CFD Modeling for the Ventilation System of a Hospital Room

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Abstract

Indoor ventilation with good air quality control prevents infection with minimizing the spread of airborne respiratory and other infections in hospitals. CFD can be utilized to optimize flow pattern in clean rooms especially hospital clean rooms. More than two million people in Europe are infected due to Health-care Associated Infection (HAI) (Pittet et al., 2005). It is believed that transfer of infection via contact is the main cause for HAI. There are evidence that airborne bacteria may also cause infection (Brachman, 1970). This infection is by inhalation of infectious bacteria and by contamination of surfaces by bacteria (Hathway, 2008). It is useful to understand dynamics of infectious particles due to respiratory diseases such as SARS and TB.

This paper analyses air flow pattern in a one-beded hospital room. It concentrates on respiratory transmission, using a point source at the patient mouth position. Numerical simulation of air flow pattern and bio-aersol transport of clean hospital room is performed with COMSOL Multiphysics® software, version 5.1. Ventilation rate is 6ACH for health care facilities per ASHRAE standard 170.

The hospital room contains a drawer, a bed, a patient, a doctor, a lamp, medical equipment, an inlet and exhaust. Air enters the room from ceiling diffuser shown in figure 1 it has temperature of 20(°C). Air leaves the room through a ceiling mounted grill shown in figure 1. The room is assumed thermally isolated on three sides and its base. Heat exchange between the room and outside occurs through the ceiling and the fourth side of the room. Figures 2 shows temperature distributions and velocity vectors adjacent to the doctor and patient. Average temperature of the room is measured 21 (°C). Due to the natural convection there is upward air movement next to the doctor and patient. There is also a flow of air from patient toward the doctor.We calculated predicted mean vote PMV and predicted percentage of dissatisfied PPD based on ASHRAE Standard 55-2013. Average air temperature and air speed, experienced by patient is 20.8 (°C) and 0.06 (m/s). The Metabolic rate of the patient who is sleeping is considered 1 (met).

We assumed that the patient is wearing trousers and long-sleeve shirt therefore his clothing level is 0.61 (clo). If humidity is 50% then PMV is -1.59 and PPD is 56%. Therefore the probability of patient being dissatisfied with the room temperature is 56%, with sensation of cool.
We have also simulated release of bacteria due to coughing of the patient. Coughing characteristics are obtained from "Flow dynamics and characterization of a cough" by (Gupta et al, 2009). Figure 3 shows release of bacteria; the color legend is based on velocity (m/s).

Figure 4 shows transmission probability of bacteria at the exhaust; none of the bacteria leaves the room in 30 seconds after coughing. After 3 minutes 8% of the bacteria are still remaining in the room.

Reference

1. D. Pittet, et al. "Considerations for a WHO European strategy on healthcare-associated infection, surveillance, and control", The Lancet Infectious Diseases 5(4): 242-250, (2005)

2. A. Hathway, et.al. "CFD modeling of a hospital ward: assessing risk from bacteria produced from respiratory and activity sources", Indoor Air 2008 paper ID: 45

3. J. K. Gupta, "Flow dynamics and characterization of a cough", Indoor Air 2009:19: 517-525

4. Brachman, "Airborne Infection - Airborne or not?", International Conference of Nosocomial Injection, (1970)

Figures used in the abstract

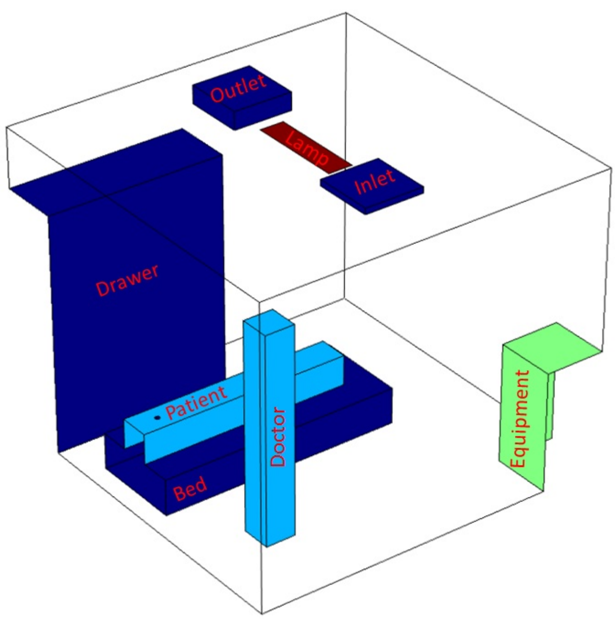

Figure 1: Room layout.

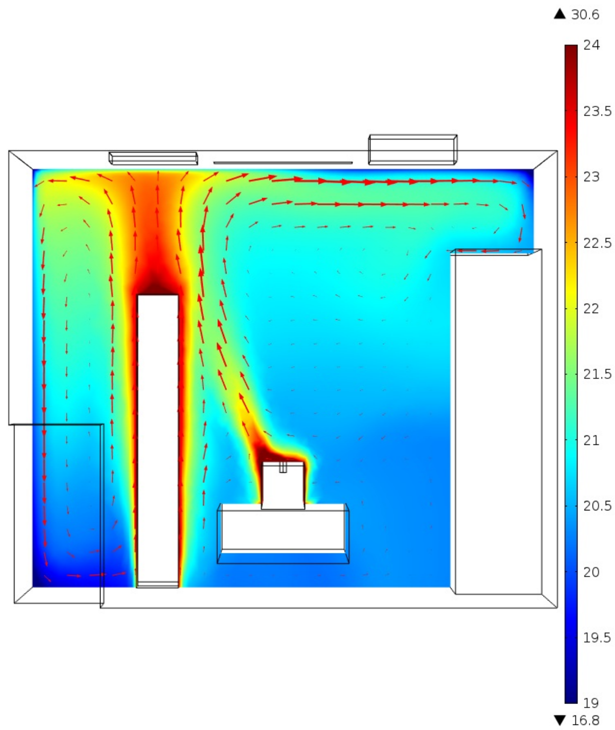

Figure 2: Velocity vector and temperature distribution.

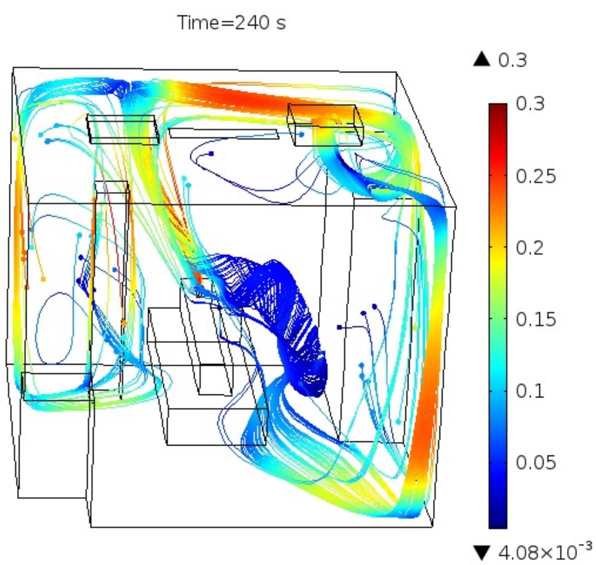

Figure 3: Release of aerosols from patient mouth due to coughing.

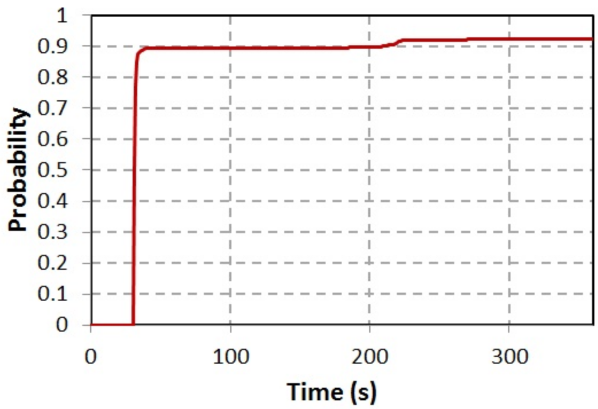

Figure 4: Transmission probability of aerosols.