Research on Temperature Control of Hospital Operating Room under Near Comfortable Conditions

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Abstract. Air temperature has a significant impact on human thermal sensation. It directly affects the heat exchange between the human body and the environment. It is the most important factor in the PMV index that affects human thermal sensation. Clothing thermal resistance is also one of the factors that affect human thermal sensation PMV. In the operating room of a hospital building, because the clothing of the operating staff is different from that of the ordinary office environment staff, the corresponding clothing has different thermal resistance values, which will directly affect the design temperature setting of the operating room. Close to the comfort zone, when wearing surgical gowns, through Matlab programming, the relationship between the PMV value in the operating room and the indoor set temperature and air flow rate is explored in detail, in order to improve the working environment of the operating room personnel and the energy saving of the operating room air conditioning system Provide a reasonable basis.

1. Introduction

With the rapid development of society, people pay more and more attention to the indoor environment in which they live. A comfortable environment not only brings a pleasant mood, but also improves work efficiency [1], in order to find a widely applicable comprehensive thermal comfort index, 1970 In 1984, POFanger proposed the comfort equation [2] and PMV, pointing out the six main influencing factors that affect human comfort. This index was determined by the International Organization for Standardization (ISO) and the standardized method of measurement (TSO7726) as the indoor thermal environment in 1984. Evaluation index.

Among the factors that affect the human body's thermal perception, environmental temperature, relative humidity, air flow rate and indoor average radiation temperature are environmental factors, and clothing thermal resistance and metabolic rate are individual factors. If you want to achieve a comfortable state, you can not only adjust the environmental parameters, and you can also improve the comfort of the human body through personalized adjustment of the human body, such as changing the way of dressing or the intensity of activity. This article analyzes the thermal resistance of the surgical gown in the hospital operating room, and when the activity level is constant, the interior design temperature and air flow rate affect the thermal comfort of the hospital operating room.
2. PMV equation

PMV is derived from the thermal balance equation of the human body. This index represents the thermal sensation evaluation of most people in the same environment. Combined with the average thermal reaction index of ASHRE level 7, this index has become an important index for people’s thermal sensation evaluation of air-conditioned rooms [3]. In this paper, PMV7 scale is used to evaluate thermal sensation moderation. The expression is as follows [2]:

\[
PMV = \left(0.303e^{-0.036M} + 0.0275\right)\left(M(1-\eta) - 3.054(5.765 - 0.007H - P_a) - 0.42(H - 58.15) - 0.0173M(5.867 - P_a) - 0.0014M(34 - t_a) - 3.9 \times 10^{-8} f_c(t_m - T_{\text{met}}) - f_c h_c(t_m - t_a)\right) \tag{1}
\]

In the formula, \(M\) is the metabolic rate of human body, which depends on the amount of human activity, W/m²; The mechanical work done by the human body, W; \(P_a\) is the partial pressure of water vapor in the air around human body, Pa; \(T_m\) is the air temperature around the human body, °C; \(T_m\) is the ratio of the actual surface area of the human body after dressing to the surface area of the naked body, namely the dressing coefficient; \(T_c\) is the outer surface temperature of clothes, °C; TMRT is the average radiation temperature of the room, °C; \(H_c\) is the convection heat transfer coefficient W/(m²·°C).

Since PMV is obtained through a large number of specific experiments, it is not possible to accurately predict human thermal sensation in some experiments with large activity and clothing thermal resistance. Therefore, Professor Fanger obtained PPD, the percentage of predicted dissatisfaction through sorting out a large number of experimental data:

\[
PPD = 100 - 95\exp\left[-(0.03353PMV^{4} + 0.2179PMV^{2})\right] \tag{2}
\]

When PMV = 0, the corresponding PPD = 5%, which is commonly known as thermal neutrality, that is, when the human body feels the environment of the air-conditioned room is moderate, 5% of the people are still dissatisfied with the environment, and the calculation results are shown in Table 1.

| Thermal sensation | Cold | cool | slightly cool | moderate | slightly warm | warm | hot |
|-------------------|------|------|---------------|----------|--------------|------|-----|
| PMV               | -3   | -2   | -1            | 0        | 1            | 2    | 3   |

In this paper, Formula (1) and (2) are programmed by MATLAB to obtain PMV changes under corresponding environmental conditions.

3. Determination of PMV parameters and solution of equations

3.1. Determination of parameters

This article studies the activities of the operating room staff, so the mechanical work is 0W. When the human body is displaced in the vertical direction, the human body will do work, such as climbing mountains and riding elevators. The six parameters affecting PMV are determined as follows.

1) Activity level \(M\): The average energy metabolism rate during the surgeon’s operation is approximately equal to the energy metabolism rate during moderate physical activity. The average energy metabolism rate during the surgeon's operation is estimated to be 120W/m².

2) Relative humidity \(\phi\): In a comfortable air-conditioned room, the indoor relative humidity is within a certain range of variation, according to the "Design Standard for Energy Efficiency of Public Buildings" (GB50189-2015) [4], 30%-60% in winter, 40% in summer 65%. This paper studies the winter environment, and the relative humidity is 40%.

3) Average radiant temperature \(T_m\): The operating room temperature is 22~25°C and the relative humidity is 40~60% specified in the "Technical Specification for Hospital Clean Operating Department Building". The average temperature of the operating room is 23°C during the calculation process.
(4) Air velocity $v$: According to literature [5], indoor air velocity is allowed.

(5) Clothing thermal resistance $I_{cl}$: This article only considers the clothing thermal resistance of surgical gowns in the operating room. The average thermal resistance of surgical gowns and hand-brushing gowns is $1.06\text{clo} \ (0.17 \text{m}^2 \cdot \degree\text{C}/\text{W})$.

3.2. MATLAB solution process
According to formula (1), it can be seen that there is a complicated non-linear relationship between the equation and the included parameters. The key to solving PMV is to solve $t_{cl}$, and the $t_{cl}$ solution depends on $h_c$, and the solution of $h_c$ depends on $t_{cl}$. Therefore, a loop nesting relationship is formed between these two parameters. The manual calculation process is complicated. Therefore, this article uses MATLAB in the iterative procedure in programming, other parameters are determined as constants, and the value of PMV is solved. The solution structure is shown in the figure below.

![Figure 1 Schematic diagram of MATLAB solution process](image)

4. The relationship between indoor design temperature, airflow velocity and PMV
MATLAB programming was used to obtain the influence of indoor design temperature and airflow velocity on PMV, as shown in the following figure.
Figure 2. Relation between indoor airflow velocity and PMV under different TA

As can be seen from Figure 2, when other factors are constant, indoor airflow velocity has little influence on PMV value at a certain design temperature, which is basically horizontal. Interior design temperature has a great influence on PMV value, and PMV gradually increases with the increase of interior design temperature. When the operating room design temperature is lower than 22°C, the human body feels colder; when the operating room design temperature is higher than 23°C, the human body feels warmer.

Figure 3. Relationship between interior design temperature and PMV when Va=0.15m/s

Figure 4. Relationship between interior design temperature and PMV when Va=0.20m/s

Figure 5. Relationship between interior design temperature and PMV when Va=0.25m/s
As can be seen from Figure 3, 4 and 5, when the indoor air velocity is 0.25m/s, the PMV value increases with the increase of the indoor design temperature. When the indoor design temperature is between 22°C and 23°C, the PMV value is close to 0, and the human body feels the most comfortable.

5. conclusion
(1) For the operating room, because the thermal resistance of clothing is different from that of office staff, the thermal and humid environment parameters of the operating room should be adjusted to meet the thermal comfort requirements of medical staff. MATLAB programming shows that indoor airflow velocity has little influence on thermal comfort, while indoor design temperature has greater influence on thermal comfort.
(2) When the ambient temperature and activity level are certain, the thermal resistance of the clothing is taken from the operating clothes, and the indoor air velocity is set within the range of 0.15m/s ~ 0.25m/s. When the indoor design temperature is 22°C ~ 23°C, the PMV value is close to 0, which makes the human body feel the most comfortable.

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