Title
Smoke Evacuator Use with Ultra-Low Particulate Air Filtration in Rhinoplasty and Sinus Surgery

Journal
Facial Plastic Surgery & Aesthetic Medicine, 22(6)

ISSN
2689-3614

Authors
Wong, Brian JF
Hakimi, Amir A
Elghobashi, Said

Publication Date
2020-12-01

DOI
10.1089/fpsam.2020.0434

Facial Plastic Surgery & Aesthetic Medicine
Volume 22, Number 6, 2020

DOI: 10.1089/fpsam.2020.0434

Facial Plastic Surgery & Aesthetic Medicine

VIEWPOINT

Smoke Evacuator Use with Ultra-Low Particulate Air Filtration in Rhinoplasty and Sinus Surgery

Brian J.F. Wong, MD, PhD,[1–3,*] Amir A. Hakimi, BS,[1] and Said Elghobashi, PhD, DSc[4]

Introduction

Coronavirus disease 2019 (COVID-19) is known to reside within the nasal vault and nasal pharynx. False negative rates in nasal reverse transcriptase polymerase chain reaction studies may be high, ranging from 20% to 100% depending on when in the course of illness a patient is tested.[1] Many operations within the nose include the use of mechanical instruments such as microdebriders and piezoelectric instruments that are known to create droplets, which may, in turn, disperse within the ambient operating room (OR) environment, potentially exposing surgeons to biohazard. For patients with a known positive test for COVID-19, measures such as powered air-purifying respirators (''PAPRs'') and other protective devices are used to protect OR personnel from disease transmission due to droplets.

Droplet sizes vary widely over a broad range of values (10–100 μm), with the larger droplets effectively falling to the ground within ~2 m, which is the basis for social distancing guidelines adopted throughout many regions of the world. Droplet size generated from energy-based devices within the nasal vault is unknown, and this is complicated by mechanical actuation or irrigation. Control of droplet dispersion within the operative field during elective nasal and sinus surgery with or without the use of powered instrumentation remains a challenge and a potential risk to OR personnel, even with the use of proper protective gear. In this study we present a method to minimize the dispersion of these droplets using a standard smoke evacuator (Neptune 3; Stryker, Kalamazoo, MI).

Methods

The Neptune 3 is a widely used waste management system providing suction for surgical procedures, and has largely replaced wall-based suction devices in most medical centers. This device was employed for use in rhinoplasty to draw air through a flexible tube (22 mm inside diameter) at a nominal maximum volumetric flow rate of ~34 ft^3/min (CFM; 0.96 m^3/min). The air is then directed through an ultra-low particulate air (ULPA) filter. ULPA filters are constructed from a fine mesh of borosilicate glass microfibers that arrest particle motion through four principle mechanisms: sieving, interception, inertial impaction, and diffusion.[2] They are designed to trap particles less than ~0.12 μm with 99.9995% efficiency. For comparison, intact COVID-19 viruses have been estimated to be 0.08 to 0.12 μm in size. We position the tubing along the patient's chin, and either have an assistant hold and maneuver the inlet or simply secure it in place with surgical tape, clamps, drapes, *etc.* The Supplementary Video S1 shows the use of the smoke evacuator during a rhinoplasty operation wherein a piezoelectric device (Sonopet; Stryker) is used to contour the bony dorsum.

We have developed a computational fluid dynamics model to study the turbulent flow created by the suction device and that of the entrained air. The numerical method solves the time-averaged Navier–Stokes equations in cylindrical polar coordinates in conjunction with a two-equation turbulence model. This is known as RANS model and was used as a computationally economic means of solving for turbulent flows like that generated by the suction device. Time delay is computed through Stokes equation for the droplet response time, $\tau\ p$, that is, $\tau_p = \frac{\rho_p d^2}{18\mu_f}$, where ρ_p is the droplet density, d is the droplet diameter, and μ_f is the dynamic viscosity of the surrounding fluid.

The suction pipe is an axisymmetric cylinder of 22 mm outer diameter. Thus, we simulated only half the cylinder (radius = 11 mm) as the presented streamlines would be computationally identical. The air velocity at the pipe inlet is 51 m/s and the Reynolds number is 56,670, that is, Reynolds number is $\frac{UD}{v}$, where U is air velocity at pipe inlet, D is pipe diameter, and v is kinematic viscosity of air. The flow in a pipe becomes turbulent if Reynolds

[1]Beckman Laser Institute and Medical Clinic, University of California Irvine, Irvine, California, USA.
[2]Department of Biomedical Engineering, Samueli School of Engineering, University of California Irvine, Irvine, California, USA.
[3]Department of Otolaryngology—Head and Neck Surgery, University of California Irvine Medical Center, Orange, California, USA.
[4]Department of Mechanical and Aerospace Engineering, Samueli School of Engineering, University of California Irvine, Irvine, California, USA.

*Address correspondence to: *Brian J.F. Wong, MD, PhD, Beckman Laser Institute and Medical Clinic, University of California Irvine, 1002 Health Sciences Road East, Irvine, CA 92617, USA,* Email: bjwong@uci.edu

number is >2000. The computational domain is a large (60 × 30 cm) half cylinder whose axis coincides with the centerline of the suction pipe. The computational domain's left, top, and right boundaries above the pipe inlet are all open to the atmosphere.

Results

Figure 1 shows the streamlines of the turbulent air flow entering the suction pipe at the lower right corner of the figure. The streamlines that are not entering the pipe represent the air flow entrained by the suction. The velocity of that entrained air is ∼1% of the velocity of the air entering the suction pipe. Figure 1 also shows the pressure distribution contours superimposed on the streamlines. To get a sense of the capacity of this system to remove air particles from the vicinity around the nose, an air sphere of 20 μm diameter located at point A, 14 cm away from the pipe inlet, will take 0.18 s to reach the inlet. A 20 μm diameter water droplet located at point A will lag the air particle by 1.2 ms. A 100 μm droplet located at point A will lag the air particle by 37 ms. Any droplets within this zone but closer to the pipe will take less time to reach the pipe inlet. Thus, placing the suction inline no more than 15 cm away from the droplet source (nose) will provide extremely robust droplet collection.

Discussion

Smoke evacuator technology and viruses have existed for well >40 years as there was much concern regarding laser ablation of papillomaviruses in the vulva, vaginal vault, and upper airway.[3] Smoke evacuators attempted to control viral nucleic acids dispersion by evacuating and filtering plume.[4] ULPA filtration is key, and the 99.999% filtration efficiency provides a substantial theoretical safeguard above and beyond N95 filters (95%) routinely worn today.[5] ULPA filters though must be replaced regularly. Its cost is relatively modest and no more than that of most common OR consumables when averaged over multiple cases.

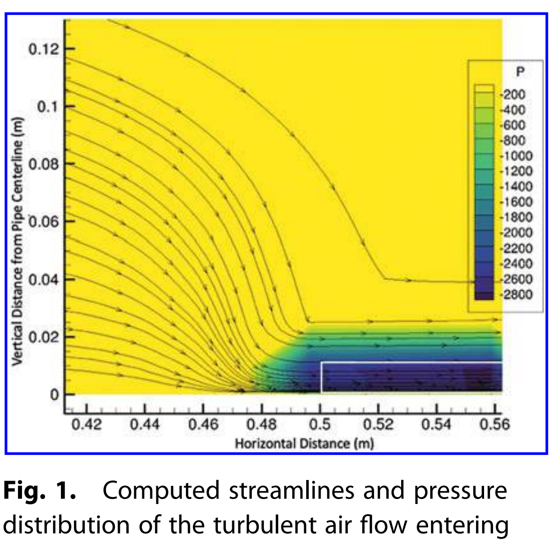

Fig. 1. Computed streamlines and pressure distribution of the turbulent air flow entering the upper half of the suction pipe. Y = 0 represents the centerline of the pipe. Pipe inlet is at 0.5 m. Pa = Pascal, white rectangle = upper half of pipe, *m* = meter.

Although collection of droplets is certainly feasible and efficient using a smoke evacuator with an ULPA filter, to date there are no studies that have demonstrated efficacy of this technology in reducing nosocomial spread of COVID-19. Regardless, we posit there is some logic to consider the use of these devices in surgical cases using energy-based instruments within the nasal vault and sinuses, particularly knowing the physics of airflow and the filtration process.

Our CFD model demonstrates that although the smoke evacuator collects much of the droplets that would be otherwise dispersed in the surgical theater, small droplets that bypass the suction pipe may be dispersed at a relatively higher velocity. Nevertheless, the physical characteristics of such particles are the same in that larger droplets will succumb to the forces of gravity and smaller droplets have the potential to aerosolize. Our proposed system potentially decreases the total number of droplets that may outweigh this potential effect. The use of this system within sinus surgery has the potential to be even more effective as droplets are already contained within the nasal vault. Although many instruments related to sinus surgery have suction capability, they are generally of low flow rates and may actually entrain particles out of the nasal vault.

Acknowledgment

The authors would like to thank Ms. Diane Tweedy of Stryker Corporation for her guidance in study design. Ms. Tweedy was not compensated for her contributions.

Author Disclosure Statement

No competing financial interests exist.

Funding Information

No funding was received for this article.

Supplementary Material

Supplementary Video S1

References

1. Kucirka LM, Lauer SA, Laeyendecker O, et al. Variation in false-negative rate of reverse transcriptase polymerase chain reaction-based SARS-CoV-2 tests by time since exposure. *Ann Intern Med*. 2020;173(4):262–267. Doi:10.7326/M20–M1495.
2. Zhang S, Liu H, Yin X, et al. Tailoring mechanically robust poly(m-phenylene isophthalamide nanofiber/nets for ultrathin high-efficiency air filter). *Sci Rep*. 2017;7:40550.
3. Manson LT, Damrose EJ. Does exposure to laser plume place the surgeon at high risk for acquiring clinical human papillomavirus infection? *Laryngoscope*. 2013;123(6):1319–1320.
4. Schultz L. An analysis of surgical smoke plume components, capture, and evacuation. *AORN J*. 2014;99(2):289–298.
5. Lange JH. The best protection. *CMAJ*. 2003;168(12):1524.