AIR-CONDITIONING SYSTEMS' DEVELOPMENTS IN HOSPITALS:

COMFORT, AIR QUALITY, AND ENERGY UTILIZATION

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Abstract *The balance between thermal comfort and air quality in healthcare facilities to optimize the Indoor Air Quality (IAQ) is the main aim of this paper. The present paper will present this balance from the viewpoint of the air conditioning design. It was found that the design of the HVAC airside systems plays an important role for achieving the optimum air quality beside the optimum comfort level. This paper highlights the importance of the proper airside design on the IAQ. The present paper introduces some recommendations for airside designs to facilitate the development of optimum HVAC systems. This paper also stresses on the factors that improve the thermal comfort and air quality for the already existed systems (for maintenance procedure).*

Keywords: *CFD, Hospitals operating Theatres, Air flow regimes*

1. INTRODUCTION

The balance between thermal comfort and air quality in healthcare facilities to optimize the Indoor Air Quality (IAQ) is the main aim of this paper. The present paper will present this balance from the viewpoint of the air conditioning design. It was found that the design of the HVAC airside systems plays an important role for achieving the optimum air quality beside the optimum comfort level. This paper highlights the importance of the proper airside design on the IAQ. The present paper introduces some recommendations for airside designs to facilitate the development of optimum HVAC systems. This paper also stresses on the factors that improve the thermal comfort and air quality for the already existed systems (for maintenance procedure). To design an optimum HVAC airside system that provides comfort and air quality in the air-conditioned spaces with efficient energy consumption is a great challenge. The present paper defines the current status, future requirements, and expectations. Based on this analysis and the vast progress of computers and associated software, the artificial intelligent technique will be a competitor candidate to the experimental and numerical techniques. Finally, the researches that relate between the different designs of the HVAC systems and energy consumption should concern with the optimization of airside design as the expected target to enhance the indoor environment.

Health considerations and hygiene requirements necessitate the following:

- To restrict air movement in and between the various departments
- To use appropriate ventilation and filtration to dilute and reduce contamination in the form of odour, air-borne micro organisms, viruses and, hazardous chemicals.
- To regulate different temperature and humidity requirements for various medical areas.
- To maintain accurate control of environmental conditions.

2. ENVIRONMENTAL CONTROL

2.1. Temperature & Relative Humidity Control

Codes and guidelines specify temperature range criteria in some hospital areas as a measure for infection control as well as comfort. Local temperature distributions greatly affect occupant comfort and perception of the environment. Temperature should be controlled by change of supply temperature without any airflow control; the temperature difference between warm and cool regions should be minimized to decrease airflow drift. Efficient air distribution is needed to create homogenous domain without large difference in the temperature distribution. The laminar airflow concept developed for industrial clean room use has attracted the interest of some medical authorities. There are advocates of both vertical and horizontal laminar airflow systems. For high-contaminated areas, the local velocity should be greater than or at least equal to 0.2 m/s. For patient rooms 0.1 m/s is sufficient in the occupied area. The unidirectional laminar airflow pattern is commonly attained at a velocity of 0.45 ± 0.10 m/s.

2.2. Air Change and Filtration

Three basic filtration stages are usually incorporated namely: Primary filter, second stage filter (the high efficiency particulate bag filter) and a third stage filter which is the high efficiency particulate filter located at the air supply outlets. Air Change per Hour (ACH) plays in important role to provide a free contamination place. The patient rooms are served by (2 ACH – 6 ACH) in usual. Some critical rooms could be served by value up to 12 ACH. The critical rooms, such as the surgical operating theatres, are supplied by (15 ACH – 25 ACH) in usual. There are some guidelines, which advise the value of 60 ACH for the critical areas (NHS, 1994 and SSI, 1995).

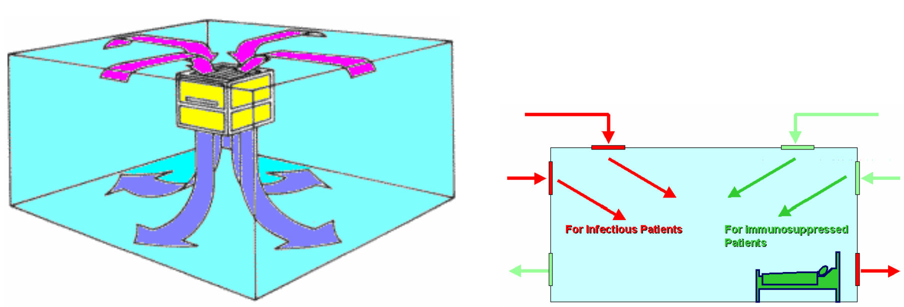

Figure 1: Airflow Movement in Rooms

The negative pressure is obtained by supplying less air to the area than is exhausted from it. This induces a flow of air into the area around the perimeters of doors and prevents an outward airflow. The operating room offers an example of an opposite condition. This room, which requires air that is free of contamination, must be positively pressurized relative to adjoining rooms or corridors to prevent any airflow from these relatively highly contaminated areas. In general, outlets supplying air to sensitive ultraclean areas and highly contaminated areas should be located on the ceiling or on sidewalls closing to ceiling, figure 1, with perimeter or several exhaust inlets near the floor. The bottoms of return or exhaust openings should be at least 0.075 m above the floor.

3. DESIGN SPECIFICATIONS

3.1. Hospital Facilities

As, perfect air conditioning system is helpful in the prevention and treatment of disease, the construction of air conditioning system for health facilities presents many precautions not encountered in the usual comfort air conditioning systems.

Critical Care and Isolation Rooms. In the isolation rooms for infectious patients, the patient bed should be located close to the extract ports. The infectious isolation rooms should be maintained at negative pressure. The immunosuppressed patient's bed should be located in the side of supplied air, or close to the supply outlets, figure 2. Previous predictions of local velocity profiles, air temperatures, relative humidity distributions were reported by Kameel and Khalil,(2002,2003), using a finite difference computer package , Khalil (1994,2000), that solves the governing equations of mass, three momentum, energy, relative humidity and age equations in three dimensional configuration of rooms as indicated by (Khalil ,2004).

Protective Isolation Units Immunosuppressed patients are highly susceptible to diseases. An air distribution of 15 air changes per hour supplied through a nonaspirating

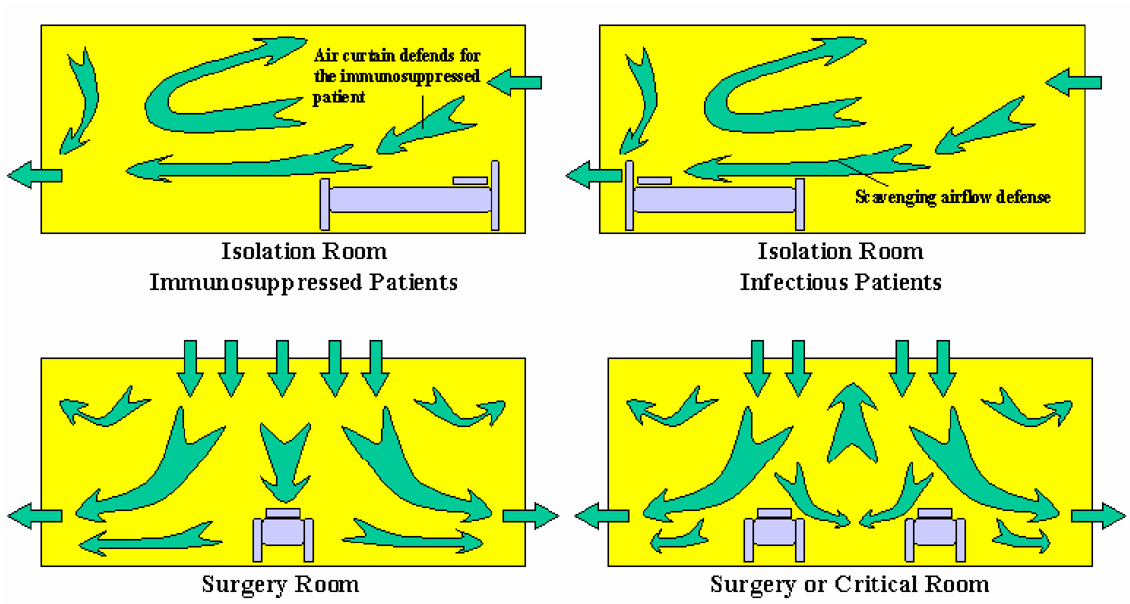

Figure 2: Airflow Configurations for Critical Areas

diffuser is recommended. When the patient is immunosuppressed but not contagious, a positive pressure should be maintained between the patient room and adjacent area. Figure

3 shows the velocity, air temperatures and relative humidity contours in an immunosuppressed patient room.

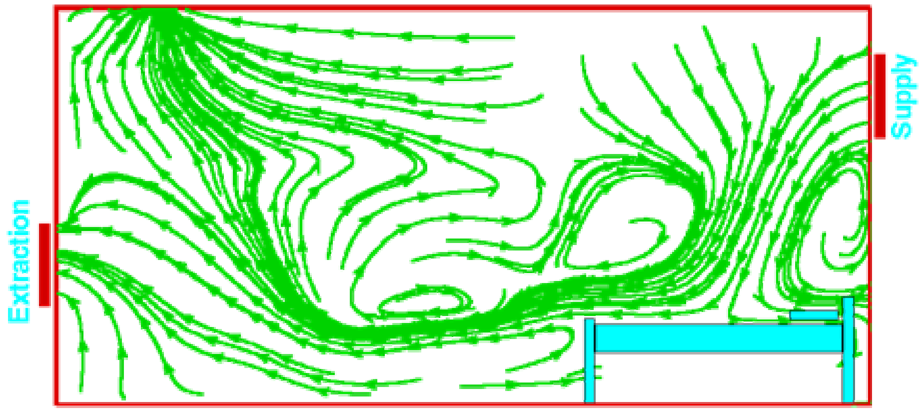

Figure 3-a: Predicted Velocity Contours immunosuppressed patient room

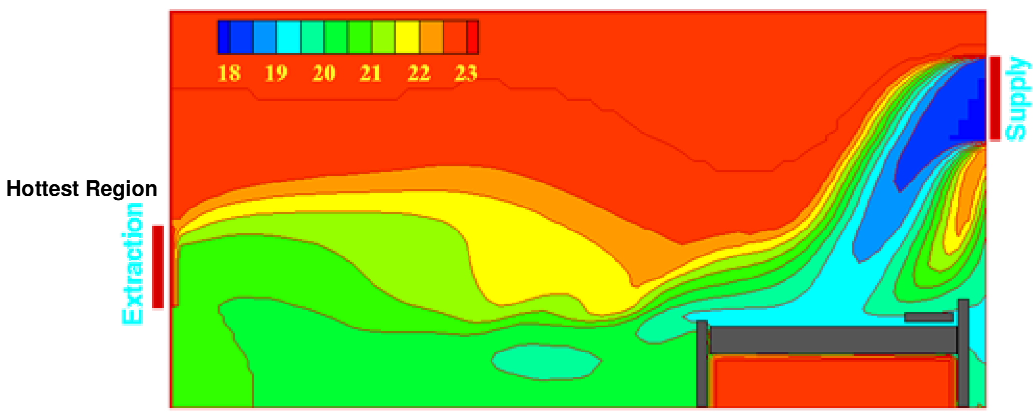

Figure 3-b: Air Temperature Contours In immunosuppressed patient room

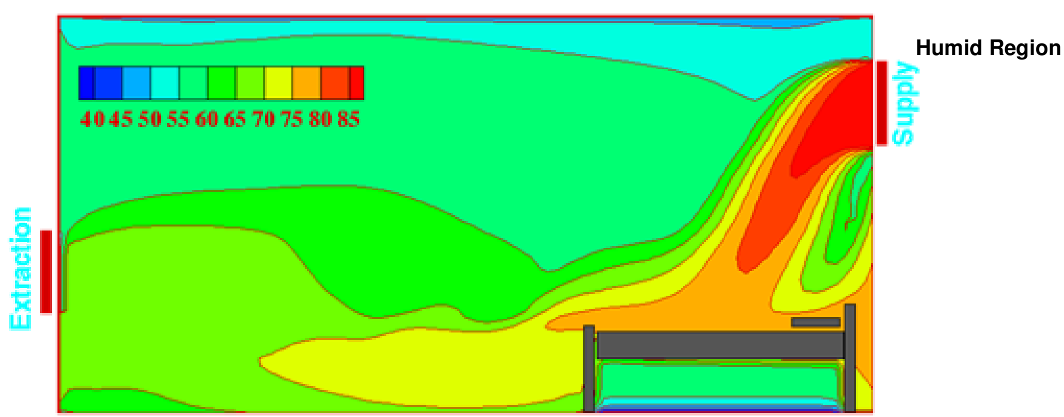

Figure 3-c: Relative Humidity Contours immunosuppressed patient room

Surgical Operating Rooms

Operating room air distribution systems that deliver air from the ceiling, with a downward movement to several exhaust inlets located on opposite walls, is probably the most effective air movement pattern, figure 4.

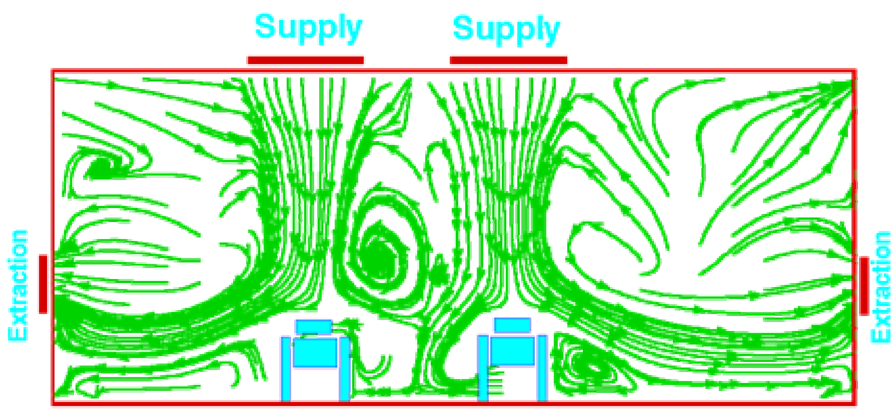

Figure 4-a: Air Flow Distributions in Operating Theatre Open Heart Surgery

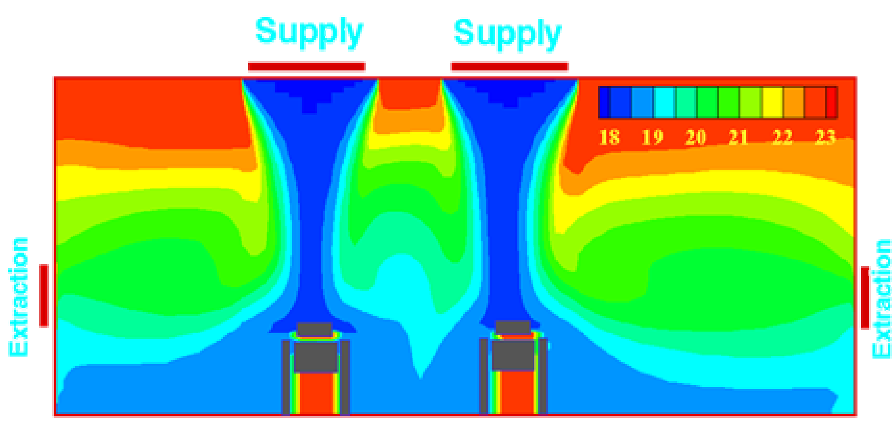

Figure 4-b: Temperature Distributions in Operating Theatre Open Heart Surgery

Based on the above analyses, the following design conditions are recommended for operating, catheterization, cystoscopic, and fracture rooms, figure 5:

1. There should be a variable range temperature capability of 20 °C to 24°C.
2. Relative humidity should be kept between 50% and 60%.
3. Positive air pressure should be maintained by supplying about 15% excess air.
4. Differential pressure indicating device should be installed.
5. Humidity indicator and thermometers should be located for easy observation.
6. Filter efficiencies should be in accordance with codes
7. Entire installation should conform to NFPA Standard 99, Health Care facilities.
8. All air should be supplied at the ceiling and exhausted from at least two locations near the floor.

9. Control centres that monitor and permit adjustment of temperature, humidity, and air pressure may be located at the surgical supervisor's desk.

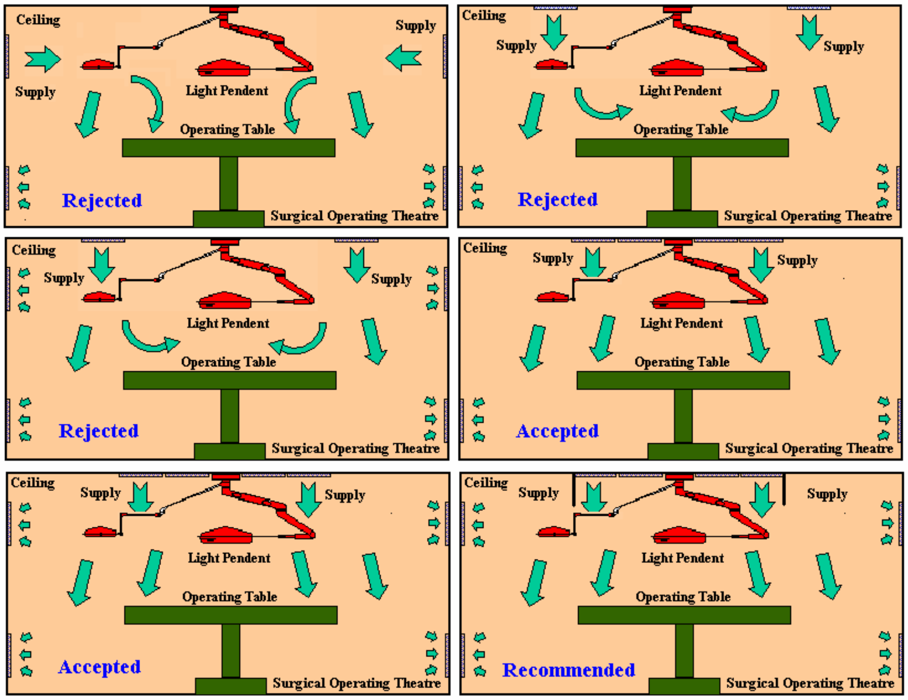

Figure 5: Different Configurations of Surgical Operating Theatres

The surgical operating suite should be located in complete floor in the hospital, to be separated from the other suites and patient rooms. The above design features were strongly supported by the predicted air flow pattern, temperature contours and relative humidity as obtained in different operating theatres as discussed by Kameel and Khalil (2003) and Khalil (2004).

4. CONCLUSIONS AND RECOMMENDATIONS

The air is not just a medium but it can be regarded as a guard in the critical health applications. The proper direction of the airflow increases the possibilities of successful pollutant scavenging from healthcare applications. The numerical tool, used here, was found to be so effective to predict the airflow pattern in the healthcare facilities at reasonable costs and acceptable accuracy. Good architectural design allows the HVAC system designers to properly locate the supply outlets and extraction ports in the optimum locations.

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