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Can We Innovatively Modify the Surgical Helmets to Protect Against the Droplets and Aerosols of COVID-19?

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Abstract

We tested the filtration efficiency of Stryker T5 surgical helmets with and without the addition of a filter medium. Two particle counters were used to count the particles of sizes .5 μm, 1 μm, and 5 μm, both inside and outside the Stryker T5 helmet, concurrently. The total inward leakage (TIL) for the helmet with and without the filter was zero for 5 μm particles at all time points. The TIL (3.4) for the .5 μm particles decreased significantly after application of the filter (1.7; P = .007). We recommend that an N95 should be used inside the helmet system.

Keywords

orthopedic surgery, surgical education, biomedical engineering

The Need

Some recently published reports have recommended that the surgical helmets are not sufficiently protective during the COVID-19 pandemic.[1-3] Theoretically, a filter medium attached to the top of the helmet may filter out the droplet particles. Hence, we evaluated if modifying the helmets by the addition of a filter medium will improve the filtration of the surgical helmet system to the expected level.

Technical Solution

A 3-layer filter medium (manufacturer Kromega biotech) of 70% proven filtration efficiency (laboratory certified)[4] was affixed over the window of the fan of the helmet (Figure 1A). This was done with the help of an innovatively designed and manufactured fixture that held the filter medium firmly and that sealed the filter medium over and all around the fan grill of the helmet so that the air passes through the filter before entering the grill window of the fan. The firm sealing of the fixture to the helmet was confirmed by the manufacturer before the final version was used in our testing protocol.

Proof of Concept

We tested the Stryker T5 helmet in our operation theater (OT) with a vertical laminar airflow setup (LAS). A 6 N Laskin nozzle generator was used to generate poly-alpha olefin (PAO4) aerosolized particles. The helmet was mounted on a dummy skull and a disposable T5 urethane hood cover was used to cover the helmet. Two thermo-systems incorporated AeroTrak portable particle counters were used to collect the particles (in per cubic meter) synchronously (one from inside and one from outside the helmet) during the test for the .5 μm, 1 μm, and 5 μm sized particles. In order to collect the particles from inside the helmet, a flexible polyvinyl chloride (PVC) tubing was introduced and fixed inside the helmet near the nose of the skull (Figure 1B). This PVC tubing was connected to the particle counter that counted the particles inside the helmet system. Another particle counter was kept 25 cm away from the helmet and it collected the ambient particles from outside the helmet (Figure 1C).

Testing Protocol

The helmet's fan was set at maximum speed and was active for 30 minutes prior to starting the testing protocol.

1. Helmet with no filter (HNF): First, the helmet system was tested without a filter. The particle counters were activated for a total 15 minutes, but they were allowed to reach equilibrium for the first 4 minutes and then the particle counters collected

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Figure 1. (A) Filter medium affixed on top of the Stryker helmet. (B): 2 TSI AeroTrak portable particle counters were used to collect the particles during the experiment; red broken arrow points toward the PVC tube that collected particles from inside the helmet; black solid arrow points toward the particle counter that collected particles from outside the helmet; (C): Stryker T5 helmet with the hood; inset (b) shows the flexible PVC tube affixed near the nose of the skull. Abbreviation: PVC, polyvinyl chloride; TSI, thermo-systems incorporated.

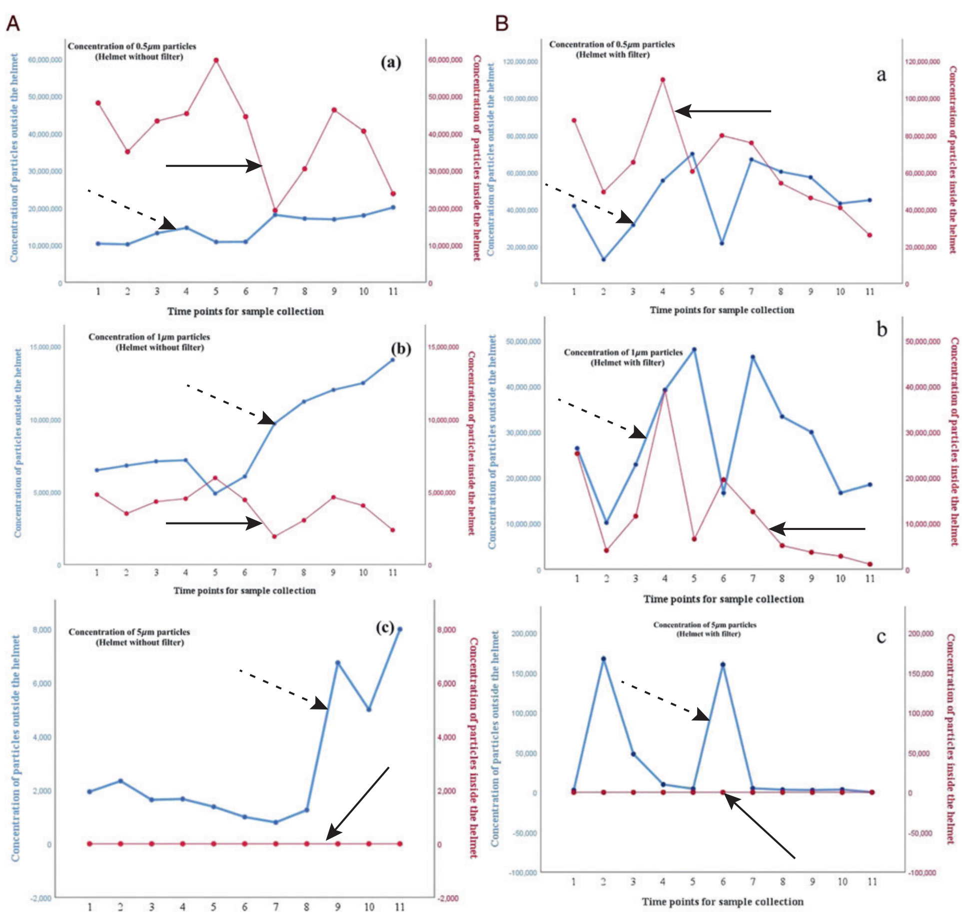

Figure 2. (A) No filter: Graph showing the concentration of particles (in m^3) inside (redline that is indicated by solid arrows) and outside (blueline that is indicated by broken arrows) the helmet (HNF) at 11 successive time points; (a) concentration of .5 μm particles; (b) concentration of 1 μm particles; (c) concentration of 5 μm particles. (B): With filter: Graph showing the concentration of particles (in m^3) inside (red) and outside (blue) the helmet (HWF) at 11 successive time points; (a) concentration of .5 μm particles; (b) concentration of 1 μm particles; (c) concentration of 5 μm particles. Abbreviations: HNF, helmet with no filter; HWF, helmet with filter.

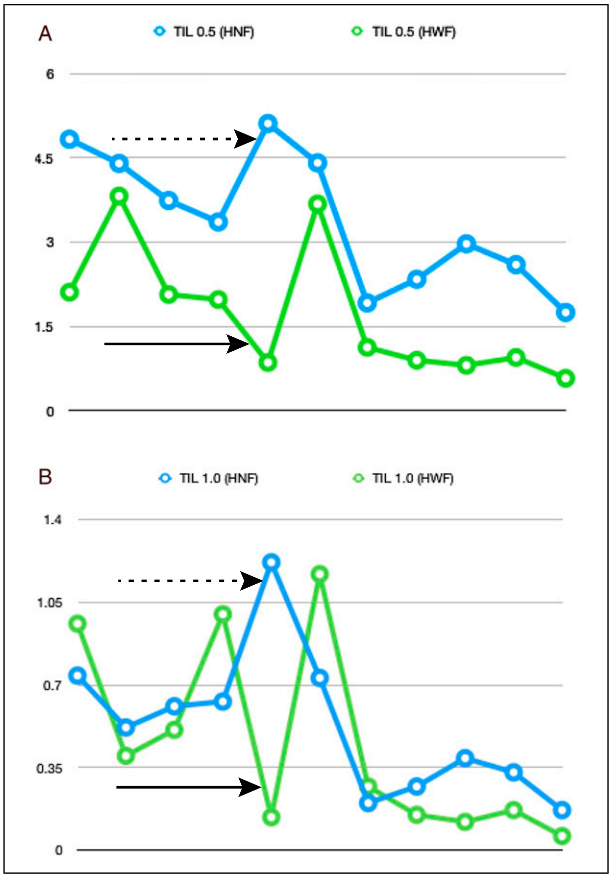

Figure 3. (A) Line graphs showing the calculated total inward leakage (TIL): (blue line indicated by broken arrow) TIL (HNF) for 0.5 μm particles; (green line indicated by solid arrow) TIL (HWF) for 0.5 μm particles. (B): Line graphs showing the calculated total inward leakage (TIL): (blue line indicated by broken arrow) TIL (HNF) for 1 μm particles; (green line indicated by solid arrow) TIL (HWF) for 1 μm particles. Abbreviations: HNF, helmet with no filter; HWF, helmet with filter.

11 continuous samples at successive time points, from both inside and from outside the helmet.

2. Helmet with filter (HWF): The helmet was tested again in the same manner after applying the filter on the helmet as described.

Data Analysis

The total inward leakage (TIL) was recorded as TIL = concentration of particles inside the helmet/concentration of particles outside the helmet. The Mann Whitney U test was used to compare the TIL of the helmet with and without the filter for all the 3 particles sizes.

Results

The TIL (HNF, 3.4) for the .5 μm particles decreased significantly after application of the filter (TIL HWF, 1.7; $P = .007$). However, the TIL (HNF, .44) for 1 μm particles did not change significantly after application of the filter (TIL HWF, .41; $P = .373$). The TIL for both the conditions (HNF and HWF) was 0 for 5 μm particles as the 5 μm particles did not permeate inside the helmet (Figures 2A, B and 3). The concentration of the .5 μm sized particles was significantly higher inside the helmet than outside it for both the conditions (HNF and HWF) (Figures 2A, B and 3). This was denoted by a TIL that was above 1 for .5 μm particles.

Next Steps

Future steps may include testing the helmet with a filter of 95% efficiency to evaluate if the TIL decreases to less than .05% as is recommended during COVID-19.

Conclusion

The T5 helmet system completely filtered out the 5 μm droplet particles even without the use of the filter. Addition of a filter significantly decreased the concentration of .5 μm particles inside the helmet. However, the TIL for the .5 μm particles was more than 1 (more than 100%) even after the filter was applied. Hence, an N95 or a surgical mask should be used inside a helmet system.

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Author Contributions

Dipit Sahu and Vaibhav Bagaria designed and conducted the experiment. Dipit Sahu and Vaibhavi Rathod performed the data evaluation and statistical analysis. All authors approved the final version of the manuscript.
Study concept and design: Dipit Sahu and Vaibhav Bagaria
Acquisition of data: Dipit Sahu and Vaibhav Bagaria
Analysis and interpretation: Dipit Sahu and Vaibhavi Rathod
Study supervision: Dipit Sahu

Declaration of Conflicting Interests

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