NUMERICAL ANALYSIS OF CONVENTIONAL VERTICAL AIRFLOW IN A HOSPITAL OPERATING ROOM

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Abstract. This paper presents the airflow analysis in a hospital operating room, in conventional (turbulent) vertical airflow. The simulations results allow optimal design of ventilation and air conditioning systems to satisfy the imposed requirements for air quality control and thermal comfort in a hospital operating room.
Keywords: hospital, operating room, conventional vertical airflow, air ventilation

1. INTRODUCTION

A hospital is a complex environment that requires specific conditions of heating, ventilation and air conditioning systems [1, 2].

An operating room is the most important and complex zone in the hospital and requires more careful control of the aseptic conditions of the environment [3].

The ventilation system of a hospital operating room is to provide a comfortable and healthy environment for the patient and the surgical team [4].

Thermal comfort can be achieved by controlling the temperature, the humidity, and the air movement. A healthy environment can be achieved by minimizing the risk of contamination through appropriate filtration and air distribution scheme [5].

Proper airflow field design and contaminant source placement can be used to control particle transport [6].

In design process, computational fluid dynamics (CFD) simulation allow quick and inexpensive comparisons between operating room designs and provide details about airflow and contaminant transport [7].

2. MATERIALS AND METHODS

A standard 9 m (length) x 4.5 m (width) x 4 m (height) orthopedic operating room, with area of 40.5 m^2 and the volume of 162 m^3 was considered the baseline model for the CFD simulations (Fig. 1).

A typical operation table of standard size (length 2.20 m, 0.90 m in width and height 1.10 m) is located in the middle of the room. In the middle wall access doors with standard dimensions are located, with a double door located on one wall of the large enclosure.

Because in the room is ensured a regime of excess, at the bottom doors of each is placed a grid of size excess GS l00 x 200 mm^2, that permit the excess air out of the room. For this 3D model the air repression is forced through an input-space air distribution (GR) located in the repression area in the ceiling above the operating table (Fig. 1).
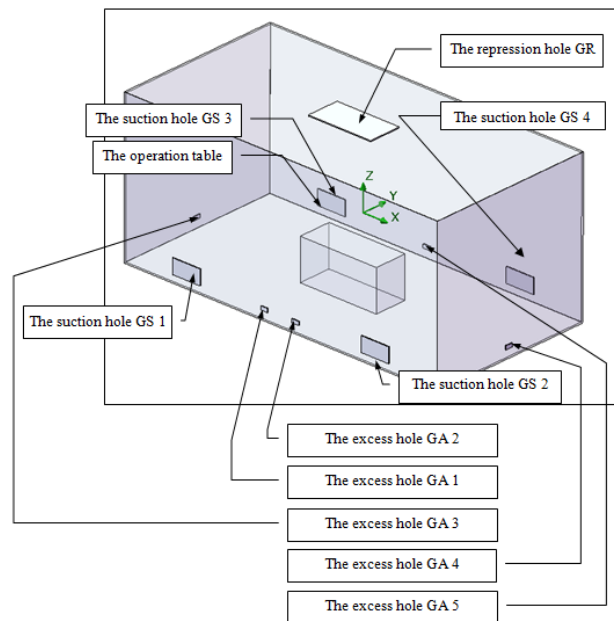

Figure 1. The hospital operating room

The repression hole (GR) is rectangular and has dimensions of 900 x 1800 mm^2. The air entered in the room is Q = 4082.4 m^3/h and the air speed in the representation plane/surface is v = 0.70 m/s.

Venting of the chamber is still constrained, with four suction rectangular holes (GA) located below (at 0.2 m from floor), two on each big wall.

GA holes suction each have size of 400 x 800 mm^2 and each discharge 925 m^3/h, so in total 4000 m^3/h. Average speed of aspiration in each hole is v = 0.8029 m/s. The difference between the amounts of air entered the room and that evacuated is 382.4 m^3/h and will leave the camera, because excess by 5 grids (GS) placed in the bottom of doors.

Because interest only sections and position in which air entering or leaving the cavity, and a hole by pressing (GR) located in the ceiling, 4 holes to suction (GA) have placed on-wall room, the 5 grids (GS) and body inside the enclosure and the operating table, the space it has included only those in the structure. During the operation room access doors are closed, and the representation of their shape is not important for simulation, but only

corresponding slots of GS grids practiced in them. Usual, the operation room incorporates a different number of obstructions such as the operating table, equipment tables, electrical equipment, lights, pendants, staff and patient.

3. INITIAL DATA FOR NUMERICAL ANALYSIS OF CONVENTIONAL VERTICAL AIRFLOW

Initial data for numerical analysis of conventional vertical airflow in a hospital operating room are:
- relative air humidity $\varphi = 50$ %;
- air temperature $T = 22\ ^0C$;
- the impurities diameter $\phi = 0.1\ \mu m$;
- the temperature of the interior wall surfaces room $Tp = 22\ ^0C$;
- the wall rugosity $k = 0.4$ mm;
- air velocity suppress in the room $v = 0.70$ m/s.
Flow of air entered the room, which were simulations (4082.4 m^3/h) provide about 25.2 exchanges per hour.

4. NUMERICAL ANALYSIS OF CONVENTIONAL VERTICAL AIRFLOW

The conventional vertical airflow numerical simulations were made for a closed cavity of the operating room using the Fluent 6.3.26 software [7].
The study was made using a spatial model generated by the Gambit 2.2.30 software for the studied 3D configuration.
In Fig. 2, .. , Fig. 7 are shown the chromatic graph 2D distribution of field velocity, in plane section parallel to the floor room at: 0.15, 0.3, 0.6, 1.0, 3.0 and 3.8 m.
In Fig. 8, .. , Fig. 17 are shown the chromatic graph 2D distribution of field velocity, in plane section parallel to the front of the room at: 0.1; 0.4; 1.0; 1.5; 2.0; 2.25; 2.6; 2.8; 3.2 and 3.9 m.
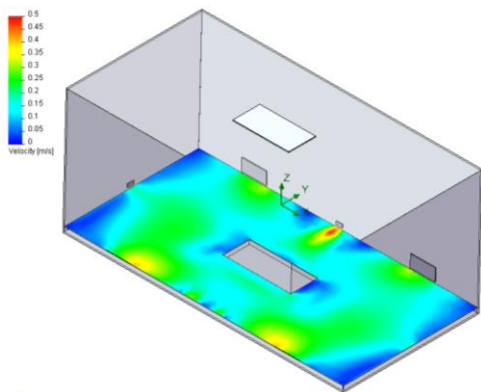

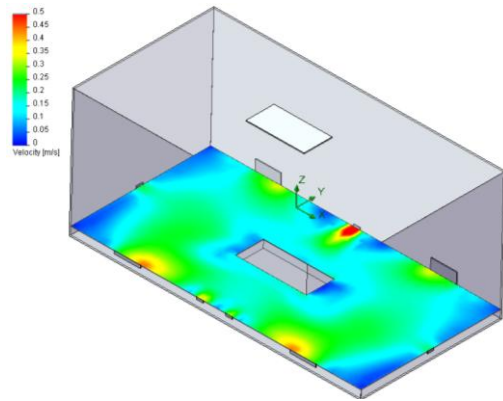**Figure 2. The chromatic 2D distribution of field velocity, in plane section parallel to the floor room at 0.15 m.**

Figure 3. The chromatic 2D distribution of field velocity, in plane section parallel to the floor room at 0.3 m.
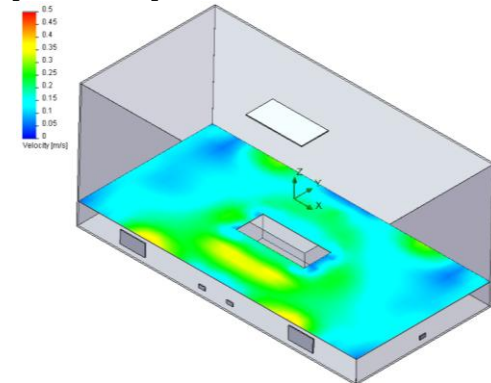

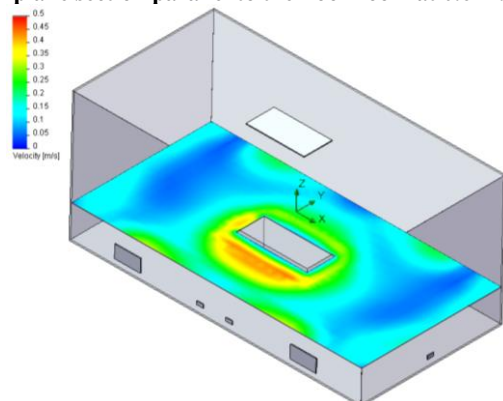**Figure 4. The chromatic 2D distribution of field velocity, in plane section parallel to the floor room at 0.6 m.**

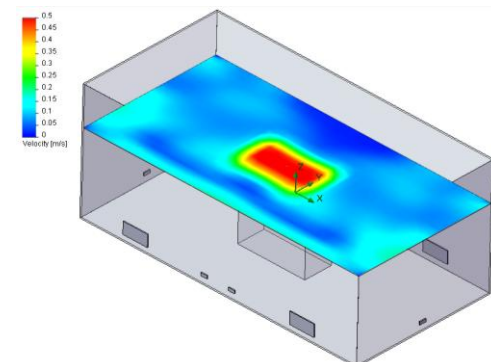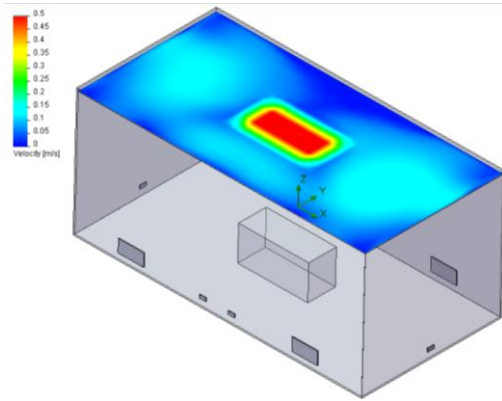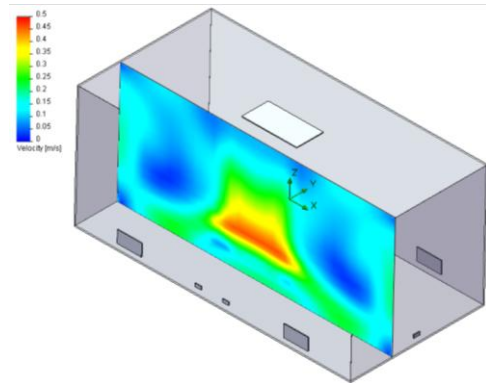**Figure 5. The chromatic 2D distribution of field velocity, in plane section parallel to the floor room at 1.0 m.**

Figure 6. The chromatic 2D distribution of field velocity, in plane section parallel to the floor room at 3.0 m.

Figure 7. The chromatic 2D distribution of field velocity, in plane section parallel to the floor room at 3.8 m.
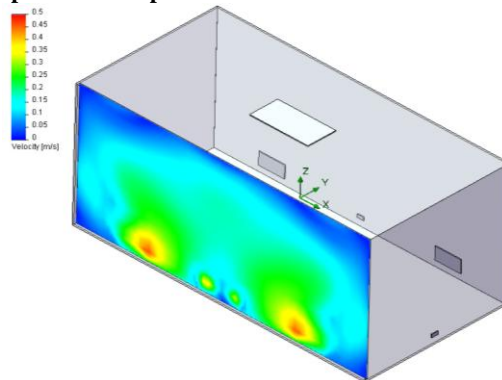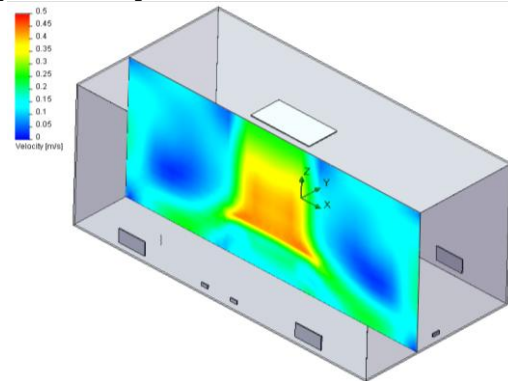

Figure 8. The chromatic 2D distribution of field velocity, in plane section parallel to the front of the room at 0.1 m.
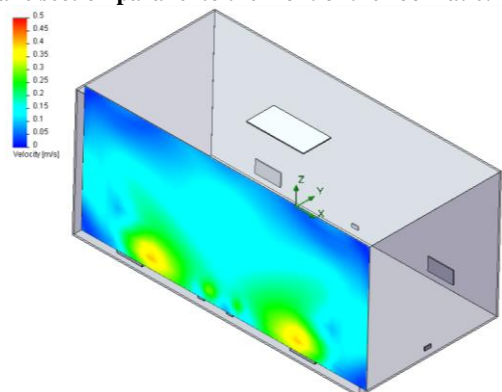

Figure 9. The chromatic 2D distribution of field velocity, in plane section parallel to the front of the room at 0.4 m.

Figure 10. The chromatic 2D distribution of field velocity, in plane section parallel to the front of the room at 1.0 m.
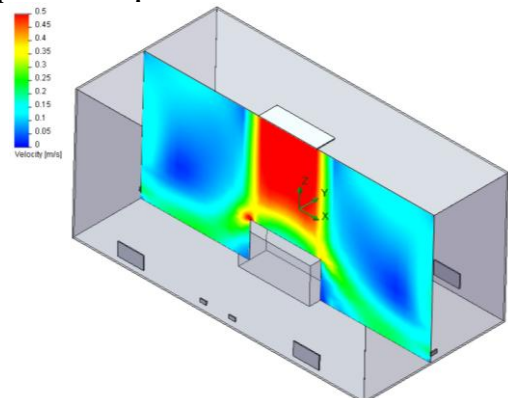

Figure 11. The chromatic 2D distribution of field velocity, in plane section parallel to the front of the room at 1.5 m.

Figure 12. The chromatic 2D distribution of field velocity, in plane section parallel to the front of the room at 2.0 m.

Figure 13. The chromatic 2D distribution of field velocity, in plane section parallel to the front of the room at 2.25 m.
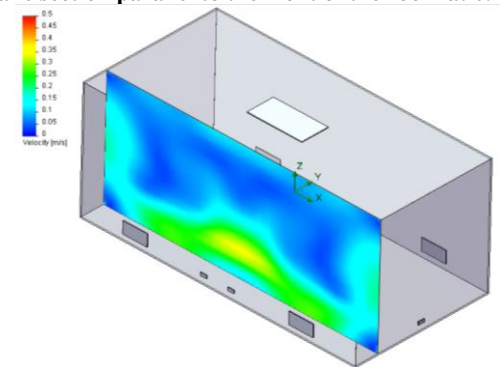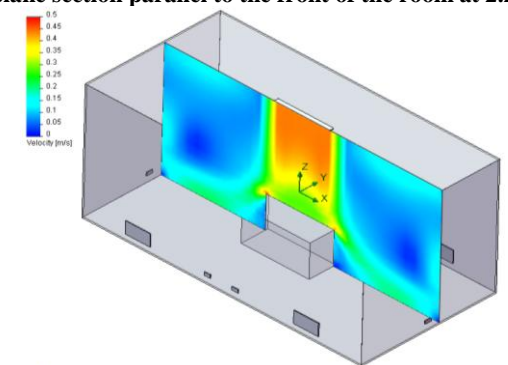

Figure 14. The chromatic 2D distribution of field velocity, in plane section parallel to the front of the room at 2.6 m.
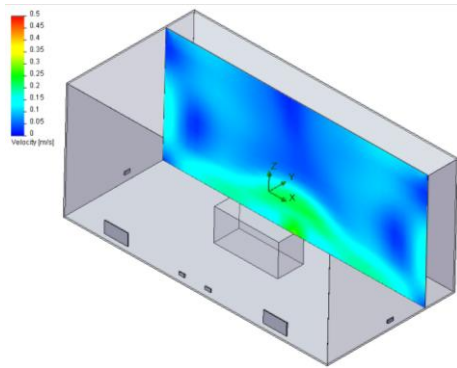
Figure 15. The chromatic 2D distribution of field velocity, in plane section parallel to the front of the room at 2.8 m.
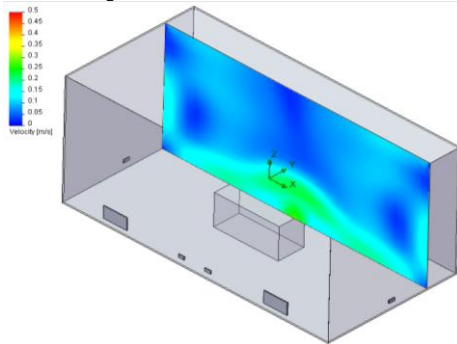

Figure 16. The chromatic 2D distribution of field velocity, in plane section parallel to the front of the room at 3.2 m.
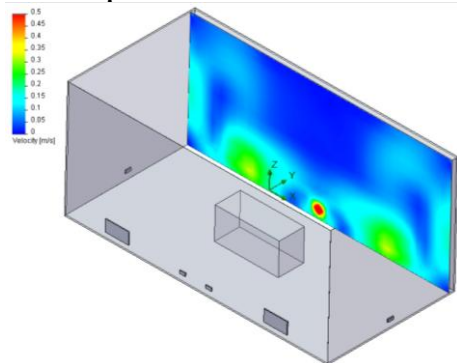

Figure 17. The chromatic 2D distribution of field velocity, in plane section parallel to the front of the room at 3.9 m.

To analyze the airflow inside the operating room and around the operating table is shown isosurfaces on which the speed is constant for v = 0.1 m/s, in Fig. 18.
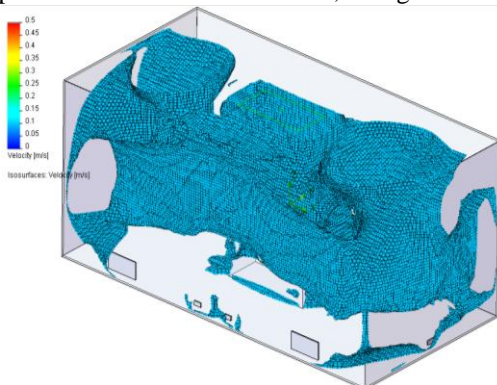

Figure 18. The isosurface on which the speed is constant for v = 0.1 m/s

5. CONCLUSIONS

A CFD analysis of the distribution of airflow velocity, temperature, density and pressure, in a 3D hospital operating room with a conventional vertical airflow, are presented and discussed. The simulation results show a good agreement with experimental data from the literature. The model for thermal comfort and contaminant removal as functions of this location are built for design optimization.

Simulations results confirm a uniform air movement to higher speeds near the operating table, moving closer to laminar flow and rest room a turbulent motion, with lower speeds, but with no stagnant air areas. The air velocities are well within the required air speed ranges to prevent drying of the wound. The air distribution indicates that the air velocity at the wound site is also within the required ranges. The air supply quantity, rate, distribution and temperature provide comfortable conditions for staff and patient, and also permit to maintain the positive pressurization. Particle trajectories were great influenced by the flow field structure, particle launch position and flow turbulence.

The average temperature in the occupied area (the operating table to head height) is between 23 °C and 25 °C, within the recommended range of 17 °C to 26 °C.

6. ACKNOWLEDGMENTS

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