevent excess air leak. (**D** and **E**) Operating room setup with continuity maintained from wall-mounted high-volume suction to surgical access points.

Table 1. Particulate Matter Concentrations as Recorded by the CEM DT-9880 Air Particle Counter During Frontotemporoparietal Craniotomy

Particle Size (μm)	During Drill Use (Inside NEPA-MESH)	After Drill Suction (Inside NEPA-MESH)	Diathermy (Inside NEPA-MESH)	After Intubation	Outside NEPA-MESH During Drill Use	Near OR Vent/ Air Duct	Along OR Suite Corridor
0.3	130,414	1102	2059	252	754	7811	8758
0.5	61,666	399	630	74	292	2003	3283
1.0	16,385	98	164	7	42	338	625
2.5	6178	19	26	11	9	89	153
5.0	991	11	3	1	1	22	50
10	517	6	3	1	1	13	27

Particulate matter concentrations are reported as parts per million (ppm).
NEPA-MESH, negative pressure assisted microenvironment surgical hood; OR, operating room.

also showed variable concentrations of particles within the corridor of the operative suite (8758 ppm), near the operating room window (2749 ppm), outside the NEPA-MESH while drilling (754 ppm), and near the operating room air duct/vent (7011 ppm). Mean particle concentrations inside the NEPA-MESH and outside during drilling in various procedures was calculated and compared using unpaired t test (Tables 2 and 3). The lowest concentration of 0.3 μm particle matter inside the NEPA-MESH was seen while performing midline suboccipital craniotomy and occipital craniotomy, and the highest concentration of 10 μm particle matter was seen in frontotemporoparietal craniotomy. Significant reductions in particle concentrations were noticed outside the NEPA-MESH for particle sizes 0.3 μm ($t = 17.55$, $P < 0.0001$), 0.5 μm ($t = 11.39$, $P < 0.0001$), 1 μm ($t = 6.36$, $P = 0.0002$), 2.5 μm ($t = 2.04$, $P = 0.074$), 5.0 μm ($t = 7.026$, $P = 0.0008$), and 10 μm ($t = 4.39$, $P = 0.0023$). As scientific evidence for the presence of COVID-19 in aerosol particles is awaited, we have found the use of the NEPA-MESH to be a safe, inexpensive, and noncumbersome method for quantitatively reducing aerosol concentration in and around the operative field.

DISCUSSION

The present guidelines to have negative pressure within operating rooms while preventing contamination of the operating suite are futile in improving the aerosol concentration within the operating room and lead to contamination being sucked in from the outside corridors.[4-6] The NEPA-MESH plastic canopy contains the aerosols that are being generated by high-speed tools. The NEPA-MESH is easy to assemble and allows visual verification for proper installation. The volume and shape of the enclosure always allow for adequate surgical maneuverability without taking away from the routine workflow. The metallic wire rings and self-locking plastic rings can be sterilized with ethylene oxide and reused. The image intensifier cover is an easily available consumable. Additionally, the NEPA-MESH can be used in the absence of a microscope in the initial stages of a neurosurgical procedure, such as when raising the subgaleal flap, making burr holes, and completing a craniotomy. The transparent image intensifier cover makes this feasible. High-volume suction pipes fitted into the drapes keep the atmosphere within the canopy from getting clouded, and visibility through the cover also remains clear. We have attached the NEPA-MESH to the top light while performing several decompressive craniectomies and evacuation of subdural hematomas. The upper ring can be secured to an overhead light source, and lower rings can be secured around the field with metallic clamps.

We have used the NEPA-MESH in various cranial and spine procedures. It does not interfere with patient head positioning or fixation. Raising a subgaleal flap and performing a pterional/frontotemporal or retrosigmoid craniotomy can be carried out with adequate precision without or under microscopic visualization. The image intensifier cover comes with adequate slack for allowing motion of the microscope as per the surgeon's convenience. We have modified the NEPA-MESH structure for use in endoscopic transnasal transsphenoidal procedures for excision of pituitary adenomas (Figure 5) as a single entry port NEPA-MESH. We noted significant reduction in concentration of various sized particles outside the NEPA-MESH. All cases performed underwent standard histopathologic assessment as the patient's neurosurgical disease dictated, but none were proven to be osteomyelitic or primarily tubercular in nature.

Using fiducial-based or electromagnetic neuronavigation was not a problem. The thin metal rings of the canopy do not cause hindrance in registration or navigation during the procedure.

Figure 4. Particle counter recordings as seen on the CEM DT-9880 device monitor during various stages. (**A**) During drill use. (**B**) Outside the canopy during drill use. (**C**) Suction after drill use. (**D**) After intubation. (**E**) Diathermy. (**F**) Operating room suite corridor. (**G**) Air vent/operating room duct.

Owing to the built-in slack of the image intensifier cover, the microscope can be elevated easily without breaking the seal of the NEPA-MESH. The light-emitting diode camera does not create any problems in recognizing the fiducial probes through the plastic cover (Figure 6). In low-risk cases, after performing the initial aerosol-generating craniotomy this shield could be removed to complete the operation. In spinal procedures, we found it extremely useful in minimally invasive spinal decompression/discectomy; however, adapting the same construct for spinal fixation procedures may be challenging.

Table 2. Mean Particle Concentrations Recorded Inside Negative Pressure Assisted Microenvironment Surgical Hood During Drill Use in Different Procedures

	Particle Size (μm)					
Craniotomy	**0.3**	**0.5**	**1.0**	**2.5**	**5.0**	**10**
FTP	130,414	61,666	16,385	6178	991	517
RMSO	114,879	58,630	20,031	2745	961	381
MLSO	96,087	36,908	7432	1732	449	206
Frontal	101,329	63,700	18,407	4509	732	309
Occipital	121,807	59,651	23,352	3881	619	117
Endoscopic TNTS	108,356	54,289	21,009	3763	822	408
Mean concentration	112,145.3	55,807.3	17,769.3	3801.3	762.3	323

Particulate matter concentrations are reported as parts per million (ppm).
FTP, frontotemporoparietal craniotomy; RMSO, retromastoid suboccipital; MLSO, midline suboccipital, frontal craniotomy, occipital craniotomy; TNTS, transnasal transsphenoidal.

A similar concept (negative-pressure otolaryngology viral isolation drape)was described for otolaryngological skull base and transoral surgeries, which was supported by subjective fluorescein-based evidence in a study comprising 4 patients.[3] We found the use of a particle counter to be objective and unbiased and found the application of the NEPA-MESH for a wide array of neurosurgical procedures useful in our setup.

CONCLUSIONS

As the COVID-19 pandemic continues, neurosurgeons need to devise safe, cost-effective, and convenient means for performing operations. Incorporating constant high-volume suction evacuation within the reusable NEPA-MESH can reduce aerosol-related hazard to health care professionals.

Table 3. Mean Particle Concentrations Outside Negative Pressure Assisted Microenvironment Surgical Hood During Drill Use in Various Procedures

	Particle Size (μm)					
Craniotomy	**0.3**	**0.5**	**1.0**	**2.5**	**5.0**	**10**
FTP	754	292	42	9	1	1
RMSO	1713	735	120	55	14	6
MLSO	1010	375	96	15	2	0
Frontal	1500	650	82	12	4	3
Occipital	1943	479	91	11	2	0
Endoscopic TNTS	1437	582	90	23	5	2
Mean	1392.8	518.8	86.8	20.8	4.6	2

Particulate matter concentrations are reported as parts per million (ppm).
FTP, frontotemporoparietal craniotomy; RMSO, retromastoid suboccipital; MLSO, midline suboccipital, frontal craniotomy, occipital craniotomy; TNTS, transnasal transsphenoidal.

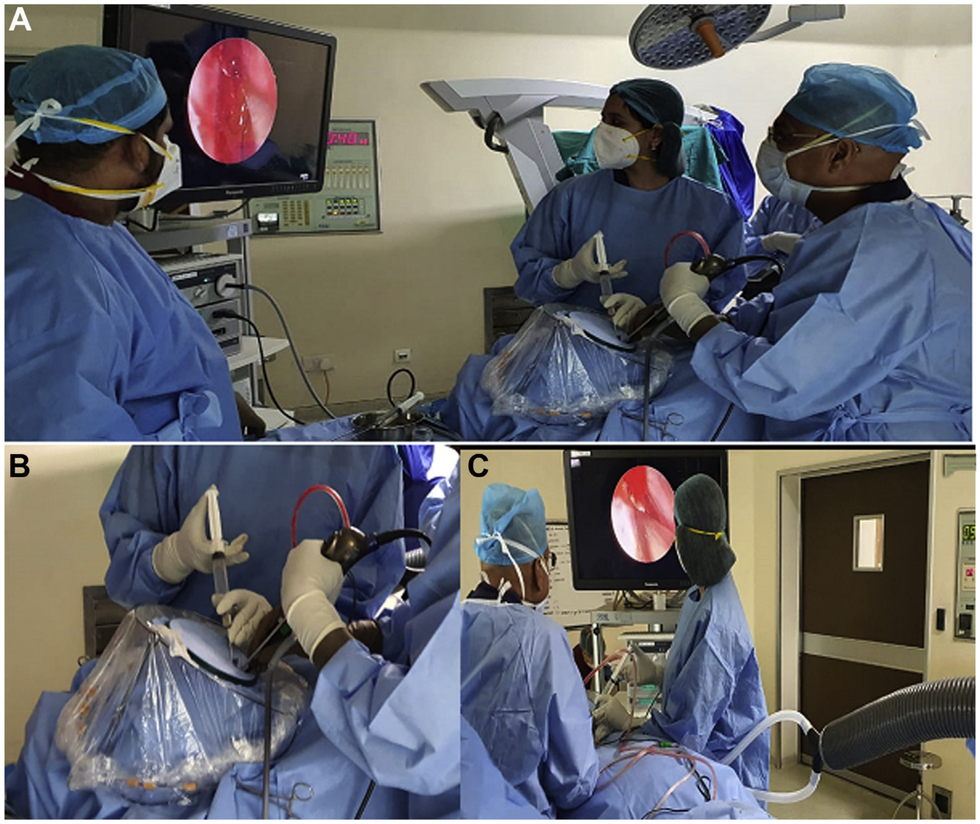

Figure 5. Use of single entry port negative pressure assisted microenvironment surgical hood for endoscopic transnasal transsphenoidal excision of pituitary adenomas. (**A**) Single plastic locking ring used for entry of endoscope, suction cannula, and irrigation cannula. (**B**) Zoom-in view of the metallic rings covered with image intensifier cover and single entry port fitted on one side of the device. (**C**) Large-bore suction pipes fitted into the negative pressure assisted microenvironment surgical hood system to allow aerosol clearance.

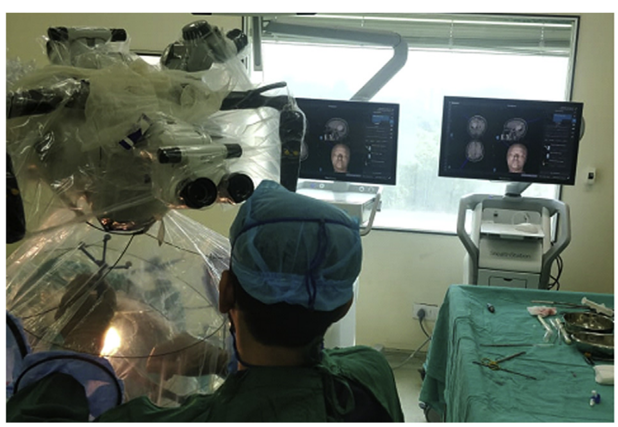

Figure 6. Image depicting use of the navigation wand inside negative pressure assisted microenvironment surgical hood and simultaneous depiction of images in all planes on the navigation monitor screen. The slack of the plastic cover allows the surgeon to lift it slightly and use neuronavigation as and when required.

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