Computational Modeling of Operating Room Airflow

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Introduction: Operating room (OR) door openings and increased foot traffic during total joint arthroplasty (TJA) presents a concern for surgical site infection (SSI). Door opening events occur frequently in TJA surgeries with an average of 60 door openings during a primary TJA and 135 openings during a revision TJA. Door opening and obstruction of OR air vents can disrupt optimal OR airflow patterns and allow contaminated air to be deposited on the surgical site. Understanding how airflow patterns change as a result of human action or equipment positioning could potentially improve patient outcomes. Our purpose was to define 1) operating room airflow patterns during various door opening and vent blockage conditions with direct measurements, 2) develop a computational fluid dynamic airflow model based on these measurements to better visualize airflow patterns under various adverse conditions.

Methods: This observational and computational study was performed during off-hours in an empty OR normally utilized for TJA. The heating, ventilation, and air conditioning (HVAC) settings in each room were recorded. Pressure data and air velocity was recorded at 9 different sites in the room: main and inner substerile door, air exhaust vents, OR table, and anesthesia equipment under the following conditions: 1) baseline, 2) main door opening, 3) substerile door opening, and 4) simultaneous door opening. These measurements were repeated in triplicate

while the exhaust vents were open and while they were sequentially blocked with equipment. The experimental data was then fed into a standard renormalization (RNG) κ-ε computational flow model using ANSYS® engineering software to visualize the results.

Results: Door opening rapidly depressurized the OR within 3 seconds of opening to a near zero pressure gradient and this depressurization persisted until the door was closed. Air velocity of the air around the OR table did not appreciably deviate from baseline during door opening events (either main or substerile door) with and without the exhaust vents blocked. The computational model of airflow demonstrated large volumes of stagnant air in the corners of the operating room away from the table and exhaust vents. This stagnant air was mobilized during door opening events. Blockage of the exhaust vents further increased the size of this stagnant air.

Discussion: Door opening events in the OR mobilize large volumes of stagnant and potentially contaminated air. The OR table appears to be protected from this stagnant air but large swathes of the OR could be susceptible to the contamination. This is exacerbated with blockage of the exhaust vents. Sterile equipment, personnel, and instruments outside the area protected by the air inlets are at risk for contamination during door opening events.

Clinical Relevance: Door opening events happen frequently during TJA surgery. Understanding the impact of door opening events on operating room airflow patterns will help better educate operating room staff on equipment placement and arrangement, as well as lead to traffic calming measures to reduce door opening frequency.