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Thermal environment conditions in Polish operating rooms

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ABSTRACT

Although difficult to implement, thermal comfort of medical staff in an operating room (OR) deserves adequate attention because it can influence the effectiveness, and efficiency of medical procedures.

The aim of this study was to evaluate thermal conditions and thermal sensation of medical staff working at Polish hospitals and operating rooms. Therefore, measurements of thermal environmental parameters were conducted, and results of calculation of PMV index were compared to ISO 7730 requirements. Additionally, the measurements were compared to standards: Polish 'Design guidelines for hospitals', DIN 1946, FprCEN TR 16244 and ASHRAE 170 and domestic regulations.

Thermal environment in majority of Polish ORs was assessed as 'warm' by surgeons, as 'slightly warm' by nurses and surgeon's assistants and as comfortable by anaesthetists. Anaesthetists (70 W/m^2) wearing light insulated surgical clothes (I_{cl} = 1clo) perceive thermal comfort as satisfying in ca. 90% of ORs, while surgeon's assistants and nurses (100 W/m^2) in ca. 30% of ORs. The surgeons (130 W/m^2) perceive thermal comfort only in ca. 5% of ORs. Wearing medium insulated surgical clothes (I_{cl} = 1.3clo) anaesthetists perceive thermal comfort as satisfying in ca. 60% of ORs, while surgeon's assistants and nurses in ca. 5% of ORs. The surgeons in any of the ORs perceive thermal environment as comfortable. Wearing highly insulated surgical clothes (I_{cl} = 1.5clo) anaesthetists perceive thermal comfort as satisfying in ca. 40% of ORs, while surgeon's assistants, nurses and surgeons in any of the ORs.

1. Introduction

In an operating room a patient is given the highest priority and indoor environment conditions are designed in such a way to ensure patients' safety, health and comfort [1–6]. Yet, considering patient safety and comfort completely, it is important to remember about operating staff, as their comfort has an indirect influence on the quality of work [6–10]. An impact of uncomfortable thermal conditions on operating staff's work efficiency has not been verified sufficiently [6,9], however, considering experiments on office workers it can be expected that, similarly to them uncomfortable thermal conditions in operating rooms can adversely affect medical staff, and thus lead to a greater number of mistakes and decreased work efficiency [6,7]. Uncomfortable thermal conditions are not rare in operating rooms. This fact was confirmed by the results of measurements and surveys conducted in different countries [6,8,11–14]. The problem with meeting comfortable thermal conditions is caused by the two following factors [6]:

- A thermal conflict between medical staff's expectations, and the hygienic/technological requirements of operating rooms.
- Differing thermal expectations among medical staff.

With regard to thermal requirements, medical staff can be divided into three basic groups [8]: surgeons, nurses and surgeon's assistants, anaesthetists. Each group works under a different physical and mental load [6,8,11]. The most strenuous physical work is performed by surgeons. They are also encumbered with the biggest responsibility for medical activities, and therefore perceived by experts as key ones for surgery [15]. The remaining groups, for the major part of a surgical procedure, perform relatively less responsible tasks. Nurses and surgeon's assistants usually carry out work which, in comparison to anaesthetists, is more physically strenuous, nevertheless their thermal preferences are similar (expected ambient temperature for anaesthetists were within the range of 23–24 °C, while for nurses within the range of 22–24.5 °C) [6,8].

Furthermore, the work area of particular groups of operating staff is different [6,8,11]. Surgeons are usually in the closest contact with a patient that is operated on. This area is heavily influenced by surgery lamps, the patient temperature control system and others

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appliances generating high heat gains. As a result of their operation the air temperature and mean radiant temperature increases. Heat gains occur also at workstations occupied by other medical staff, however they are smaller than in the case of surgeons.

In summary, in a standard operating room, and for typical surgical procedures, the lowest thermal expectations are noted for surgeons (they expect the lowest room temperature). Surgeon's assistants and nurses report a need for relatively higher temperatures, whereas the highest temperature expectations come from anaesthetists. In the course of complex and non-standard surgical procedures a composition of operating staff may be more complicated; the character and scope of realised tasks by particular persons of medical staff may also be different.

Thermal sensation of medical staff is also hugely influenced by surgical clothing made of materials resistant to body fluids. This type of clothing must comply with the Council Directive 89/686/EEC (1989) and with the Medical Devices Directive (MDD) [16,17]. Depending on the type of medical procedures, thermal insulation of clothing is in the range from 1 to 1.5 clo which considering the OR's indoor air temperature at approx. 23 °C causes that thermal environment to be perceived as 'slightly warm' [11]. This type of clothing limits the release of humidity from the human body, and permeability of air in the area between skin and clothing. As a result, the heat exchange between a body and the environment is hindered [14]. Such an effect expressed via air permeability of clothing is generally perceived as uncomfortable [17].

In order to ensure medical staff have comfortable work conditions while wearing clothing of high insulation and low air permeability it is necessary to apply low indoor temperatures. Furthermore HVAC systems should be designed to provide each member of medical staff with the maximum available thermal comfort while in each type of surgical clothing used. At the same time priority should be given to protecting patients against hypothermia [2–6,18].

The above mentioned conflict of requirements might be partly solved by the use of local systems for shaping patient's thermal sensations [6]. If such systems cannot be used, temperature in an OR should not fall below 23 °C [3]. If, however, individual systems for the heating/cooling of the patient can be applied, the temperature in a working zone should be adjusted with the consideration of the medical staff's expectations [6] and temperature in a patient's surroundings should not be reduced below 21 °C [6,18]. The publications such as [6,11,14,17], point to different indoor air temperature in OR, however they stay within the range of 20–25 °C. Furthermore it is recommended to decrease the air temperature to even 18 °C or lower, while surgery is conducted in a heavier surgical gown (e.g. with patients infected with HIV virus) [14,19].

The aim of this article was the evaluation of thermal conditions and thermal sensation of medical staff working at Polish hospitals and operating rooms. Therefore, measurement of thermal environment parameters were conducted, and results of the calculation of PMV index were compared to ISO 7730:2005 requirements. Additionally, the measurements were compared to standards [20–23]: and domestic regulations [24–26] in this field.

2. Guidelines concerning the thermal environment in operating rooms

Polish requirements concerning the thermal environment conditions in ORs are included in regulations [24–26], standards [27,28] and design guidelines [20].

Essential requirements regarding the HVAC systems are set out in the Regulation of the Minister of Health [26]. The Regulation stipulates that operating rooms should use a supply/exhaust ventilation or air-conditioning system ensuring air quality parameters suited to the function of these spaces. The provision is general. Therefore, more detailed design documents are used. For many years in a designing stage, the document [20] published in 1984 was used. Taking into account the rapid development in medical technology and HVAC systems, strict adherence to the [20] can result in designing inefficient, costly installations with an unsatisfactory level of cleanliness and thermal conditions. Under such circumstances it is common practice to use foreign documents. The most popular ones worldwide include: [21–23]. Nowadays in Poland the most popular in use is the German standard [22].

Thermal conditions recommended in the documents [20–23] are shown in Table 1. In the documents [20,21] thermal conditions are described similarly to [29], by means of indoor air temperature, contrary to documents [22,23] where they are defined by means of supplied air temperature. The range of temperature control in operating rooms designed in accordance with the standards [21–23] is relatively wider than in the guidelines [26]. Heat transfer through radiation issue is not completely specified in any standard, although recommendations that radiant temperature should be similar to indoor air temperature.

Whereas air humidity is described in two different ways: as relative air humidity [20] and [21] and specific air humidity [23]. In standard [22] there are no air humidity recommendations. Table 1 shows air humidity recommendations included in the above mentioned standards and guidelines. Humidity requirements set out in the guidelines [20] are more restrictive than the ones set out in standards [21,23]. The scope of admissible RH is narrower RH (50 ÷ 60%, in 20 ÷ 60%, in 6.5 ÷ 11.5 g/kg) and a precise system of humidity control is required (in Ref. [20] accuracy ±5%, in Refs. [21,23] accuracy is not specified).

In every standard the air velocity requirements depend on the type of air distribution system. Air velocities, in the case of diffusers with laminar flow are higher than in the case of mixed flow diffusers. There is technical obligation to ensure the minimum velocity so as to provide stable laminar, or low turbulent airflow. According to [20] in systems with conventional airflow, the stream should be directed from legs to head, and in the operating area it should stay within the range of 0.15 ÷ 0.25 m/s. Considering construction of LTF diffusers produced in 1980s, air velocities proposed in Ref. [20] are relatively higher than provided in Ref. [23]. According to [20] they should stay within the range of 0.4 ÷ 0.5 m/s, while in the contemporary document [23] requirements are as follows: the local velocity should stay within the range of 0.23 ÷ 0.45 m/s [23] and the average velocity should be at least 0.25 m/s [23], or stay within the range of 0.23 ÷ 0.25 m/s [22]. The use of higher air velocities, which are not required for technological reasons, causes an increase in construction and exploitation costs, while lowering the thermal comfort of users and deterioration of indoor environmental quality [29,30].

3. Research methods

Local thermal environment parameters were measured in 37 ORs in 7 Warsaw hospitals. The aim was to use a well-known and standardised method for thermal comfort analysis, therefore the selected method was based on the Fanger's PMV model [32] and described in ISO 7730:2005 [29] and ASHRAE 55:2013 [31]. In some applications the above mentioned method is criticised for underestimating users thermal comfort outside comfort zone [29,33,34]. In such cases, it is recommended to use adaptive models (e.g. de Dear [33], Yao [34]) that consider behavioural, physiological or psychological adaptation. However, according to [29,32] the standardised adaptive models are appropriate only for naturally conditioned indoors. According to [11,29,31,32] in case of surgical staff in ORs i.e. healthy adults whose working specificity limit their