Assessment of Thermal Comfort During Surgical Operations

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ABSTRACT

The thermal environment was studied in two operating rooms at the Montreal General Hospital. Thermal comfort of the staff was assessed based on measurements of the environment during surgical operations and on questionnaires given to the staff. Infrared pictures of representative surfaces and people were also taken and, when possible, skin and core temperatures of the patient were also measured. The thermal resistance of clothing and the activity levels for all the people were estimated from published tables and previous research studies. Three thermal zones were studied: zone 1, bounded by the patient, the surgical staff, and the surgical lights; zone 2, the adjacent area; and zone 3, the farthest one. It was found that under the present environmental and personal conditions it is not possible to provide all groups of people with an acceptable thermal environment. In general, surgeons tend to feel from slightly warm to hot (they sweat very often), anesthesia staff and nurses from slightly cool to cold, and the patient from slightly cool to very cold (patients sometimes woke up shivering). In addition to questionnaires, thermal comfort was predicted based on Fanger's PMV model, which assumes a uniform thermal environment. Based on Fanger's model, the air temperature that could have ensured satisfactory thermal comfort for the surgeon, under the particular conditions studied, was about 66°F (19°C). However, at that temperature, to remain in good thermal comfort, nurses and anesthetists must be clothed with at least 0.9 clo and the patient covered with at least 1.6 clo. In practice, however, the radiant temperature asymmetry from the surgical lights in zone 1, which ranges between 11°F (6°C) and 13°F (7°C) over the operating table and between 18°F (10°C) and 22°F (12°C) over the floor (at a level of 1.1 m), causes surgeons' dissatisfaction with the environment at any air temperature. Possible solutions to minimize radiation and its effects on the surgeons are discussed, which would permit ambient temperatures more favorable for the patient and all the staff.

INTRODUCTION

The environmental design of hospital operating rooms (ORs) is a challenging process. Its aim is to prevent the infection of the surgical wound by airborne infectious (viable) microorganisms while keeping the staff and the patient comfortable. Unlike office buildings, where environmental design is aimed to provide thermal comfort, in hospitals (and more specifically in hospital ORs) thermal comfort is considered a secondary issue. However, the good thermal comfort of the surgeon and all the staff must be ensured so that they can work under the best possible conditions for a successful operation. Therefore, a major aim of the environmental design for operating rooms should be to provide the surgeon with the best conditions in which to work comfortably without ignoring the other people present in the OR.

There are two groups of people, in addition to the patient, in the OR: the surgical team (surgeons, scrub nurses) and the service team (anesthetists, nurses, technicians). The service team is positioned away from the patient and they circulate within or outside the room most of the time.

For aseptic purposes the OR can be divided into three zones, as shown in Figure 1 (Woods et al. 1986). Zone 1 is bounded by the surgeons, the patient, and the surgical lights, and is called the "microenvironment." This must be the cleanest zone in the OR. Zone 2 surrounds the microenvironment and is called the "sterile zone." It is the area that contains the surgical instruments and equipment. The scrub nurse (assis-

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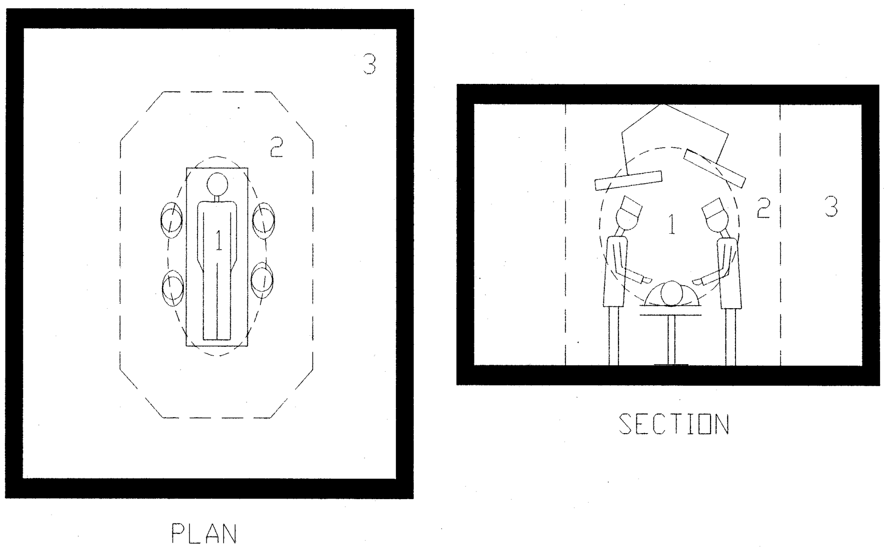


Figure 1 *Zoning of the operating room according to sepsis criteria.*

tant nurse) circulates between zones 1 and 2. Zone 3, called "mini-environment," is the least clean zone in the OR. The circulating nurses, technicians, and anesthetists circulate in this zone. As stated by Lewis (1987), "optimum air distribution systems must provide the cleanest conditions within the surgical field (i.e., zones 1 and 2) rather than in the entire room."

The same three zones in the OR can be adopted for thermal comfort analysis. Due to the air distribution system, higher air speeds and lower turbulence intensity are expected in zones 1 and 2. It follows that a greater convective heat loss is expected from people in zones 1 and 2 as compared to people in zone 3. On the other hand, the thermal radiation from surgical lights and the greater concentration of people increase the heat generated in zone 1, and so a greater heat gain by radiation is to be expected by staff around zone 1 as compared to zones 2 and 3. In addition, the thermal resistance of clothing and the activity level are higher for people who are near the patient, i.e., bounding zone 1.

Such thermal differences between zones and people in the OR have been reported by different researchers. Woods et al. (1986) found an air temperature difference of about 2.7°F (1.5°C) between zone 1 and zones 2 and 3. Johnston and Hunter (1984) stated that in order to prevent the patient from becoming hypothermic during surgery, a temperature between 75°F (24°C) and 79°F (26°C) is required. They stated that at temperatures below 70°F (21°C) the patients nearly always become hypothermic. For the staff they recommended air temperatures between 68°F (20°C) and 72°F (22°C). Wyon et al. (1968) defined an index temperature (which combines the actual air temperature and the mean radiant temperature under 50% relative humidity and at mean air velocity of 0.127 m/s) preferred by surgeons, anesthetists, and nurses. They found that the index temperature at which the highest proportion of the staff is comfortable is 68.9°F (20.5°C). For the highest comfort of the surgeons they recommend an index temperature of about 64°F (18°C). They also found that anesthetists prefer temperatures of about 70.7°F (21.5°C) (1° higher than the average). Olesen and Bovenzi (1985) also recommend different equivalent temperatures (similar to operative temperature but takes into account the effect of airflow) for the members of the staff. For anesthetists they recommend equivalent temperatures between 73°F (23°C) and 76°F (24.5°C), for nurses between 72°F (22°C) and 76°F (24.5°C), and for the surgeons about 66°F (19°C).

This study focused on the Montreal General Hospital (MGH), taking into account complaints from staff. It investigated in detail the thermal environment during surgical operations and its effect on occupant thermal comfort. This paper follows a factual approach to the problem based on field measurements and the application of the Fanger thermal comfort model (Fanger 1970, 1982).

METHODOLOGY

The Surgical Facilities

Eleven tests were performed in two operating rooms at the MGH. The hospital was built in 1955 and its mechanical system has been partly upgraded. For the surgical area, a traditional HVAC system was provided (i.e., 100% outside air, constant volume, terminal reheat) with two dedicated air-handling units, each one for half of the ORs. The temperature in each OR is set by the staff with the aid of manual pneumatic controls that are connected to the terminal reheat coils. The system is not provided with individual humidity control for each OR. Most of the tests were performed in an orthopedics OR, in which the air distribution system is laminar (i.e., unidirectional) horizontal, supplying air directly to zones 1 and 2.

The laminar flow was maintained throughout zones 1 and 2 by lateral extensible panels. An OR with an air shower flow system was also used for three of the tests. The air shower flow was supplied at the ceiling level by perforated metal diffusers in a unidirectional fashion, but no panels or curtains were placed to maintain unidirectional flow and to prevent the primary air from mixing with the room air.

Measurements

All tests were performed while surgical operations were taking place. During each test the air temperatures, relative humidities, and surface temperatures of the walls, ceiling, and floor were measured approximately every 15 minutes. The air temperatures and relative humidities were measured at 0.1 m, 1.1 m, and 1.7 m above the floor and at different positions within zones 2 and 3 (due to sepsis control, measurements were not permitted in zone 1). However, it was found that there was no significant variability in the air temperature and relative humidity over space (zones 2 and 3) and time during the operation. The airspeed was always measured near the patient's head at 1.7 m above the floor level. In some occasions, it was also measured in different places in the OR, such as in zones 2 and 3 and near the diffusers when the room was empty. Infrared thermograms of people and room surfaces were also taken.

Measurements in zone 1 were also performed while no operations were taking place. Subjects were positioned simulating the surgical staff, with the surgical lights in position and turned on, to identify the thermal differences between the zones. The plane radiant temperature in six directions was measured at 1.1 m from the floor level with the operating table in normal position.

Questionnaires

Immediately after each operation, questionnaires were completed by the staff. A total of 51 questionnaires were completed. Thermal comfort was assessed based on a nine-point scale, the same as the PMV scale but with the “very cold” and “very hot” points added at both extremes. This is because results far from the comfort zone were expected. A model of the questionnaire is presented in the appendix.

Personal Comfort Variables

The activity level was obtained from published data (ASHRAE 1997) based on similar activities. For the service staff 1.4 met was assumed and 1.6 met for the surgical staff (values in agreement with Olesen and Bovenzi 1985). The thermal resistance of clothing for the staff was also based on published data (ASHRAE 1997). In addition to underwear, the basic uniform for the staff consists of thin pants and a short-sleeve, wide-neck blouse for a total clothing insulation of 0.42 clo. However, during the experiments this insulation level was found only in the anesthesia staff and in some nurses. Most of the nurses expressed that they felt cold wearing the basic uniform only. Therefore, in addition to the uniform, they often wore a t-shirt below the uniform blouse and/or a thin jacket for a total insulation of 0.78 clo. Due to the cleanliness requirements in zones 1 and 2 (near the patient), the surgical staff needs to be clothed, in addition to the uniform, with a surgical gown, sterile gloves, and galoshes (for the feet), for a total insulation of 0.86 clo. When x-rays are taken during an operation, a lead apron is also required for all the staff. For the patient, the bedding and covering insulation were calculated based on McCullough and Jones (1984) and McCullough et al. (1987). The patient’s insulation varies widely (from 0.6 clo to 1.0 clo), depending on the type of surgery and on the extent of body area covered by the blankets. For long surgeries, hot air convective blankets are also used to keep the patient warm. However, the patient deserves special attention and further research: he/she is largely uninsulated, and because of his/her low metabolic heat generation, there is a potential risk of becoming hypothermic. Table 1 shows the personal comfort variables for the staff and the patient.

TABLE 1
Thermal Resistance of Clothing

Staff	I (clo)	Remarks
Anesthesia	0.42	Basic uniform
Nurses	0.42–0.78	0.78 clo: added t-shirt + jacket
Nurses walking	0.20–0.58	Speed = 3.7 km/h
Surgeons/scrub nurses	0.86	Basic uniform plus surgical gown, gloves, and galoshes
Patient	0.60–1.10	Depending on how well covered the patient is

RESULTS AND DISCUSSION

Despite the fact that the setpoint temperature was almost always set by the surgical staff to the lowest value (65.3°F, 18.5°C), the average room air temperature for all tests was about 70.7°F (21.5°C) and ranged between 66°F (19°C) and 77°F (25°C). This could be due to a calibration problem with the pneumatic controls or to higher thermal loads in the OR as compared to design. On the other hand, the average relative humidity was about 43% and ranged between 24% and 63.5%.

In zones 2 and 3 it was found, by infrared thermograms, that the surface temperature for all room surfaces was always within 1°C and 2°C of the air temperature. This indicates that the air temperature, the mean radiant temperature, and the operative temperature had approximately the same value. In zone 1, the mean radiant temperature ranged from 79.7°F (26.5°C) to 80.6°F (27°C), and the operative temperature (T_{op}) ranged between 74.3°F (23.5°C) and 75.2°F (24°C) due to the thermal radiation from the surgical lights. A temperature asymmetry between 11°F (6ºC) and 13°F (7ºC) over the operating table was also found. Based on this asymmetry and on floor temperatures, the radiant temperature asymmetry over the floor level was estimated to range between 18°F (10ºC)

TABLE 2
Summary of the Environmental and Personal Variables in the OR

	Units	Zone 1	Zones 2 and 3
Environmental Variables			
Air temperature	°C	21.0–25.0	19.5–25.0
Operative temperature	°C	23.0–27.0	19.5–25.0
Operative temperature, surgeons (45% zone 1, 55% zones 2&3)	°C	21.5–25.5	—
MRT	°C	26.0–28.0	19.5–24.0
MRT surgeons (45% in zone 1, 55% in zones 2&3)	°C	22.5–26.0	—
Air velocity	m/s	0.13–0.30	0.07–0.26
Relative Humidity	%	43.0%	43.0%
Radiant asymmetry	°C	6.0–7.0	—
Personal Variables			
Activity:			
Surgeons	met	1.6	—
Anesthetists	met	—	1.4
Nurses	met	—	1.4
Patient	met	0.69	
Clothing thermal resistance			
Surgeons	clo	0.86	—
Anesthetists	clo	—	0.42
Nurses	clo	—	0.42–0.78
Patient	clo	0.6–1.10	—

and 22°F (12ºC). In addition, the operative temperature difference between zone 1 and the rest of the room was found to be about 5.4°C. However, the operative temperature felt by the surgeons is a combination of T_{op} in zone 1 and T_{op} in zones 2 and 3. Taking a weighted average according to the part of the body in each zone resulted in T_{op} felt by surgeons about 2°C to 3°C higher than for the rest of the staff. Finally, as expected, the airspeeds were highly variable over space and time: they ranged between 0.07 m/s and 0.30 m/s; the highest airspeeds and the lowest turbulence intensities were found in zone 1. Table 2 shows a summary of the environmental and personal variables measured and calculated in the different zones of the OR.

The thermal differences between zones and people in the OR were confirmed with the aid of infrared thermograms. Figure 2 shows four representative infrared thermograms, and Table 3 shows average skin temperatures for the different groups on the staff. From the thermograms it is apparent that the face and neck temperatures of the surgical team are elevated about 1.8ºC ≈ 2°C over that of the anesthesia staff and about 3.6°C over that of the circulating nurses. In addition, the surgeons' hands are about 5.4°C warmer than the anesthesia staff's hands and about 7.2°C warmer than the nurses' hands.

TABLE 3
Approximate Skin and Clothing Temperature for the Staff

Part of the Body	Average °C		
	Surgeons/ Scrub Nurses	Nurses (women)	Anesthesia (men)
Face	35.85	33.50	34.40
Hands	37.35	33.20	34.20
Neck	36.15	34.15	35.10
Clothing	27.50	27.00	27.10

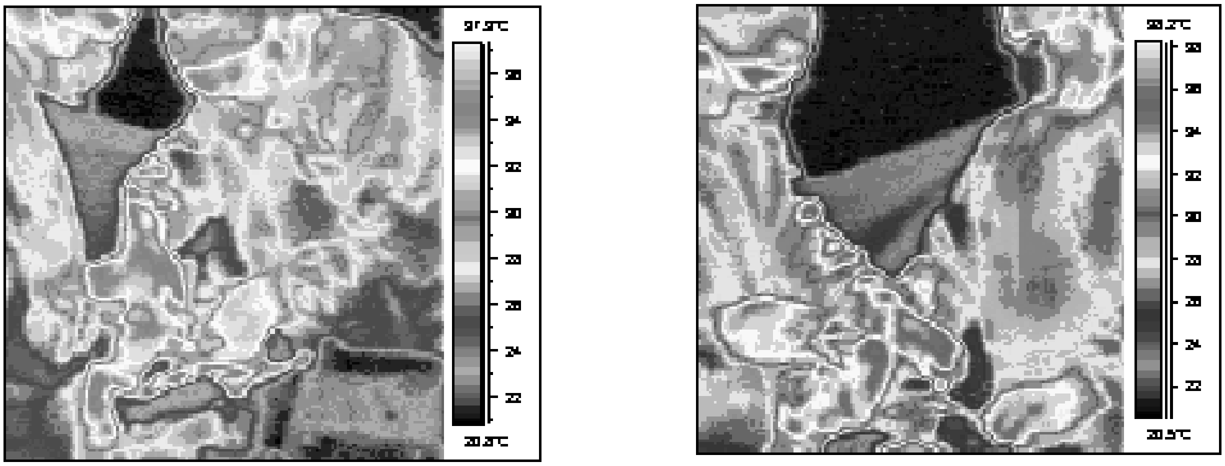
The elevated skin temperatures on the surgeons' hands, upper torso, and head clearly show the heating effect on the surgical team of the thermal radiation from the surgical lights. As a consequence, warm local discomfort is expected in these areas.

The results from questionnaires were analyzed in terms of trends and percentages in order to find the thermal comfort zone for the different members of the staff. Figure 3 shows the average thermal sensation per operation and the corresponding air temperature.

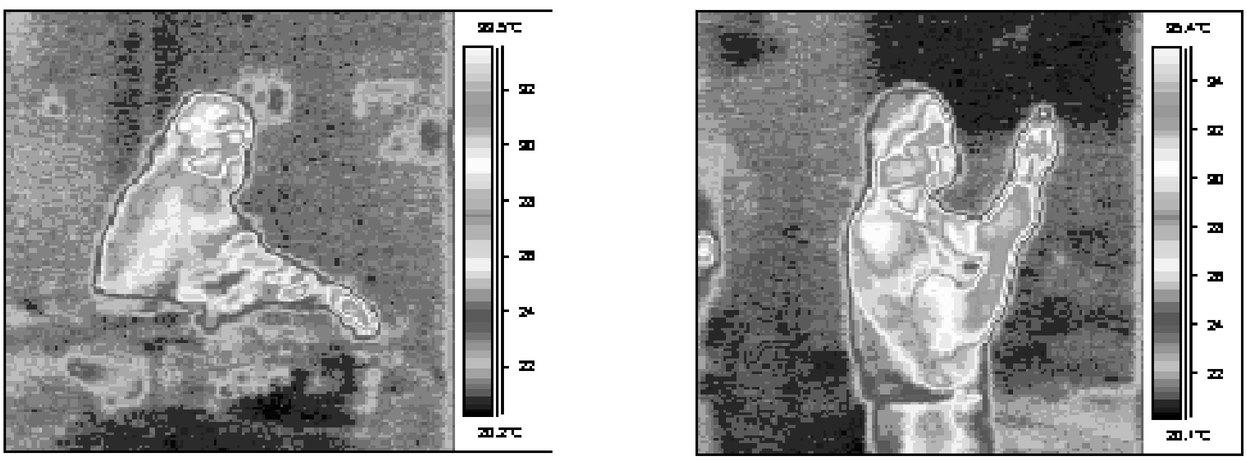
Figure 3 shows that the preferred air temperature (for thermal sensation between ± 0.5) for all the staff ranges from about 64.°F (18°C) to about 68°F (20°C). However, due to the great variability in the thermal conditions between zones and people in the OR, this result is inconclusive and the trend in the figure just confirms an expected relation between these two variables (air temperature and thermal sensation).

Figure 4 gives a better idea of the thermal sensation in each thermal zone. For the surgical team (squares), the figure shows that they feel warm no matter what the air temperature is. This means that, under their present working conditions, thermal comfort cannot be achieved. For nurses and anesthetists, by contrast, the comfort air temperature ranges between 69.8°F (21.0°C) and 72.5°F (22.5°C). However, if they wear the basic uniform only, the comfort air temperature will increase significantly as is predicted later using Fanger's thermal comfort model.

For the surgical team, 52% answered that they sweat during the operations, and 43% felt localized warm discomfort on the head region due to the thermal radiation from the surgical lights. However, this percentage (43%) could have been higher considering that most of the surgeons answered that they felt uncomfortably warm on the head region but they did not know the cause, which could be thermal radiation from surgical lights, elevated clothing insulation, nervous tension, or higher activity level. On the other hand, draft was felt only by 13% of the surgical staff. For the service team, draft was felt 48% of the time, and it was felt mainly on the exposed arms, head, and back of the neck. This is because of the uniform,



Surface	Maximum Temperature °F (°C)	Surface	Maximum Temperature °F (°C)
Wound	99.5 (37.5)	Surgeon’s arm and hands	101.3 (38.5)
Surgeon’s hands	99.1 (37.3)	Clothing, chest to stomach	87.8 (31.0) to 82.4 (28.0)
Surgeon’s face	95.7 (35.4)		
Clothing, shoulders to waist	88.7 (31.5) to 75.2 (24.0)		



Surface	Maximum Temperature °F (°C)	Surface	Maximum Temperature °F (°C)
Neck	92.3 (33.5)	Face	92.3 (33.5)
Face	92.3 (33.5)	Arms	93.6 (34.2)
Hand	90.7 (32.6)	Neck	95.4 (35.2)
Clothing, shoulders to waist	82.4 (28.0) to 76.1 (24.5)	Clothing, shoulders to waist	88.2 (31.2) to 73.4 (23.0)

Figure 2 *Representative infrared thermograms. Top pictures show surgical staff, bottom pictures show nurse and anesthesia staff.*

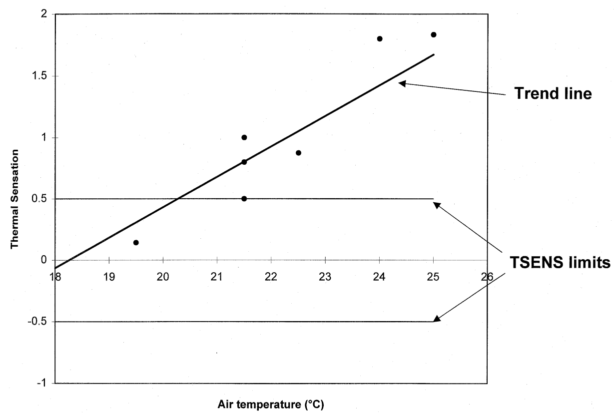


Figure 3 *Thermal sensation vs. air temperature (average per operation).*

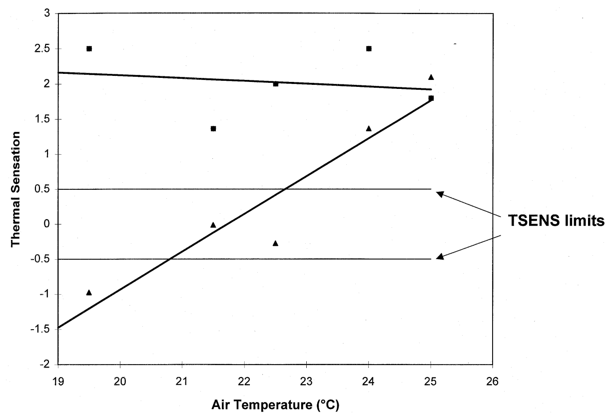


Figure 4 *Thermal sensation in zone 1 (squares) and zones 2 and 3 (triangles).*

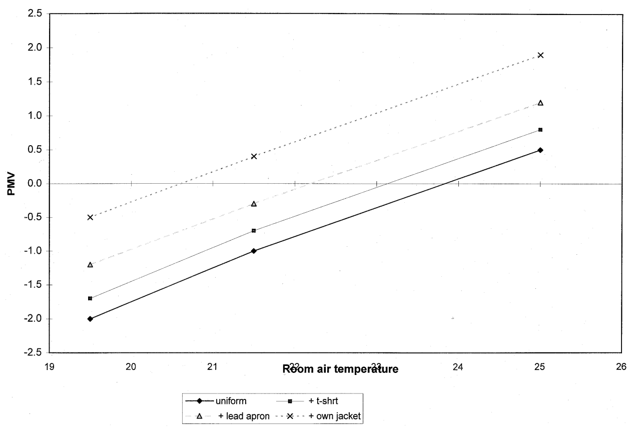


Figure 5 *PMV for nurses and anesthetists.*

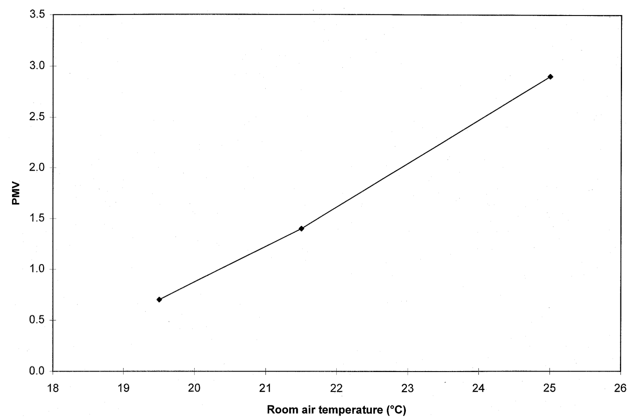


Figure 6 *PMV for surgical staff.*

which leaves these two body areas uncovered. It is important to add that after some of the operations the patient woke up shivering and his internal body temperature was (when measured) usually below normal.

As a conclusion from the questionnaires, a “slightly warm” to “warm” thermal sensation is always felt by the surgical staff. Regulatory sweating is also present very often. The service staff, by contrast, experiences a “slightly cold” thermal sensation. This is especially true for temperatures below 70°F (21°C), mainly because of the low clothing insulation. Draft is also a factor of discomfort for the service staff.

In addition to the questionnaires, Fanger’s model was used to predict the thermal comfort of the staff and the patient with different clothing ensembles and bed coverings. Figures 5, 6, and 7 show the predicted mean votes for the service staff, the surgical staff, and the patient, respectively. As shown in Figure 5, for the nurses and anesthetists wearing uniforms, in order to achieve thermal comfort, the room air temperature should range from about 73°F (23°C) to 75°F (24°C). Figure 6 shows that the surgeon’s air temperature for thermal comfort

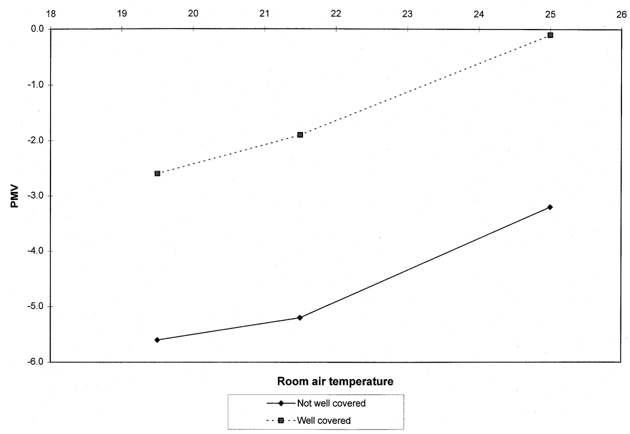


Figure 7 *PMV for the patient.*

would be expected to range between about 64°F (18°C) and 66°F (19°C). And Figure 7 shows that if the patient is well covered (1.1 clo) the required room air temperature for thermal comfort should range from about 76.1°F (24.5°C) to 77.9°F (25.5°C).

These results are in agreement with the results given by Olesen and Bovenzi (1985) who specified equivalent temperatures for thermal comfort for anesthetists (73°F to 75°F [23°C to 24°C]), for nurses (72°F to 76.1°F [22°C to 24.5°C]), and for surgeons (66°F [19°C]). Wyon et al. (1968) specified an equivalent index temperature of 64°F (18°C) as more comfortable for surgeons. For the patient, Johnston et al. (1984) recommended air temperatures ranging from 75°F (24°C) to 79°F (26°C), which is in agreement with the present results.

Through the analysis of the previous data it is apparent that the simplest means to improve the thermal comfort of all the occupants is by clothing variations. Since the surgical staff cannot reduce their clothing level (0.86 clo), the only possible room air temperature that would maintain their thermal comfort is about 66°F (19°C). At this air temperature, the patient would require at least 1.6 clo and the circulating nurses and anesthetists at least 0.9 clo (add t-shirt and jacket to their uniforms).

However, Fanger's model does not include the effect of nonuniform environmental conditions caused by drafts on uncovered arms and necks of nurses and anesthetists and asymmetric thermal radiation from surgical lights on the surgical staff. Sweating produced by uncomfortably warm surgeons and shivering by surgical patients, who are not well covered, are also not considered in Fanger's model. The effect of the asymmetric thermal radiation from surgical lights may be clearly appreciated by comparing the experimental results shown in Figure 4 (zone 1) with the predicted results shown in Figure 6. The asymmetric thermal radiation produces local thermal discomfort on the surgeons' upper bodies and reduces their thermal acceptability of the room. This factor is not considered in Fanger's model (Figure 6) and it explains why, in practice, the surgical staff never reaches thermal comfort (Figure 4). In this study, asymmetric thermal radiation between 11°F (6°C) and 13°F (7°C) was measured in zone 1, i.e., above the operating table, between the table and the lamps. However, the estimated asymmetry between the floor and the ceiling (lamps), which is the one affecting the surgical team, ranges between 18°F (10°C) and 22°F (12°C). Fanger et al. (1980, 1985) found that people are more sensitive to asymmetric radiation caused by an overhead warm surface than to any other type of asymmetry. Based on their results, ASHRAE Standard 55 (1992) specified a maximum of 9°F (5°C) of radiant temperature asymmetry in the vertical direction. Considering the surgical lights acting as a hot ceiling, and using the results from Fanger et al. (1980), radiant asymmetries like the ones affecting the surgical team, between 18°F (10°C) and 22°F (12°C), may cause 21% to 23% dissatisfaction when the body is thermally neutral as a whole.

It is apparent from the above results that the only means to provide a thermally comfortable environment for the surgical staff is to eliminate or to minimize the thermal radiation from the surgical lights or its effect on the upper bodies of the surgical team. The problem can be tackled at the source by cooling the surgical lights or replacing them with surgical lights with an integrated cooling mechanism. A second type of solution is to offset the effect of thermal load from the lamp with radiant cooling or convective spot cooling systems oriented toward the head and upper torso of the surgical team. However, convective spot cooling has the limitation that it may interfere with the airflow patterns in zone 1, and radiant cooling panels are limited to a minimum temperature of about 54°F (12°C) if condensation is to be avoided due to the raised OR humidity. This temperature may not be sufficient to offset the thermal radiation from the surgical lights, which radiate at an approximate temperature of 131°F (55°C). A third type of solution is to protect the surgeons from radiation by the use of special clothing. Reflective clothing may be used for the head and upper body, e.g., clothing with metallic threads, or moistened clothing to result in evaporative cooling. Howorth (1985) proposed for cleanliness control the use of a total-body gown with negative pressure exhaust. The gown covers the body from the head down and provides a window mask at the face level. A total-body gown could be adapted for thermal comfort, with a cooling system to cool the upper body. From the above solutions, the first—cooling the surgical lights or replacing them with surgical lights with an integrated cooling mechanism—seems the simplest and most readily available solution. In fact, some surgical light manufacturers today produce surgical lights that reduce thermal radiation; some of them claim that their lamps reduce 99% radiant heat from the bulb. Further research is required to analyze in more detail the possible alternatives to minimize the radiation from the surgical lights or its effect on the heads and upper bodies of the surgical team.

Considering the patient, further research is necessary in order to study the effect of the different variables influencing the patient's thermal comfort (i.e., surgery duration, type of surgery, etc.). Possible individual solutions to guarantee the patient's thermal comfort need also to be analyzed in great detail.

CONCLUSIONS

This paper focuses on a field study of thermal comfort in the operating rooms of the MGH and analysis of the results. It was found that in the ORs, under the present environmental and personal conditions, it is not possible to provide all groups of people with an acceptable thermal environment. In general, surgeons tend to feel from slightly warm to hot, anesthetists and nurses from slightly cool to cold, and the patient from slightly cool to very cold. Assuming a uniform thermal environment, the room air temperatures required for good thermal comfort for nurses and anesthetists, wearing standard uniform, would range between 73°F (23°C) and 75°F (24°C);

for the surgical staff, between 64°F (18°C) and 66°F (19°C); and for the patient, well covered (1.1 clo), from about 76.1°F (24.5°C) to 77.9°F (25.5°C).

However, nonuniform conditions prevail in the ORs. Due to the special ventilation requirements in the ORs and considering that the ORs are small and crowded, it is very difficult to introduce the required quantity of outside air without causing any drafts to nurses and anesthetists, and the effect of any draft is exacerbated by the short-sleeve uniform, which leaves their arms exposed. The simplest solution for the nurses and anesthetist is to increase their clothing insulation, taking care to cover their neck and arms to protect them from drafts. For the surgeons, the problem deserves more attention, as they feel dissatisfied with the thermal environment no matter what the air temperature is. The warm discomfort may be attributed in part to their higher activity level and higher clothing insulation. However, the greatest source of discomfort comes from the thermal radiation from surgical lights. The lights produce a radiant asymmetry ranging from 11°F (6°C) to 13°F (7°C) over the operating table in zone 1 and from 18°F (10°C) to 22°F (12°C) over the floor level (at a height of 1.1 m). Considering the surgical lights to be acting as a hot ceiling and using the results from Fanger et al. (1980), radiant asymmetries ranging between 18°F (10°C) and 22°F (12°C) may cause 21% to 23% rates of dissatisfaction even though the body is thermally neutral as a whole. This result was expected from the previous analysis of the infrared thermograms. As shown in the thermograms, the lights warm the head region of the surgeons and that is the most heat-sensitive part of the body.

As a consequence, the only means to provide a thermally comfortable environment for the surgical staff is to eliminate or to minimize the radiation from the surgical lights or their effect on the head and upper body of the surgical staff. Several possible solutions are proposed, such as using surgical lights with an integrated cooling mechanism, a readily available solution. Other solutions may include the use of reflective clothing for head and upper body, moistened clothing for evaporative cooling, etc. However, further research is required in order to analyze feasible solutions to provide the surgical staff with an acceptable thermal environment. Individual solutions to guarantee the patient's thermal comfort need also to be analyzed in greater detail.

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DISCUSSION

Charles A. Gaston, Assistant Professor, Pennsylvania State University, York, Pa.: Did anything change at the hospital as a result of this study?

Andreas Athienitis: They are currently implementing some of our recommendations.

Mary Jane Phillips, Mechanical Engineer, Olney, Md.: How is the "thermal comfort" of the patient during surgery determined since the patient is under anesthesia?

Athienitis: The patient was interviewed after the operation. This was not a major focus of the study and it needs to be further investigated.

David P. Wyon, Research Fellow, Johnson Controls Inc., Plymouth, Mich.; Adjunct Professor, International

Centre for Indoor Environment & Energy, Technical University of Denmark, Copenhagen, Denmark: In 1968, I reported almost identical results identifying an increase in clothing for non-sterile staff as the solution and cooling of the operating lamp as an important improvement. Very little has changed in over 30 years. The reason is that this is regarded as a comfort problem less important than health. The forum should be on determining whether internal conditions in operating theatres are affecting surgical skill and/or the outcome of operations. No reference to my research of this kind is given in the paper.

Athienitis: Unfortunately, not much has changed during these 30 years concerning the problem because the health funding agencies do not see this as a life-threatening problem. However, there is research showing that it adversely affects surgical operations.

APPENDIX

QUESTIONNAIRE TO THE SURGICAL STAFF AFTER OPERATION

PART I:

Date (dd/mm/yy): ______________________ Time: ______________________

1. Type of operation: ____

2. Sex (M/W): __________ Age:

Between 20 and 30 years old:	☐
Between 31 and 40 years old:	☐
Between 41 and 50 years old:	☐
More than 50 years old:	☐

3. To which Category of the staff do you belong? (detail if necessary)

Surgeon	☐	____________________
Anesthesia	☐	____________________
Nurse	☐	____________________
Technician	☐	____________________

4. How do you assess your thermal comfort at the moment you entered the OR to start the surgery:

Very cold	cold	cool	slightly cool	neutral	slightly warm	warm	hot	Very hot
-4	-3	-2	-1	0	1	2	3	4

5. How do you assess your thermal comfort during the operation:

Very cold	cold	cool	slightly cool	neutral	slightly warm	warm	hot	Very hot
-4	-3	-2	-1	0	1	2	3	4

6. How do you assess the thermal comfort of the patient during the operation:

Very cold	cold	cool	slightly cool	neutral	slightly warm	warm	hot	Very hot
-4	-3	-2	-1	0	1	2	3	4

Why? Give an example: i.e. the patient shivers, the appearance of the skin (color, texture), etc.

____

____

7. Did you feel any drafts during the operation? No ☐ Yes ☐
Draft: Unwanted local cooling of the body caused by air movement

8. List clothing you wore into the operating room:

____

QUESTIONNAIRE TO THE SURGICAL STAFF AFTER OPERATION

PART II:

9. Did you sweat during the operation? No ☐ Yes ☐

10. Did you feel local thermal discomfort due to: No / Yes

Heat from surgical lamps: ☐ ☐
If yes specify in which part of the body (neck, head, etc.): ____________

Heat from a specific equipment: ☐ ☐
If Yes specify the equipment: ____________

Cold because of drafts: ☐ ☐
If Yes specify in which part of the body: ____________

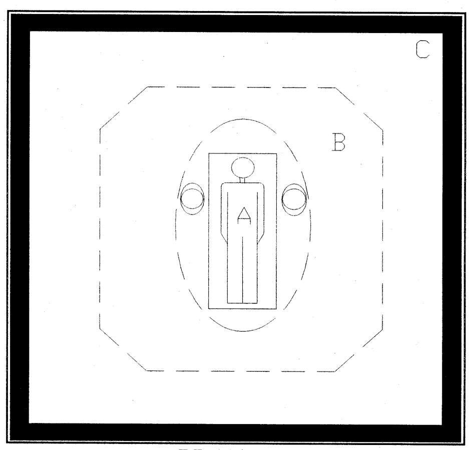
Cold because of nearby colder surfaces: ☐ ☐
If Yes specify a surface that bothers you: ____________

Cold some parts of the body. Unknown cause: ☐ ☐
If yes specify in which part of the body (neck, head, etc.): ____________

Warm some parts of the body. Unknown cause: ☐ ☐
If yes specify in which part of the body (neck, head, etc.): ____________

11. In which zone(s) (A, B, C) of the operating room did you work?
(see plan view)

A ☐
B ☐
C ☐



PLAN VIEW