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STUDY OF THE THERMAL COMFORT, OF THE ENERGY CONSUMPTION AND OF THE INDOOR ENVIRONMENT CONTROL IN SURGERY ROOMS

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ABSTRACT
In this research were investigated the influence of different layouts of operating rooms on thermal comfort, on the indoor environment control and on energy consumption.

The layouts studied were: Case 1 (a surgery room and a hallway); Case 2 (a surgery room and two hallways); and Case 3 (a surgery room, an anteroom and a hallway). These environments were simulated for five Brazilian cities.

It was used the software EnergyPlus.

The environmental parameters were pre-established by standards.

On Case 2 the energy consumption was the lowest and the thermal sensation for people was the best. The thermal sensation of the patient was extreme discomfort, while the anesthesiologist presented discomfort in some cases and in other much discomfort. The other people remained in comfort or in a little discomfort.

In the three layouts, the temperature and relative humidity remained within in the required range. Therefore, there was not growing of microorganisms.

INDEX TERMS
Indoor environment quality; thermal comfort; energy consumption; operation room; building simulation

INTRODUCTION
The people stay the major part of the time in the indoor of the environment. The characteristics this environment will influence in the health, in the productivity of the work and also in the thermal comfort of these people.

The quality of the environment will depend of various variables, for example, of the indoor air quality, of the characteristics of the architecture and of the use of the environment.

In environments where the indoor air is controlled by air-conditioning it is necessary a major care. The air-conditioning is used to maintain the requirements of the environment in accordance with the use and number of people. In hospital, for example, it is very important to maintain the requirements of the patient, and sometimes it is deteminant factor to the treatment of the patient.

Various research have been realized about indoor environemtn quality in Hospital. In thesre researchs were verified also the influence of the environment in the infection control. For example, Siqueira (2000) verified that from 0% until 20% of the infection in hospital had the main source the environment.

The control of the indoor environment in hospital it is possible through of the control of the temperature, of the relative humidity, of the use of different pressures, of the use of filters, of the politic of access in the environment, and also of the politic of infection control.

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The proposal of this research was to evaluate the indoor environment control, the Predicted Mean Vote (PMV) and the energy consumption in three different layouts of operating room and different type of surgeries.

To research the thermal comfort it is very interesting, because each person present different type of the activity and different type of the clothes. Some times these people had different influence of the variables of the environment in accordance with your position in the operating room.

The types of surgeries evaluated were the orthopedic and the abdominal. These surgeries were considered aseptic and septic, respectivaly.

The orthopedic surgery need indoor air requirements Class I, while the abdominal surgery need requirements Class II, in accordance with the ASHRAE (2001).

In this research was made only simulation. The environments were simulated through of the EnergyPlus software. It was determinate this software because it presented good results in other researches. The EnergyPlus was validating, and on researches of Grings, E. T. O., Beyer, P. O. (2002), of Wallauer, M. D. e Beyer, P. O. (2002) and of Grings, E. T. O. (2003) was verified its efficiency.

All characteristics of the environment, of the indoor air, standards used e other details will be commented on simulation.

RESEARCH METHODS

Two types of software were used in the simulation: the Cterm version 2002 and the EnergyPlus version 1.03.

The Cterm was used to calculate the level of activity of the person (LAP=metabolism x 1,8 [W/people]), thermal resistance of clothes (TRC, [clo]) and effectuated work (EW, [W/m^2]).

Dr. Paulo Otto Beyer and M. José Luis Salvadoretti developed the Cterm, both of the Federal University of the Rio Grande do Sul (Brazil). This software calculates the thermal comfort through thermal balance. The table 1 presents the results of the simulation which afterwards were used in the software EnergyPlus.

The data solicited by Cterm were: the temperature (19°C), the relative humidity (45%) and the wind speed - 0,25 to patient, for the surgeon and for the auxiliary nurse; 0,28 to anesthesiologist and other nurse[4,5] when occurred the abdomen surgery and 0,39 for orthopedic surgery).

Table 1. *Results of Cterm*

People	LAP	TRC	EW
Patient	72	0,63695	0
Surgeon	230,4	0,87910	11
Anesthesiologist	108	0,68700	3,49
Nurse [4]	216	0,8791	9,92
Nurse [5]	180	0,68700	9,92
Nurse [6]	180	0,68700	7,45
Cleaning view washing	284,4	0,68700	15,51

1

The Cterm need also information about the people occupying the surgery room. In this research was stipulated a typical person of weight (70 kg), height (1,70 m) and the clothes. The clothes were described in accordance with the function of this person during the surgery. The Emissivity and Permeability of clothes used on the software were 0,9 and the 0,4, respectively.

About the software EnergyPlus, this was developed by the U.S. Department of Energy - Energy Efficiency and Renewable Energy. It enables various calculations. However, in this research were simulated the PMV, the

4 - Auxiliary nurse
5 - Nurse work into surgery room and in the hallway
6 - Nurse that prepare the room and patient

variables temperature and relative humidity, and the energy consumption.

Three types surgery room layouts were simulated: Case 1, Case 2 and Case 3. The layout Case 1 presents a hallway and an operating room. The Case 2 present a clean hallway (Class I), the operating room and one hallway (Cass II). The Case 3 has one hallway, one anteroom and one operating room. These layouts can be observed in Figure 1. The dimensions of these environments were established by Ministério da Saúde (2002) regulations.

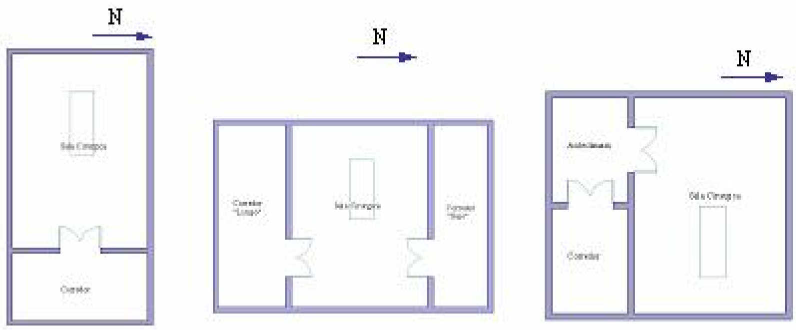

Figure 1. *Layouts evaluated – Case 1, Case 2 and Case 3, respectively*

The patient requirements were pre-established in accordance with the type of surgery studied.

The dry bulb temperature, relative humidity, wind speed, pressure and other variables were based on the standard ABNT (1982), ASHRAE (2001) and for Ministério da Saúde (2002). The pressure was defined in accordance with the ABNT (1982).

The Brazilian cities evaluated were Belem, Brasilia, Porto Alegre, São Paulo and Recife. These cities were chosen, because each present one different type of climate. Of these cities, four were simulated for one year, one summer day and winter day. The city of Porto Alegre was only simulated for one summer day and one winter day. The data about the climate were collected in the ASHRAE (2001). However, the humid bulb temperature was based on the values of Gourlart, Lamberts and Firmino (1997).

The days simulated were the 21 January (summer day) and the 21 July (winter day).

The "Sky Clearness" was stipulated clean.

The details of the built will be described below.

In the three layouts, the walls north and east divided the indoor environment with the outside. The other walls divided the operating room with other environments.

The walls north, east and the other walls of the operating room had a width of 0,27 m, while other walls had a width of 0,22 m.

The walls were "built" in brick (0,15 m and 0,20 m – type "six hole"), mortar (0,025 m), plaster (0,01 m) and paint. These walls were described in layers, where the first were plaster, mortar, brick, mortar and plaster again. The paint was not considered, because its thickness is insignificant. However, it was stipulated that the absortivity of paint on the place of the absortivity of the plaster (last layer). For orthopedic surgery it was used steel in the walls.

The floor was described in layer: ceiling of gypsum (0,03 m), air (1 m), flagstone (0,12), mortar (0,02 m) and gait (0,05 m, this is made of "plastic").

The ceiling was described first by a flagstone (0,12 m), air layer (1 m) and a ceiling of gypsum (0,03 m).

The doors were described by two pieces of steel and air (total thickness was 0,15 m). However, when it was simulated the orthopedic surgery, the door was described with a pieces of lead (Pb) between the steel.

The characteristics of the materials were stipulated conform specification of Lamberts, R., Ghisi, E. and Papst, A.L (2000), and Incropera, F.P. and Witt, D.P. (1992).

It was also fundamental to consider the factors that would influence the thermal environment and in the energy consumption. The heating sources considered were the medical equipment, the lights and the people – hospital team and patient. The values with illumination were 240 W of incandescent light, 630 W of operating light, 480 W of fluorescent light and 150 W of auxiliary operating light. The lights were described in accordance with the time of use of the environment.

The incandescent light, the operating light and auxiliary operating light were switch the period from 07:00 hrs until 09:00 hrs, from 10:00 hrs until 13:00 hrs, from 14:00 hrs until 16:00 hrs, from 18:00 hrs until 20:00 hrs. The fluorescent lights in the surgery room and anteroom were switch on at 06:00 hrs until 22:00 hrs.

The equipment had power total of 2245 W for the orthopedic surgery, and 1815 W for the abdominal surgery.

The operating room was occupied in the times: from 07:00 hrs until 09:00 hrs, from 10:00 until 13:00 hrs, from 14:00 hrs until 16:00 hrs and 18:00 hrs until 20 hrs.

In the times from 09:00 hrs until 10:00 hrs, from 13:00 hrs until 14:00 h, and from 20:00 hrs until 22:00 hrs, the operating room was occupied for cleaning view washing.

The case simulated were: **C1AS** [**C**ase **1** and **a**septic **s**urgery], **C1SS** [**C**ase **2** and **s**eptic **s**urgery], **C2AS** [**C**ase **2** and **a**septic **s**urgery], **C2SS** [**C**ase **2** and **s**eptic **s**urgery], **C3CA** [**C**ase **3** and **a**septic **s**urgery] and **C3CS** [**C**ase **3** and **s**eptic **s**urgery].

RESULTS AND DISCUSSION

The dry bulb temperature remained within in the required range and it was conform expectation in all cases. The medium air temperature and medium radiant temperature modified in accordance with the use of the environment.

The operating room and the hallway (Class II) presented 60% of relative humidity. In 87,76% of the cases evaluated the relative humidity was above of the limit accepted. Therefore, it was necessary to use a dehumidifier.

The humidity in the anteroom and hallway (Class I) presented a little increased in the time that the environments were used.

The thermal comfort was simulated and evaluated in accordance with ISO (1993). In all the cases the patient presented the thermal sensation of extreme discomfort, with alterations in the PMV from **-** 4 until **-** 6. The anesthesiologist presented values between discomfort and much discomfort. The surgeon, the auxiliary nurse and cleaning view washing presented one slightly discomfort, with thermal sensation of slightly hot. The nurses[5,6] presented the slightly comfort, with thermal sensation of slightly cold.

Five cities were simulated. However, only the city of São Paulo and of Porto Alegre will have reported the results.

The best situation of thermal comfort was observed for city of Sao Paulo, in the Case 2 and in the winter day. The thermal sensation improved for the patient and for the anesthesiologist. In the case C2CA1 the patient presented **-**4 and the anesthesiologist the value between **-**1 and **-**2. However, in the same case the slightly discomfort of the surgeon and auxiliary nurse increased a little – but it does not reached **-**1 on the scale of PMV.

The thermal sensation for the city of São Paulo was similar to the summer day and to the winter day, on majority of the cases.

For the city of Porto Alegre, the Case 2 was also the best to the PMV. In some cases, the thermal comfort presented a little alteration, because of the climate and simulation day. However, the thermal sensation these people do not changed.

In the total energy consumption were included the consumption with light, equipment and air-conditioning. In this part, it is important to remainder that only four cities were simulated. However it will be commented only the cases simulated to orthopedic surgery, because these presented the highest energy consumption.

The Table 3 present the results of annual energy consumption in orthopedic surgery for the cities of Belem, Brasilia, São Paulo e Recife.

Table 2. *Annual Thermal Consumption*

Cases	Energy Consumption (kWh)
C1AS2 - Belem	25715,02
C1AS2 - Brasilia	25492,86
C1AS2 - São Paulo	25520,63
C1AS2 - Recife	25659,48
C2AS1 - Belém	28880,80
C2AS1 - Brasilia	28880,80
C2AS1 - São Paulo	28880,80
C2AS1 - Recife	29158,50
C3AS1 - Belem	28880,80
C3AS1 - Brasilia	28603,10
C3AS1 - São Paulo	28603,10
C3AS1 - Recife	29436,20

The highest energy consumption occurred on case C1CA2 to Belem city, while in the case C2CA1 and C3CA1 it was verified to the city of Recife. These cities presented these results, because both present the winter day with characteristics of a summer day.

In the cities of São Paulo and Brasilia was verified a difference on energy consumption of 27 kWh. In other cases the energy consumption was the same.

The Case 2 and Case 3 presented highest annual energy consumption and it was verified a difference of 277,70 kWh.

The Case 1 presented lowest energy consumption. However, the Case 2 presented the lowest energy consumption, when evaluated only the energy consumption on operating room.

CONCLUSION

It was verified that the layout of the operating room had a little influence in the thermal comfort.

The thermal comfort in the operating room was influenced for type of surgery and also for climate of the city. The type of surgery influenced, because the requirements and the heating sources were different for the orthopedic and abdominal.

About the indoor environment control, the temperature and relative humidity remained within in the required range for all cases. Therefore, there were not favorable conditions for growth of microorganisms.

The Case 2 presents the advantage in the control of the environment, because it permitted to use different pressures in each zone. Other advantage this case, it is that in this layout there is a major control on access of people in the operating room. Therefore, it was possible to difference in accordance with the type of surgery.

The layouts also influenced on energy consumption, like it could verify in the results. However, it was not significant the difference between each case.

Other analyse important is to evaluate the cost-benefit of each layout. Of the cost to built the three layouts, the Case 2 is the more expensive. It must to be also evaluated, before to opt for a layout or other, what case it the more efficient on infection control, and to compare the cost of the treatment/day of one patient with infection.

In this research it was made these analises. It was verified various advantages in the Case 2, mainly because this ensure a more control of the environment.

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