SYNOPSIS

KEY POINT SUMMARY

OBJECTIVES

The objective of this research was to study the performance of a ventilation system in an orthopedic OT in real time using different combinations of vertical and horizontal unidirectional airflow with air curtain and sliding door solutions.

Numerical investigation of different airflow schemes in a real operating theatre

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Key Concepts/Context

Efficiency of a ventilation system in providing an effective airflow that contributes to the removal of contaminants (pathogens, anesthetic gases, carbon dioxide, etc.) is crucial to alleviating the risk of surgical site infection, protecting patients and staff from infection, and in ensuring thermal comfort to the occupants in operating theatres (OTs). In this study, the authors examined the performance of six simulated models of ventilation systems. They found that although vertical air curtains, in combination with ceiling air inlets, were more suited to good airflow, efficient ventilation, and contaminant removal, systems with unidirectional horizontal airflow were more effective in maintaining thermal comfort.

Methods

A numerical model that was used and validated in earlier studies by the authors was used for this study. The validated model (referred to as M_real) comprised of a rectangular room having a base area of 43m2 and a volume of 120 m3 and a sliding entry door; equipped with an operating bed, and a lighting system with three arms. There were two rectangular supply diffusers in the central zone of the ceiling and two groups of 14 conical outgoing grilles on two opposite walls to facilitate the outflow of the internal air. The computation of air quality and thermal comfort indexes was conducted for three different zones – breathing zone (BZ), occupied zone (OZ), and peripheral zone (PZ). The six different ventilation schemes examined in this study were:

- Unidirectional vertical airflow; return scheme similar to M_real but with one air curtain and two return grilles at the sliding door: M_1

DESIGN IMPLICATIONS

The authors indicate that there is no 'best' solution for an ideal ventilation strategy. They suggest that an optimal solution may be determined. Designers may also consider the inclusion of vertical air curtains with an air supply diffuser located in the center of the ceiling.

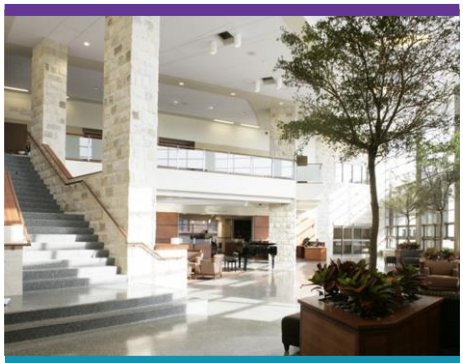
- Unidirectional vertical airflow; return scheme similar to M_real but with two air curtains at the ceiling supply diffuser on two sides of the OT table: M_2
- Unidirectional vertical airflow; one central air supply diffuser, four air return grilles located down and two return grilles located at the sliding door: M_3
- Unidirectional vertical airflow; one central air supply diffuser, four air return grilles located down and four perimetral air curtains located on the ceiling corresponding to the OZ: M_4
- Unidirectional horizontal airflow; one lateral air supply wall diffuser with four air return grilles located at the bottom and top of the opposite wall; one air curtain with two return grilles at sliding door: M_5
- Unidirectional horizontal airflow; one lateral air supply wall diffuser with four air return grilles located at the bottom and top of the opposite wall; without air curtain with two return grilles at sliding door: M_6

A commercial software was used to conduct the simulations and multi-physical analyses using the Finite Element approach. These were computed under real operational conditions of an OT.

Findings

Airflow and temperature distribution:

- The airflow patterns were different in all six strategies. These patterns depended on the location of the air supply and the exhaust grille.
- In the case of M_1 and M_3 models, the air velocity was higher in the zone below the ceiling supply diffuser and at the door with one air curtain. In M_3, the air velocity was more uniform in the BZ and OZ. The air velocity was the lowest in the PZ. The airflow in both cases has a dragging effect because the air curtain at the door disrupts the airflow.
- In M_2 the airflow has a well-pronounced sharp direction (which is attributed to the two symmetrical air diffusers and lateral air curtains). This ventilation strategy displays effective air washing because there are no air curtains at the door to disturb the air velocity.
- The ventilation strategy in the case of M_4 shows a uniform air velocity in all three zones. It also has an air-washing effect that is more effective over the operating table. The M_4 strategy of having the air inlet diffuser in the center of the ceiling and four vertical air curtains created a perimeter that did not break the airflow between the inlet and outlet diffusers and it



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contributed to providing a clean zone in the OT by reducing the concentration of contaminants.

- In the case of M_5 and M_6 models, the horizontal airflow contributed to the creation of a specific air motion field. Air washing was not as effective, particularly for M_5 because of the air curtains at the door.
- The airflow is disrupted when it encounters a solid object like a lamp or a staff member. In the case of M_2, M_4, and M_6 the clean air around the patient is not affected by this disruption in airflow.
- The air temperature distribution is not uniform in the case of M_1 and M_3, even though temperatures comply with the thermal standards at the operating table. The air temperature in the M_2 model also was in compliance with the temperature requirements at the operating table. The air temperature distribution for M_4 was found to be the best, especially in the BZ and OZ. Air temperature distribution is good in the BZ and OZ of M_5 and M_6, but shows less uniformity in the PZ.

Indoor air quality and comfort indices:

- M_2 and M_4 models showed better performance and efficacy in terms of ventilation efficiency (VE) and contaminant removal efficiency (CRE) than the mean air age for the BZ and OZ.
- M_6 and M_5 models had higher mean age air values for the BZ and OZ. M_5 values were the highest.
- M_5 and M_6 provided the best thermal comfort for its occupants.
- Colony-forming unit values were low for M_2 and M_4; M_6 had the lowest values for all zones.

Limitations

Although the authors do not indicate any limitation to their study, it may be noted that this is a simulation study; studies conducted in real life scenarios may yield more robust findings.

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