CLIMATIZATION IN OPERATING THEATRES

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Abstract. Climatization systems in operating theatres must provide a comfortable and healthy environment for the patients and the surgical team; in fact, there are a multitude of factors to be considering and analyzing for avoiding the evidence of many problems such as hypothermia, anaesthetical gases pollution, thermal discomfort. Comfort conditions can be achieved by controlling microclimatic parameters and air movement; an healthy environment can be achieved minimizing the risks of contamination.

This article summarizes the relevant literature about methods used for the environmental evaluation of the operating theatres and the actually used HVAC systems for achieving thermal comfort and for obtaining an healthy environment.

By the use of an operating theatre model at real scale, simulations will be effectuated in order to determine the appropriate ventilation rates for obtaining the dilution of chemical (anaesthetical gases) and physic-biological contaminants. It will be useful for the determination of microclimatic parameters (temperature and relative humidity) necessary for avoiding risks for the patients, such as hypothermia, and for assuring comfort of the surgical team.
The results could be used also for the obtainment of high standards of environmental hygiene that determine a reduction of infections, costs and post-operative times.

**Keywords**: Operating theatres, Climatization, Test Operating theatres.

### 1. INTRODUCTION

The factors causing numerous infections in the operating theatres and in the adjoining places are manifold: type of operation to which the patients are subjected; introduction of external material; pre and post operating preparation of the patients and of the medical staff; ventilation rate in the chirurgical area; level of pressurization; conditions of the patients' immunitary system; antibiotic prophylaxis and so on [6].

Some of the greatest problems found inside the operating environments are constituted by: hypothermia; shivers; increase of body temperature; peripheric vasoconstriction; that manifested in young and elder patients, subjected to total anesthesia.

To avoid these problems, a study reveals that the temperature inside of operating theatres should be equal to 26°C, the so-called warm operating theatres [7]; nevertheless the ISPESL guidelines impose the following values [13]:
- temperature between the 20°C and the 24°C;
- relative humidity between 40% and 60%.

The greatest part of pathogenous infections is caused by the normal flora present on the skin of the patients and surgeons [6]. The possible remedies are:
- use of masks, gloves and sterilized clothings with a repellent fluid, that don't allow the penetration of bacteria;
- suitable information of the medical staff with the purpose to maintain sterile the operating tools;
- reduction to the least number of the people inside of operating theatres, so to avoid inopportune flows of ventilation [6].
- use of a good ventilation system with an efficient air filtering system. For obtaining this some filters must be used that can guarantee an efficiency of absorption of the polluting substances between the 80% and 95% [6].

General standards that define the limit values of bacterial content inside of operating theatres nowadays don't exist yet, neither relatively to ventilation. European and extra-European Countries, fix some guidelines based on their working experiences and their job environments [7].

### 2. THE ENVIRONMENTAL CONTROL OF THE OPERATING THEATRES

In hospital ambit certainly one of the environments that needs particular care from the point of view of the environmental monitorating, under the aspect of microclimatic, microbiologic...
conditions, and of the chemical air characteristics, is represented by the operating theatres, whatever is the type of chirurgical operation which will be effectuated [6]. Operating theatres represent a complex environment particularly necessitating accurate and constant attentions, for assuring the safety of the patient and of the medical staff.

The risk inside of operating theatres is characterized by two principal factors [14]:

- chemical;
- biological.

The chemical risk is caused, above all, by the presence of pollutants in the environment due in particular way to the anaesthetic gases; the biological risk is determined by the presence of pathogenous agents that transported by the air cause the rise up of infectious illnesses in susceptible subjects [14].

In literature [16] some studies report expansive prices about the treatment of the infections that are contracted in chirurgical ambients: in the USA, in 1992, the cost reached 1,6 thousand millions dollars; in Italy the cost for caring infections reached 1,5 thousand millions of euros every year. The average cost of a chirurgical infection is estimated between 3,500 – 8000 euros.

For this reason the major studies about environmental pollution inside of operating theatres are addressed besides to monitorating and systematic controlling of microclimatics standards, also to the determination of the microbic content of the air and the measurement of environmental concentration of the anaesthetical gases [4].

The difficulty in the choice of the microclimatic parameters, is extremely high, because there is the necessity to conciliate many factors [4] that have different origin such as:

- the omeothermical state of patients;
- the thermoigrometric comfort of the medical team;
- the appropriate reduction of the microbiological components of the air;
- the dilution of the anaesthetical gases concentration in the air.

The modern ventilation systems of an operating theatre have the purpose to reduce the phenomena of microbiologic and chemical pollution (with results not in all satisfactory), but they aren't suitable to guarantee the minimal level of comfort for the patient and the operating team, because these have different necessity.

In fact, the patient is subjected to violent processes of body refrigeration, because short clothing that he wears and because the high air turbulence existing with low temperatures. Discomfort conditions are favoured by peripherical vasoconstrictions phenomenons due to the anaesthetics that stop the blood to flow on the top of the skin, and, in this case, they also stop the heat flow on the top of the skin.

On the other hand the operating team feel enviromental conditions of overheating for its physical fatigue, its stress and its clothes, above all in the case of orthopedic operation, during which it wears lead protections for the presence of x-ray.

In literature [8] the negative repercussions on the patients are very well codified; they are due to the hypothermic state assumed by the 30% of them during the operation or in the next stages, caused by the combined effects between internal climate and anaesthetics.

Nevertheless, these opposite and grave conditions of discomfort of the medical team and the patients, today aren't still object of a systematic study about the involved phenomenons, because this fact is perceived as a secondary event and it also considered ineluctable respect of the routine activities of an operating theatres; on the other hand it is a consequence of the absence of appropriate scientific informations.

By this rises the usage, for example, to rule the body temperature of the patient only by superficial heating of him (streams of warm air, warmed mattress and so on), that are however useless for the vasoconstriction phenomenons, neglecting an adapt control of the air fluxes and the temperatures of the climatization system.

In the same way, the lack of an appropriate knowledge of the contagious phenomenons, about the microbiologic pollution sources and about their importance, has determined the usage
to climatize the operating theatres with high rates of ventilation (from 15 vol/h to 150 for particular applications), with negative repercussions about the comfort conditions of patient and medical team.

This condition of doubt and confusion suggested to the authors of this work, to try to get a deeper knowledge of the basic phenomena, of different nature, that cause conditions pollution in operating theatres and discomfort for the patient and the medical team.

3. INVESTIGATION METHODS

By this, unavoidably it seems necessary to try an appropriate investigation methodology allowing to examine the phenomena of interest from various points of view (physical, chemical, microbiological, clinical, metabolic).

Therefore a multidisciplinary investigation has been designed with the purpose to get a deeper knowledge of the causes of the treated phenomenon, both by analysis in appropriate test room, for artificially reproducing various events of pollution and local discomfort, both by directly realized surveys in really existing operating theatres, where it is possible referring to their numerous utilizations, that influencing the sources of pollutants.

For this purpose, the research has been divided in the following stages [3]:

- analysis of the HVAC system (kind of system, characteristics and performances of its components);
- location of the areas of exhaust extraction, for analyzing the contamination of the dusts both those coming from exterior and those due to recirculated air;
- microbiological analysis of the air and of the dust inside the ducts;
- qualitative analysis of the filtering plant;
- use of sensors, with the possible major precision, for determining the concentration of anaesthetic gases into the air of the operating room;
- critical analysis of the results for characterizing the exact correlation parameters among the amount of pollutants, the ventilation rate for diluting such pollutants and the kind of ventilation system.

The study of the microbiological agents is certainly difficult, because, how is reported in literature, exists a multitude of pathogenic biological agents (parasitical, mushrooms, bacterias, virus, ...) that, singly or in concomitance among them, cause the rise up of illnesses. In practice, the analysis is based on the determination of some general parameters such as the total bacterial amount and the total micotical amount.

For sampling the microbiological agents contained in the dust can be utilized some portable samplers, they inhale air at a constant speed, that crosses a metallic heading endowed with small holes and arrives on an underlaying plate containing a fit ground of culture for the insulation of the microorganisms [6].

After the sampling, the plates are analyzed in laboratory for determining the most probable number of microorganisms for cubic meter of air [3].

The ventilation system of an operating room has to furnish an healthy and comforting environment for the patient and the medical staff, that can be reached minimizing the risk of contamination by appropriate filtering of the air and by a special system of flow distribution inside the room [4]. Actually in Italian hospitals are mostly used climatization system at constant flow. Nevertheless these systems are inadequate to diluting the polluting load in the air of the operating rooms. The constant flow, imposed at 15 vol/h by the D.P.R. n. 37 of 14.01.97, increased up to 20 vol/h for high induction systems, sometimes is overestimated while sometimes underestimated [17] [7]. An increase in the rate of air exchange up to 20 vol/h causes various problems of thermal discomfort, both in the sanitary personnel and in the patient
which can feel symptoms of hypothermia [15]. There are also consistent economic problems due to a greater energetic consumption.

A great share to environmental pollution in an operating room is often caused by the presence of remarkable concentrations of anaesthesiological gases of which the nitrogen protoxide is the most diffused. In fact, in environmental surveys it is used as indicator of pollution level of the operating rooms, together with other alogenated that are also present in a remarkable amount [15].

A lot of researches have revealed teratogenic, carcinogenic, nephrotoxical, hepatotoxical, myelotoxical and abortigenic effects from the assumption of nitrogen protoxide and alogenates on animals and on men ([10] [5] [9]).

Considered that the workers under risk of anaesthetical gases exposure amount to around 50,000 [12] the importance of this problem is understandable.

Moreover, the conditions determining the amount of anaesthetical gas released inside an operating room are completely aleatory and uncontrollable [15]. For instance, the rate of emission of nitrogen protoxide and other alogenates depends by various factors, such efficiency and maintenance of the instruments use for anaesthesia, typology of anaesthesia (intubed patient or anaesthetized with mask, anaesthesia in box or directly in the operating theatre, etc.) the habits and the behavior of the surgical staff [15].

Therefore it is difficult analytically characterizing the emissions of an anaesthetical gas, it is considered like an aleatory variable [15]. Accordingly also the air exchange necessary to dilute these pollutants should be dependent from the variability of emissions of pollutants inside the room.

To such purpose is more effective a climation system of the type variable flow, as shown in a recent study [15], in which were compared the characteristics of dilution of pollutants of two climatization systems, constant flow and variable flow, by the use of an operating test room in real scale.

The same typology system could be used to rule more pollution sources as the microbiologic pollution.

Nevertheless, as the characterizetion of this last source is particulary complex and above all it only comes with long time (from 48 hours to 72 hours), it is usually to measure the pollutin level of an operating theatres with the remark of the particles concentration (ISO 14644). In this meaning we can understand that there is a relation between particles and microbic concentrations, but the litterature gives us opposite opinions of this.

For this reasons there is the necessity to make specific studies in workroom and real operating theatres.

In order to carry out the above mentioned experiences, an experimental system was built in CERTECA Laboratory (University of Ferrara), where has been located a special system (Fig.1) composed of:

- a testing room
- a HVAC system
- a monitoring system
- a control unit
The testing room (Fig. 2) was conceived to recreate in full scale a large variety of confined environments, having dimensions between 4.80x4.80 m (height 3.30 m) and 7.20x6.60 m (height 3.30 m). This room has a modular structure, geometrically and dimensionally variable.

It is composed of a number of panels which can be either blind or can be equipped with supply and extraction air devices provided with flexible ducts connected to the ventilation plant. Some panels can also be transparent in order to allow the observation, from the outside, of both the testing room and the film/fotograph shooting.

Caused the easily removable and substitutionable panels, it is possible to experiment more solutions of air conditioning in the same room by recomposing the positioning of the supply and extraction air grilles or by varying their number. Furthermore, all grilles are equipped with motorized shutters for the remote control of the air flow, supplied or extracted. The same criteria of modularity and flexibility were applied to the construction of both ceiling and entries. In this way, it is possible to simulate bacterial contamination phenomena, dust and gas pollution coming from surroundings.
The all-air conditioning plant is able to control air flow rates, temperature, relative humidity and pressure, independently of the outdoor values. The supplied air can be enriched with either tracer gases or dirt particles at prearrangeble concentration and density, in order to allow the simulation of the environmental pollution processes, using the same air conditiong system. Another system, the second one, independent of the first, allows the emission of other tracer gas in any part of the environment.

In both ways, it is possible to identify and visualize the air ways moving inside the room, and identify the presence of non-moving air zones. Therefore it is possible to study the diffusion of pollutants for different outdoor air flow rates.

In detail, all the thermodynamical, physical-chemical and functional properties are costantly monitorized (test room indoor temperature, external air temperature, test room indoor pressure, external air pressure, internal and external air relative humidity, indoor air velocity field, test room pollutant gas concentration field, particles concentration field, supply and extraction air flow rate, air flow rate for single grille, stubbed filter grade.

On the other hand, the air flow directions for single grille are manually controlled.

An appropriate system composed of a sensors set and a data acquisition apparatus interfaced to a PC, monitorally represented and memorized. In this way, it is possible to compare the obtained results with other from numerical simulation procedures.

A computer supervisor allows the modification of any single system parameter through a user friendly video interface. As previously mentioned, we have at our disposal a variable air flow plant. All data transferred to the control system can be elaborated to automatically vary the configuration of the environmental ventilation apparatus, functioning according to specific prearranged algorithms.

Therefore, this plant is able to determine, inside the test room, the desired microclimatic conditions, in thermalhygrometrical terms and determine also, the concentration level of dirt particles or toxic substances. In the future will be carry out microbiological dispersion tests too.

The field tests come developed in operating rooms of S.S. Annunziata Hospital in Cento (Ferrara), where has been installed a supervision systems able to acquire:

- all the parameters of HVAC system (temperature, pressure, air flow rates for grille, state of the doors, pressurization level of the room and so on);
- all the operational parameters, like the kind of operation, the number of personnel, the metabolic characteristics of the patient, the level of chemical pollution and particulate and microbiological concentration;
- clinic parameters (the rate of anaesthetic infusion, the clinical data of the patient - blood pressure, respiratory rate, heart rate, CO2 average end total pressure, O2 consumption rate, shivering level, antibiotic profilaxis, body temperature and so on)

A special server acquires the above mentioned data and collect them in a database with which it will be possible in the next months to have a sufficient description of the microbiological, physical, chemical, clinical and climatic condition for every operation.

The scheme of the entire installation is shown in Fig. 3 and Fig. 4.
5. CONCLUSIONS

By the use of an operating theatre model at real scale, it will be possible to determine the appropriate ventilation rates for obtaining the dilution of chemical (anaesthetic gases) and physic-biological contaminants. It will be useful for the determination of microclimatic parameters (temperature and relative humidity) necessary for avoiding risks for the patients, such as hypothermia, and for assuring comfort of the surgical team.

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