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A REVIEW OF AIR DISTRIBUTION PATTERNS IN SURGERY ROOMS UNDER INFECTION CONTROL FOCUS

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Abstract. *The problem of airborne contamination in surgical infections still continues getting up many discussions. The success of the aseptic methods and the use of medicines for the combat of infections are taking the majority of the surgeons to contempt the danger of the aerial particles course. A detailed knowledge of the characteristics of the contamination sources and of the ventilation system performance used at surgery rooms is necessary to guarantee that the ventilation system supplies the pollutant control in ventilation taxes that assure the health and the comfort of the occupants. There are a lot of configurations of air distribution systems and a wide band of potential conditions inside a surgery room that are influenced by their performance. In the same way, it is evident the lack of information in the literature regarding which characteristics of the systems of air treatment have larger influence on the amount of particles in suspension. This paper provides a review of the distribution patterns and air movement at surgery rooms, describing the importance of the airborne particles in the infection process, making a comparative analysis of the efficiency of microbiological control of the main airflow systems, identifying and demonstrating the control strategies that can reduce the risks of airborne contamination in surgical infections.*

Keywords: Infection control, Surgery rooms, Air distribution; Airflow systems.

1. Introduction

Nowadays the surgical interventions are complex and time-consuming what demands intense activities, a great team of professionals and the use of many types of equipments. This situation turns more and more important the effective control of the variables that interfere in the health, comfort and well being of the patients and of the surgical team (Dhara, 2002).

The process of infection prevention in patients submitted to surgeries many times is constituted by complex procedures of difficult application, involving different factors. This way, to get an acceptable performance, a surgery room should accomplish a complex range of control demands. Consequently, a detailed knowledge of the characteristics of the contamination sources and of the ventilation system performance used at surgery rooms is necessary to guarantee that the ventilation system supplies the pollutant control in ventilation taxes that assure the health and the comfort of the occupants.

The control of airborne particles, chemical and radioactive dangerous substances, odor, virus and microorganisms carried by the air, is considered essential for the protection of the surgical room occupants (Lidwell, 1987, Belkin, 1998, Friberg, 1998). To assure accurate control of the environmental conditions and to guarantee dilution and removal of those agents, some requirements should be considered, such as: restriction of the air movement internally and among sections, specific needs of ventilation and filter, need of temperature and humidity control, etc. (ASHRAE, 2001).

The heating, air conditioning and ventilation (HVAC) systems carry out a fundamental task in the execution of these requirements for the warranty of safety and thermal comfort to the patient, surgeons and team in the surgical room.

There are a lot of configurations of air distribution systems and a wide band of potential conditions inside a surgery room that are influenced by their performance. In the same way, it is evident the lack of information in the literature regarding which characteristics of the air treatment systems have larger influence on the amount of particles in suspension

This paper provides a review of the distribution patterns and air movement at surgery rooms, describing the importance of the airborne particles in the infection process, making a comparative analysis of the efficiency of microbiological control of the main air distribution systems, identifying and demonstrating the control strategies that can reduce the risks of airborne contamination in surgical infections.

2. Air distribution in surgery rooms

Different possibilities of airflow systems used in surgical rooms are following presented and discussed.

2.1. Turbulent airflow systems

In surgical rooms that use turbulent airflow systems conditioned air is supplied through diffusers installed at the roof (ceiling air supply) or at the wall. The air is mixed quickly and evenly with the air in the environment provoking a dilution of the tenor of pollutants. So, the contamination originated by a certain source is distributed in a very uniform way along the whole room, as well as the uniformity of the temperature is reached quickly (Howorth, !993, Woods, 1996).

This conception of air supply is one of the more used in most of the surgical centers. The turbulent distribution reduces the formation of static islands of air along the room. The project of those systems has a good flexibility and the filters and the system of air distribution are less complex and of easy maintenance. However, when the airflow is small the recovery of the environment starting from a polluted condition is slow (Lewis, 1993).

A scheme of the air distribution pattern in a surgical room using turbulent airflow system with several diffusers located at the roof, is shown in Fig. 1. In the same way, Fig. 2 shows the air distribution pattern using turbulent airflow system with wall air supply and Fig. 3 shows the distribution pattern with diagonal air supply.

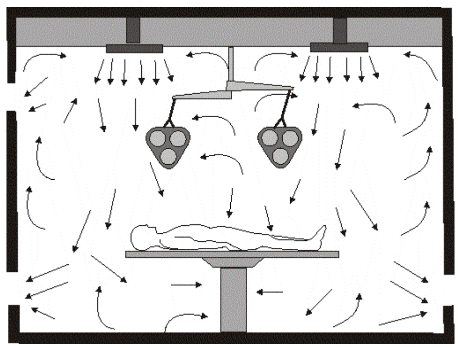

Figure 1. Conventional system (Schmidt 1987).

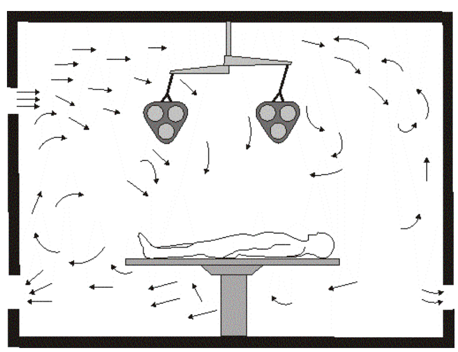

Figure 2. Conventional wall supply (turbulent) (Schmidt 1987).

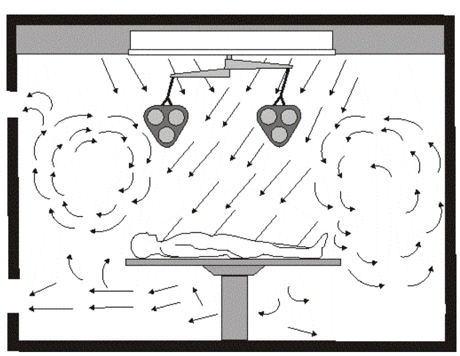

Figure 3. Diagonal system (Schmidt 1987).

2.2. Laminar airflow systems

The surgical systems with unidirectional airflow, also called laminar airflow, have been studied a lot and are used mainly in orthopedic surgeries. As some authors (Lidwell, 1987, 1988, 1993; TAT, 1997), in orthopedic procedures, as for example in substitution of articulations, aseptic precautions should prevail to compensate the risks of the wound contamination due to the great exhibition and for the massive implants, mainly when cemented.

In the systems that supply unidirectional airflow the air is moved evenly in a velocity of approximately 0,45m/s, in parallel airflow lines (ASHRAE, 2002). Some conceptions of unidirectional movement allow taking outside all the contamination generated inside the environment the fastest possible.

In this kind of airflow the equipment can supply the air in the horizontal or vertical direction. When the supply is horizontal the air is usually supplied from the whole wall or in some cases, when the supply is vertical, from the whole roof. The vertical disposition has the advantage of having the action of the gravity in the precipitation and elimination of the larger particles, being obtained a high efficiency system (Turpin, 1998).

Most of the laminar airflow systems is equipped with high efficiency particulate air (HEPA) filters, guaranteeing air free from particles above 0,3 mm (removal of 99,97%), removing like this great part of the bacteria, fungus and until some larger viruses (TAT, 1997). This filtration assures air essentially sterile.

Whitfield in 1960 was the first to create a system with laminar airflow. In 1964, Chamley developed a prototype of an encapsulated environment containing filtered air, built to hold three surgeons and a patient. In this system, the filtrated air was forced inside the compartment by the top part and the surgeons were dressing space clothes with respirators. The exhaled respiration air was extracted to avoid the mixture with the filtered air of the compartment. The objective of such a system was to eliminate the contaminations emitted by the surgeons and other sources of airborne bacteria from the surgical room (Howorth, 1993).

In the sense of guaranteeing uniform air movement in a system with unidirectional flow, several types of protections are proposed for these systems, as lateral panels and air curtains. In these type of systems air is moved parallel sweeping the whole aseptic field. The air is stratified so that it practically doesn't exist crossed contamination. The particles eventually in suspension in a flow line tend to stay in this until being captured in the inferior part of the walls (exhaustion). To guarantee uniform air movement with little mixture, the air velocity should be sufficiently high to win the thermal drafts originated by the internal heat sources (Woods, 1986). A vertical laminar airflow system with lateral panels (walls) is shown in Figure 4.

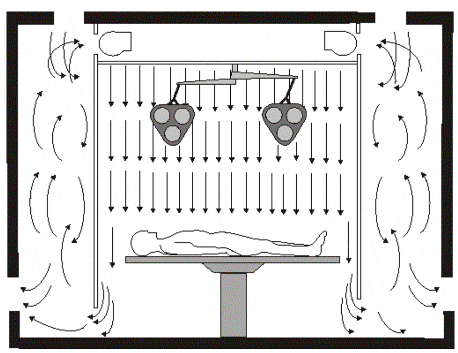

Figure 4. Vertical laminar airflow with walls (Schmidt, 1987).

Although the systems with panels have been well succeeded regarding the microbiological air control (Friberg, 1998, Howort, 1993), they provoke a considerable restriction to the surgeons' movement, to the other members of the surgical team and to the positioning of the instruments and of all of the items that are inside the surgical room. This way, to avoid this kind of problems systems with protection panels located approximately at 2 m above the floor (Fig. 5) were proposed (Lewis, 1993, Howorth, 1993).

In laminar airflow systems with air curtains (Fig. 6) uniformity flow is obtained using diffusers that supply air at the four sides of the surgical table, creating a curtain of air around this area. It happens due to the higher air velocity and the sloping in relation to the vertical (Lewis, 1993, Howorth, 1993). The curtain of air becomes a physical barrier between the filtered air from the unidirectional diffusers and the polluted environment air, even at the roof level, where the air of the unidirectional diffusers is more subject to be mixed with the environment air. The curtain of air also induces the exit of the polluted air through the return grid, diluting the contamination.

Another systems with lateral laminar airflow protection use plastic curtains, as shown in Fig. 7. Finally, it is also possible to use unidirectional laminar airflow systems without lateral protection (Fig. 8). These types of devices have little use in surgical rooms due to its low efficiency in the control of infectious particles. The air supplied by the diffusers can be mixed easily with the environment air by induction (Lewis, 1993, Howorth, 1993).

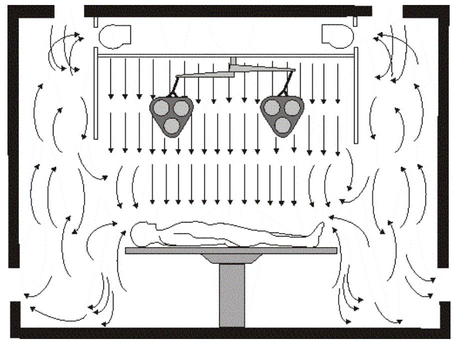

Figure 5. Vertical laminar flow with walls (2 m) (Schmidt, 1987).

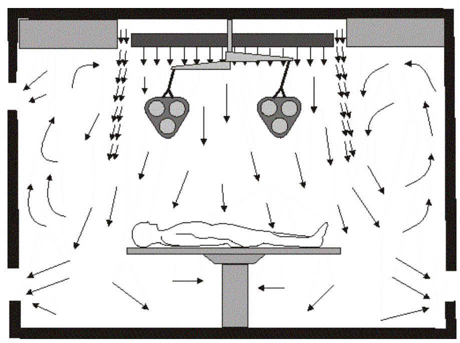

Figure 6. Air curtain around the working area (Schmidt 1987).

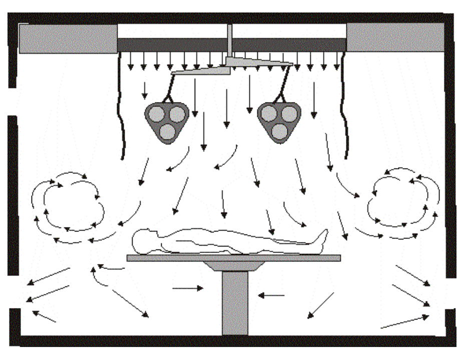

Figure 7. Unidirectional down flow with curtains (Schmidt 1987).

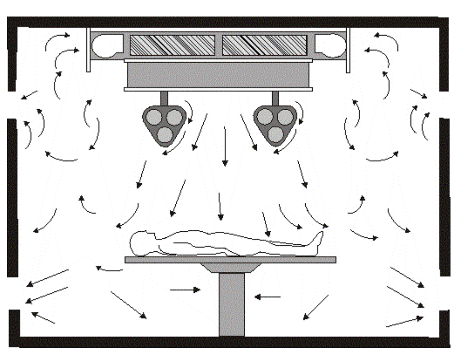

Figure 8. Without protection system (Schmidt, 1987).

2.3 System with corporal exhaustion

One of the main sources of contamination in surgery rooms are the skin fragments lost from the nude skin and also through the interstices among the fabric threads, as the cotton (Roy, 1988). The cotton fabric usually used at the hospitals possesses size of pores between 80 μm and 100 μm, while the fragments of surface skin cells have a medium size of 20 μm. One person looses more than 109 epithelial cells a day and many of them carry bacteria (Belkin, 1998).

Like this, the purpose of the use of adequate garment in a surgery room is to avoid that the contamination generated by the skin reaches the air in the environment. So the garments in surgical rooms need to have such properties that:

(a) minimize the dispersion of bacteria inside the environment;

(b) avoid that bacteria pass through the garment;

(c) and in the case the clothes be wet, avoid that bacteria be expelled by capillary action.

In Table 1 some of different garments and its effectiveness in the reduction of bacteria dispersion, depending on the ventilation system used, are summarized (Roy, 1988, Whyte, 1998).

Table 1- Airborne counts (bcp/m3)[a] in operating room depending on the type of clothing worm.

Clothing	Conventionally Ventilated Room	Ultra-clean Ventilation System[b]	Strike-through if becomes wet
Normal cotton	100 – 500[c]	30 (cross flow system) 10 (down flow system)	Substantial
Camley exhaust gown	50	0.6	Are treated against strike-through, but not fully protective
Disposable non-woven fabrics	50[d]	1.5 – 2.5	
Close-woven fabrics	50[d]	0.7	Polycotton has to be reproof at regular intervals

a bcp – bacteria-carrying particles
b Unidirectional flow
c This count may vary, depending on the number of people present in the room and their level of activity
d If garments are used as a complete system (i.e., shirt, trousers, and gown).

This way, with the objective of removing the corporal emissions due to they are the main source of contamination of surgical wounds (Lidwell 1988; Howorth, 1993), it was developed a garment that involves the body of the surgical team from the head up to 18 inches above the floor. Air is taking out the garment in a volume enough to create a negative pressure inside the garment, so that any opening the air will penetrate from way to satisfy the demands of the exhaustion system (Howorth, 1993).

The material that composes the garment should have low air permeability, to be water impermeable and it cannot allow the passage of bacteria to the air. Like this, all of the corporal emissions are removed, and the cooling and the level of oxygen are gotten better. An audio system is available in the garment mask to facilitate the communication.

3. Air distribution systems evaluation

3.1. Turbulent airflow systems

In the conventional turbulent airflow system (air supply at the roof) as well as for the conventional wall supply, when the air is introduced in the environment turbulence occurs in the air displacement direction. Due to this phenomenon these types of systems don't possess a control of the distribution patterns and air movement in the surgical room (Belkin, 1988).

In the conventional wall supply system the diffusers supply air in a greater velocity in the sense of reaching a larger distribution field. That provokes an increase in the turbulence along the environment. Besides, the surgical field is reached directly by the air jet provoking additional problems of thermal discomfort.

The use of the diagonal system also has the great inconvenience of increasing the turbulence of the air in the surgical field in function of the high air supply velocity. Like this, the instruments and all of the items that get in touch with the wound will receive a random turbulence and they won't have more microbiological protection. Also, the high air velocity can provoke a dehydration of the surgical wound (Howorth, 1993). Besides, the surgical team movements will direct the jet of air out inside, introducing the pollutants into the surgical field.

Another kind of problem associated with the use of turbulent airflow systems is that a negative pressure is generated in the nucleus and whole diffuser perimeter. Like this the polluted environment air penetrates in all of the sides and in the diffuser center mixing with the clean supplied air. This polluted mixture of air is then dispersed in the whole surgery room (Howorth, 1993). So the polluted air inside the surgery room is being continuously contaminated by the people's emissions and other sources and mixed quickly with the filtered air from the HVAC system. This situation is illustrated in Fig. 9. In a study developed by Whyte (1988), it was demonstrated that surgical rooms that use these types of systems possess above 500 particles for cubic meter carrying bacterium.

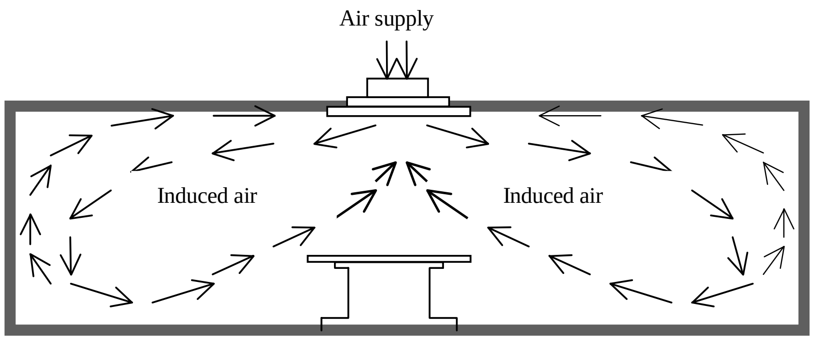

Figure 9. Air movement in surgical rooms with turbulent airflow systems.

3.2. Laminar airflow systems

In laminar airflow systems the problem of infiltration of polluted air can also happen in some types of these systems. So that the descending airflow reaches the instrumentation and table level in a velocity enough to overcome the convective ascending flows produced by hot sources, the velocity at the diffuser exit should be superior to the one of the convective flows.

According to Howorth (1993), the increase of microbiological control efficiency of these systems is very small and the operation costs are greater for the small relative profit in comparison with turbulent systems. In some cases the diffuser occupies the whole roof along the room. Like this, in function to the great volume of air supplied by the diffuser, certainly a reduction of the content of bacteria will exist due to the dilution, however it will also have a great consumption of energy.

On the other hand, regarding the systems with air curtains that provide high velocity air supply in their entire periphery, tests accomplished with this type of systems show a good microbiological control (Lidwell. 1987, Belkin, Friberg, 1998). Besides, in the systems with protected flow the velocity of discharge of the air can be smaller than the established in the systems without protection in function of the air to be unloaded 2 m of the floor indeed.

As some authors (Whyte, 1988, Lidwell 1987, Lidwell. 1988, Belkin, Friberg, 1998, NRC,1999), the system with horizontal laminar airflow don't have a lot of applications in surgical rooms due to its high index of contamination compared to the systems with vertical laminar airflow (air supply at the roof).

In Figure 10 are presented results obtained in a work developed by The National Resource Center - NRC, which compares systems with horizontal and vertical airflow in terms of colony forming units (CFU/ft^3) in function of the number of changes of air. It is observed that for both systems, the colony forming units decrease with the increase of the number of changes of air per hour (NRC,1999).

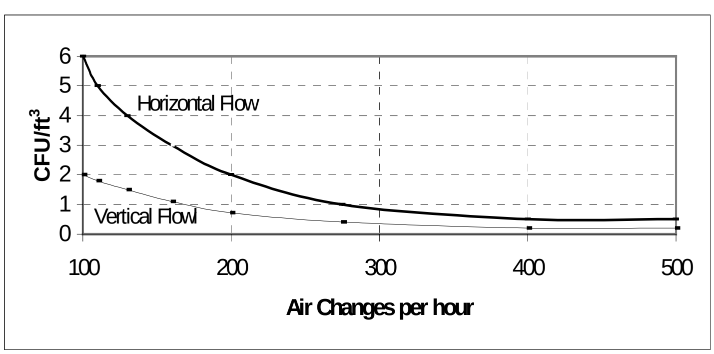

Figure 10. Airborne bacteria vs. Airflow direction and air changes (NRC,1999).

As some authors (Howorth, 1993, Friberg, 1998), systems with the diffuser centralized in the roof with exponential flow protected by air curtains are an interesting alternative. According to the authors the exponential pattern of the airflow supplies a central descending flow in conjunction with a radial flow outside of the area of microbiological clean air. According to the authors, in function of the radial outlying flow the velocities down and outside are enough to prevent that any pollutants rise of the floor.

Fribert et al (1998) developed a study comparing three types of laminar airflow systems: system with exponential flow (protected with wall at 2m above the floor), vertical system with lateral protection panel and horizontal system with lateral protection panel. According to the authors, all the three systems demonstrated a good microbiological control with the sampling values being inside of the patterns proposed by Whyte et al (1988), i.e, below 10 cfu/m3. In agreement with the authors' conclusions, although the three systems present a good control of the bacteriological contamination, the systems with exponential flow are the most versatile alternatives. Tables 2, 3 and 4 show the results obtained by the authors for different tests.

Table 2: Air counts (cfu/m³),(Friberg et al, 1998).

	Air counts cfu/m³		
	Exponential (n 5)	*Vertical (n 5)*	*Horizontal (n 4)*
BEFORE PREPARATION	0.2 (0.2)	0.2 (0.1)	0.1 (0.2)
DURING PREPARATION			
Wound	4.0 (3.3)	1.1 (0.7)	3.1 (3.0)
Instruments	0.9 (0.4)	0.6 (0.3)	0.8 (0.4)
DURING SURGERY			
Wound	1.3 (0.5)	0.8 (0.3)	1.9 (0.3)
Instruments	2.3 (1.1)	1.2 (0.9)	0.05 (0.03)

Table 3: Sedimentation (cfu/m²/h), (Friberg et al, 1998).

	Sedimentation (cfu/m²/h)		
	Exponential (n 5)	*Vertical (n 5)*	*Horizontal (n 4)*
OUTOSIDE LAMINAR FLOW	653 (170)	864 (365)	90 (53)
INSIDE LAMINAR FLOW			
Patient chest	64 (35)	58 (32)	72 (106)
Wound	39 (51)	64 (40)	32 (37)
Instruments	26 (38)	7 (13)	32 (45)

Table 4: Particle counts in the wound area, (Friberg et al, 1998).

	Particles por m³		
	Exponencial	*Vertical*	*Horizontal*
	(n 5)	*(n 5)*	*(n 4)*
> 0.3	2084 (3531)	1978 (5156)	27426 (18413)
> 5.0	141 (212)	247 (742)	1153 (307)
> 10.0	106 (141)	177 (586)	929 (285)

Schmidt (1987) presents more detailed comparisons of airflow systems on the concentration of infectious particles in the surgical field. The author included in the studies several types of airflow systems as well as their variations. However, specific data of the systems project were not included. Other medical comparisons were not included, such as real frequency of postoperative infections, statistical comparisons between the different surgery types and relative effectiveness of other possible medical interventions for the several types of airflow systems or surgeries. Nor the systems are the same in what says respect to undesirable interactions or their aspects. The Figure 11, show the data published by this author.

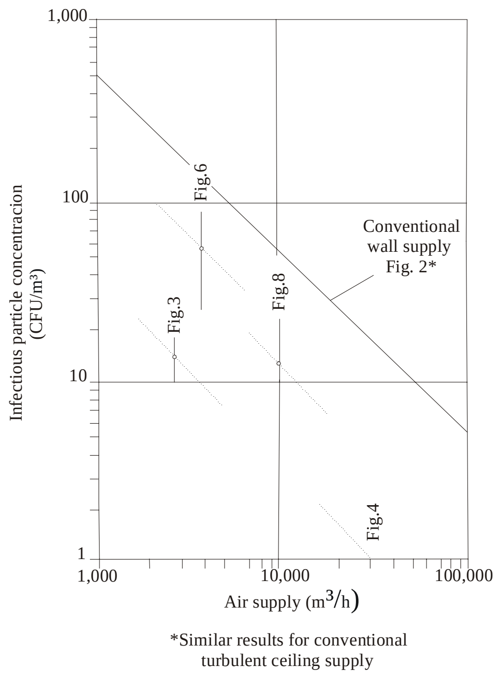

Figure 11. Comparisons of airflow systems on the concentration of infectious particles in the surgical field (Schmidt,1987).

Pasquarela et al (2003) developed studies with the aim to compare bacteriological counting in surgeries with the use of clothes with corporal exhaustion systems and conventional clothes. The studies were accomplished in surgical rooms with conventional turbulent airflow systems. According to the authors the use of corporal exhaustion didn't demonstrate considerable reductions in the level of bacteriological contamination when compared to the conventional clothes.

4. Systems performance and infection control

The Council of Medical Researches, together with the Department of Health and Social Welfare, in England, accomplished extensive study monitoring more than 8000 surgeries of replacement joints of hip and knee. The results demonstrated that the combination of the use of prophylactic antibiotics, adequate clothes to reduce dispersion of particles and air treatment systems projected to move away bacteria of the surgical wound produced a reduction in the incidence of infections that fell for just some few cases in one thousand surgeries (Lidwell et all, 1987; Lidwell, 1988).

In the work of Lidwel et all (1987) are presented some interesting observations. According to the authors, the incidence of joints infection was of 0.6% in patients whose implant were inserted at ventilated surgical rooms with laminar airflow system, compared with 1.5% in those patient ones whose operation had been made at rooms with conventional ventilation. In this study the joint infections were confirmed in a new surgery done between the first and the fourth year after the first surgery. The project of this study didn’t include a strictly controlled test of the effect of the antibiotic prophylaxis. The authors concluded that the infection taxes were reduced from 2% to 1% only with the use of laminar airflow and from 2% to 0.5% with the use of laminar airflow and Chamley corporal exhaustion.

For other types of aseptic surgical procedures only a scarce literature can sustain the idea that an ultraclean air reduces the taxes of hospital infection. In heart surgeries, laminar airflow and garments with corporal exhaustion resulted in a fall in the tax of infection from 7.3% to 0.8% (Belkin, 1998). But an intensive program of infection control implemented in the same time of those other changes doesn’t allow any conclusion on the system of airflow for itself in the fall of the infection taxes.

5. Numerical simulation

Due to the limitations of the experimental approach and to the rapid development in computational fluid dynamics (CFD) technology, comprehensive airflow analysis of the entire room space has become manageable (Chow et al, 2003). The CFD has been proven very powerful and efficient in parametric studies of room airflow and contaminant dispersion (Chen et al, 1992; Chow et al, 2003; Hartung et al, 1998; Memarzadeh et al, 2001). The developments were based on the work of Launder and Spalding in the early 1970s. Within the context of fluid mechanics, the determination of room airflow and particulate distribution requires solving the continuity and momentum equations in three dimensions. A computational model for predicting the contaminant (particle) distribution comprises two numerical parts. First, the airflow pattern must be determined. Second, substituting the already known velocity field into the equation of particle motion, a complete particle trajectory can be obtained.

The most common CFD techniques are direct numerical simulation (DNS), large-eddy simulation (LES), and the Reynolds averaged Navier-Stokes (RANS) equations with turbulence models. Each technique handles turbulence in a different manner.

Direct numerical simulation solves the Navier-Stokes equations without approximations. DNS requires a very fine grid resolution to catch the smallest eddies in the flow. Large-eddy simulation separated turbulent motion into large eddies and small eddies. The theory assumes that the separation between the two does not have a significant effect on the evolution of large eddies.

The Reynolds averaged Navier-Stokes method is the fastest but maybe the least accurate method. The Reynolds averaged Navier-Stokes method solves the time-averaged Navier-Stokes equations by using approximations to simplify the calculation of the turbulent flow. The approximations can sometimes generate serious problems. The number of grids used for simulation with RANS is normally much less than that for LES. Most important, a steady flow can be solved as time independent flow. Therefore, the computing costs are the cheapest compared to those for LES and DNS. The most popular RANS model is the standard k-ε model developed by Launder and Spalding in the early 1970s (Chow et al, 2003).

The standard k–ε model (using an eddy-viscosity hypothesis) has been widely applied in numerical predictions. The model is relatively robust in producing converged solutions, even for the flow at low turbulence level and with unstable temperature stratifications. All the model coefficients are constants and are determined from a set of experiments. Although these empirical coefficients have broad applicability, they are not universal. Modifying the standard k–ε model to improve the computed results is also a common practice. Suggestions have been made for the modification of turbulence models that would extend their use to low-Reynolds numbers, and also would calculate the flow at positions close to solid surfaces. Most of the extended models incorporate either a wall damping effect or a direct effect of molecular viscosity, or both, on the empirical coefficients and functions in the standard model. In the absence of reliable turbulence data in the immediate vicinity of a wall or at low-Reynolds numbers, these modifications are based mainly on comparisons between calculations and experiments in terms of global parameters.

5.1 CFD modeling airflow in surgery rooms

CFD modeling of particle transport has been applied for the control of airborne particles in the operating zone above the surgery table in an operating room (Chen et al, 1992; Hartung et al, 1998; Memarzadeh et al, 2001). In a surgery room, the airflow within the sterilized zone is basically unidirectional, but that outside the zone is basically turbulent (Chen et al, 1992).

It has been found that the particle source location, air (supply) inlet design, operating table location, and lamp design are among the critical parameters responsible for the particle distribution within the surgery room (Liu et al, 2003).

The Figure 12, shows the use of the technique of numeric simulation in the study of the air movement in a surgical room.

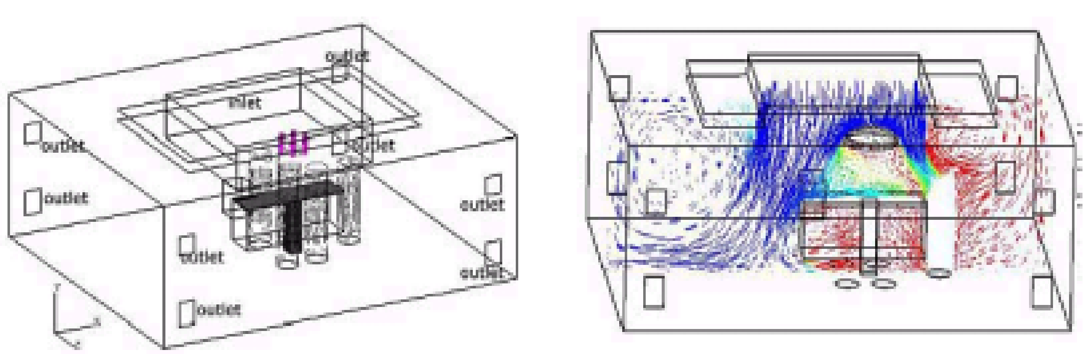

Figure 12. Computational fluid dynamics simulation of a surgery room.
(a) General layout, (Liu, 2003) (b) Airflow pattern, (Liu, 2003)

Hartung and Kugler (1998) conducted a two-dimensional numerical modeling of a surgical room. The authors suggest that the surgical team and lamps can affect the airflow. However, two-dimensional modeling is inadequate for any kind of realistic representation of the flow field and particle transport (Hartung and Kugler, 1998).

Chen et al (1992) successfully conducted the numerical simulation of airflow and particle concentration in a surgery room. The author maked use of a modified low-Reynolds number k– ε model, reported that a higher air inflow rate and a large air inlet area were desirable for contaminant control but in detrimental to the staff thermal comfort; particle concentrations in various parts of the room were very sensitive to the location of the particle sources; point sources were assumed in their study (Chen et al, 1992). Higher heat sources had little or negligible effect on particle distribution and thermal comfort.

In a case study of a teaching hospital, Kameel and Khaili (2003) applied a SIMPLE numerical algorithm with the turbulence characteristics represented by a modified model to account for near-wall functions. Optimum air distribution system was found to depend mainly on the air supply, the extract outlet positions, and the operating table orientation. Similar conclusions were reached when Liu and Moser (2002) carried out CFD analysis on a real operating room in a Swiss hospital.

Memarzadeh and Jiang (2001), used a k-ε turbulence model and particle tracking procedure to study the effects of a ventilation system and ultraviolet germicidal irradiation on minimizing the risk from airborne organism in isolation rooms in Canada.

In other work, Memarzadeh and Jiang (2002), use airflow modeling and particle-tracking methodologies to compare the risk of contaminant deposition on an operating room surgical site and back table for different ventilation room (Memarzadeh and Jiang, 2002).

A CFD analysis supported by field measurements in a surgical room in Hong Kong Hospital, Chow et al (2003), simulate the temperature distribution, airflow pattern and the contaminant dispersion. The study placed an emphasis on the health risk of the airborne bacteria released from the surgical team on the patient, and vice versa.

6. Concluding remarks

A surgery room is characterized by the grouping of factors associated to the environment air that can provoke risks to the occupants, mainly to the patients in function of their low resistance. So, one of the most important providences in surgery rooms is the adoption of control procedures in the sense to prevent airborne contamination and preserve the health and the welfare of the occupants.

Several studies indicate that some surgery room airflow systems can reduce the indexes of postoperative infection. However it is evident in the literature the lack of data to analyze the specific characteristics of the systems. There are significant studies on the sources and paths of the infection for several types of air treatment systems, with appropriate statistical methods to justify the conclusions. However, these studies don't present project and performance data necessary for the establishment of efficiency criteria.

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